DESIGN FOR ADAPTATION

Cumulus Conference Proceedings Detroit 2022

Cumulus Association

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DESIGN FOR ADAPTATION
CUMULUS DETROIT

Cumulus Conference
Proceedings Series

Cumulus: The Global Association
of Art and Design Education and Research

Detroit 2022

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CONFERENCE CHAIR WELCOME

Dear conference attendees,

Climate change is a complex, multidimensional issue where physical hazards and social and economic drivers interact. For these reasons, climate change is deeply intertwined with global patterns of inequity. While the human tendency to adapt reactively is well-known, we believe that proactive adaptation is now necessary to avoid far more impacts of climate change, and we believe that adaptation plays a crucial role in reducing communities' exposure and vulnerability.

In the last two centuries, we have entered the Anthropocene. We are removed from the evolution of the Homo sapiens by 10,000 generations, yet the five generations of the twentieth century have used fossil resources at unheard-of rates while accumulating waste and creating irreversible pollution in the air, water and soil. This is a challenge for humanity and civilization.

This challenge is enormous and has multiple dimensions, from the political, where choices can no longer be based solely on the criterion of our short-term interests, to the economy, we must abandon blind growth. The ethical dimension is where we should apply the macrocosm in the microcosm of our desires. The symbolic dimension is where we need to break the "always positive" archetypes of the individual's "material success." The list of dimensions is long and includes the arts, where we must explore other modes of reality and imagine revisions and redesigns.

If anything is clear, however, it is that climate change will not be neutralized in the course of our lives.

This necessary transition will have costs and require us to make sacrifices. Even if economists think the market will solve everything, energy and food insecurity is already a reality that plagues evermore people worldwide. People will be forced to migrate; animals will go extinct; new parasites will arrive in new areas; through various pathways, climate change will exacerbate existing health threats or create new public health challenges. We must return the human condition to the center of our future projects.

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CONFERENCE CHAIR WELCOME

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This challenge will require a team effort; just as science needs philosophy and design will need ethics, we need more stakeholders at the table. Will we be able to forge other paths? We hope so. Which ones? Nobody knows yet, but maybe the solution to the impacts of climate change lies within the Earth, our minds and our capacities.

Let's take tangible steps to prepare and respond to the greatest threat to humanity and beyond. Here at the Cumulus Conference, you will be introduced to innovative ways of training the next generation of designers, learn how everyday materials can play a role in helping laypeople recognize their impact on the environment, and see new ways of bringing the climate crisis to the public's attention.

We hope you return home with profound memories, new knowledge and inspiration for your work. Have a great conference, and welcome to Detroit!

Maria Luisa Rossi
Conference Chair
Chair and Professor
MFA System Design Thinking

CUMULUS PRESIDENT'S MESSAGE

Design for Adaptation in the Complexity

The 2022 Cumulus conference in Detroit at the College for Creative Studies is the second in the U.S. in more than 30 years of history and the first after a long global pandemic, which made us rethink how we meet, network and disseminate globally in new, creative ways. Accordingly, the topic selected revolves around the concept of adaptation, which is one of the properties of any complex system to survive and grow under the pressing global challenges, such as global warming, while reducing vulnerabilities and fostering resilience. As the call points out, climate change consequences are impacting not only our environment but human rights, poverty, inequity, global food security and health. They are calling for rapid action and adaptation. Such an emergency, without precedent, requires bold and creative thinking.

Along with three days of paper presentations, panels, keynotes and working groups, the conference sent a clear call to action to the large global design community to explore sustainable and equitable solutions: we are living in a time of emergency and at the same time of complexity, which needs bold ideas and actions, where every single element may interact to each other and the whole at different levels, without any linear predictions. The good news is that a property of a complex system is adaptivity, which means it can adapt to its surrounding environment when it is composed of many elements in a network of actions and feedback in a dynamic state.

All living and social systems are considered complex adaptive systems, from ant colonies to the stock market, from the biosphere to ecosystems, from the brain to social networks, and from technological to communication systems, therefore falling into the broad and increasingly widespread transdisciplinary cognitive paradigm developed with complexity theories in its ability to describe nonlinear systems, such as biological, ecological, financial, economic, medical and healthcare, and social systems.

What is the future of the cities? How do we combine local and global solutions? Where are the flows of migration going? What is the role of the citizens, the communities and the people? How can we develop equitable solutions to ensure access to life-saving resources? How can we foster technological innovation safeguarding access and inclusion at every social level?

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CUMULUS PRESIDENT'S MESSAGE

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Since Detroit is a UNESCO City of Design, it was the ultimate location to convene globally for sharing knowledge, research, projects and practices responding to the urgent challenges emerging from the environment and society. Additionally, Detroit is speaking a long story of technological, economic and social transformations, which are noteworthy for the design.

Moreover, the partnership developed by the College for Creative Studies for the conference with the Association of Independent Colleges of Art & Design (AICAD) gave participants coming from all over the world a broader view to design education in North America.

The memory of such a rich experience is included in the following volume, which is not only speaking about the conference proceedings, but furthermore, it is celebrating our large global Cumulus community through its common values around open exchange and knowledge sharing.

Finally, we were back in presence!

Lorenzo Imbesi
Full Professor, Sapienza University of Rome
President, Cumulus Association

COLLEGE FOR CREATIVE STUDIES

Located in the heart of Midtown Detroit, the College for Creative Studies (CCS) is a world-class institution that educates artists and designers to be leaders in the creative professions. A private, fully accredited college, CCS enrolls more than 1,400 students pursuing Bachelor of Fine Arts (BFA), Master of Arts (MA) and Master of Fine Arts (MFA) degrees.

Students in the BFA program can major in Advertising Design, Art Practice, Communication Design, Craft and Material Studies, Entertainment Arts, Fashion Design, Film, Illustration, Interdisciplinary Art + Design, Interior Design, Photography, Product Design and Transportation Design, in addition to a dual major Art Education program. Students in the graduate program can major in Art Education, Color and Materials Design, Design for Climate Action, Interdisciplinary Design Studies, Motion Design, Transportation Design and User Experience Design.

ASSOCIATION OF INDEPENDENT COLLEGES OF ART AND DESIGN

The Association of Independent Colleges of Art and Design (AICAD) is a non-profit consortium of the leading specialized arts and design schools in the U.S. and Canada. Founded in 1991, the mission is to help strengthen the member colleges individually and collectively, and to inform the public about these colleges and universities and the value of studying the arts and design.

AICAD institutions educate more than 50,000 undergraduate and graduate students each year, plus many thousands more in summer and continuing education programs.

CCS STUDENT EXHIBITION "CONSCIOUS ADAPTION"

The exhibition was a powerful visual representation of ideas and solutions of 35 students from six undergraduate programs [Fashion Design, Interior Design, Communication Design, Transportation Design, Product Design and Entertainment Arts] and three MFA programs [Systems Design Thinking, Color and Materials Design and Transportation Design].

"Conscious Adaption" featured innovative projects that sought to improve the environment, promote sustainable consumption, and foster sustainable lifestyles, and showcased designs that addressed the injustices of climate change, explored the idea of green living, and raised awareness of the importance of preserving natural resources.

The collection of student work manifested a high remark from academic guided efforts toward sustainability and through interactive elements and natural and recycled materials. The exhibition also served as an engaging experience and an opportunity to learn and discuss the issues related to climate change while absorbing the poster's content.

Sandra Olave
Exhibition Chair
Interior Design Department Chair

KEYNOTE SPEAKERS

Mikko Ollikainen

Mikko Ollikainen
Head of the Adaptation Fund

Mikko Ollikainen leads the Fund's secretariat in Washington, D.C. Ollikainen has more than 20 years of experience in climate change and other global environmental issues. Before taking office as the Manager in 2017, he served as a lead adaptation expert of the Fund since 2009, playing a pivotal role in building the Adaptation Fund's portfolio of concrete adaptation projects, which currently consists of more than 125 projects and programs, including more than 30 that are nationally implemented. He also led the development and implementation of the Fund's medium-term strategy, which sets out the Fund's ambitious vision of accelerating adaptation action, innovation and learning. Before joining the Adaptation Fund, Ollikainen worked as a technical specialist with the World Bank on nature-based climate change mitigation and forest conservation projects in Africa and Indonesia. He worked in East and Southeast Asia for five years on global and local environmental and development issues with development finance institutions, academia and the private sector.

Ollikainen holds an MSc degree in Ecology and Biodiversity Research from the University of Turku, Finland, and a postgraduate diploma in International Trade from the University of Tampere, Finland.

Ollikainen reinforced that "adaptation" to climate change will be a key factor across the design field into the future, and that designers should feel empowered to use their skills and creativity to address these challenges, especially with a focus on vulnerable populations globally. After Ollikainen's presentation, Dr. Neil C. Hawkins, President of the Fred A. and Barbara M. Erb Family Foundation, engaged Ollikainen in a discussion regarding these topics.

KEYNOTE SPEAKERS

[continued]

Anika Goss-Foster

Anika Goss-Foster
Chief Executive Officer
Detroit Future City (DFC)

Anika Goss-Foster is the Chief Executive Officer of Detroit Future City (DFC), a think-and-do tank focused on land use and sustainability, community and economic development, and economic equity in Detroit. Goss-Foster leads a team of experts to implement the DFC Strategic Framework, a comprehensive 50-year guide to decision-making and investment in Detroit. Goss-Foster is a leading force and visionary in Detroit's revitalization, playing a crucial role in Detroit as an advocate for an equitable and sustainable future for the city.

Goss-Foster drew important connections between the impacts of climate change, land use, economic development and equity in her presentation. Afterward, Orlando Bailey, Emmy-award winning journalist and director of engagement for Bridge Detroit, conversed with Goss-Foster about these topics and the role of design in developing equitable, sustainable communities.

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FOREWORD OF THE CUMULUS DETROIT 2022 PROCEEDINGS

We are pleased to present the conference program and proceedings for Design for Adaptation: Cumulus Detroit 2022. Detroit is an apt setting for a conference exploring the role of design and design education in the climate crisis: the only UNESCO City of Design in the U.S., it is a hotbed of innovation and action in sustainability and climate justice. We were able to draw upon the city's expertise for panels and speakers and examine issues and actions close-up.

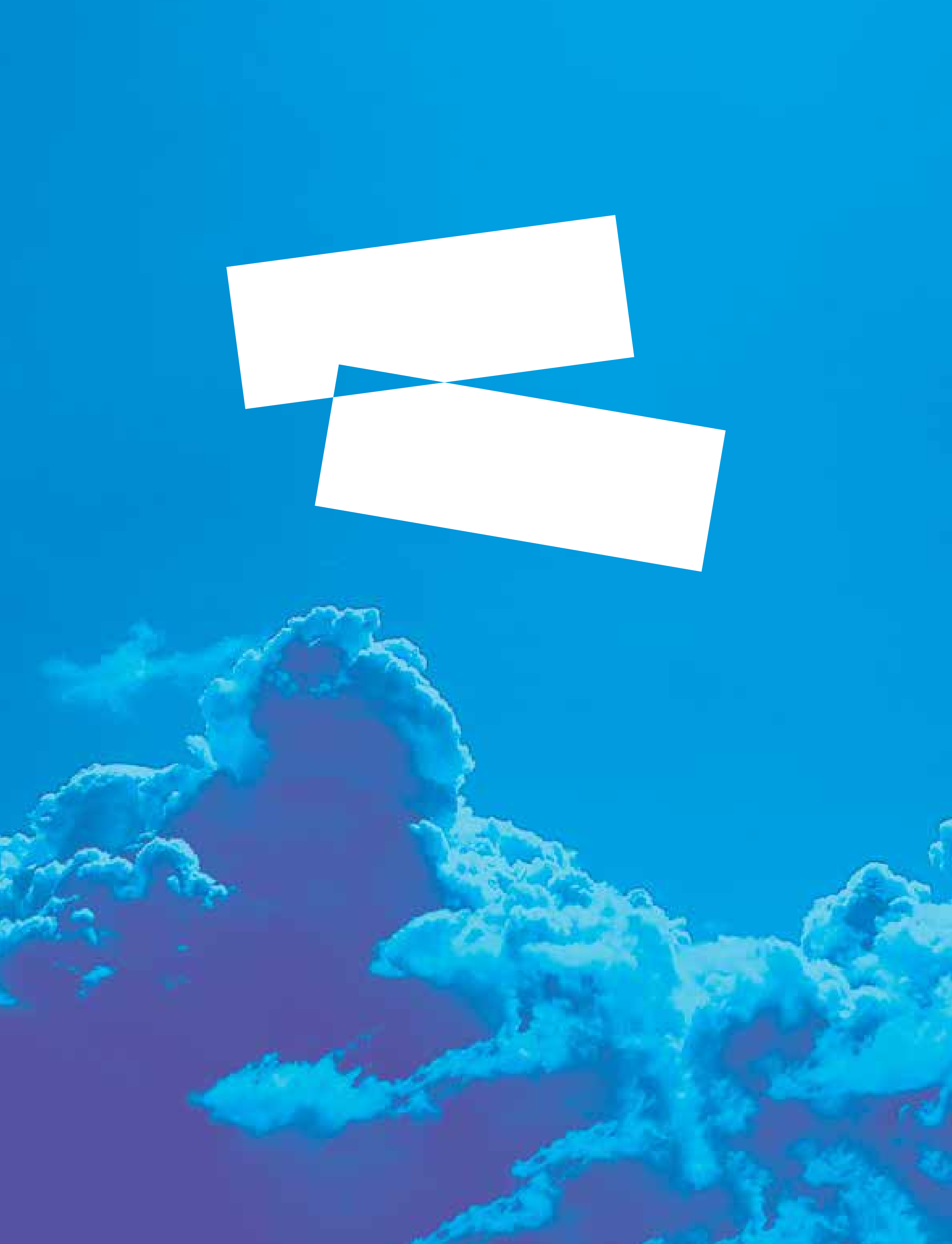
The conference had three tracks: Climate Ecosystems (systems, economies and infrastructure); Climate Citizens (action, adaptation and disruption); and Climate Apartheid (equity, equality and justice), with Climate Citizens the most popular track by some distance. The call for abstracts received 252 submissions worldwide, including 47 for posters. In the two-stage review process of abstracts followed by full papers or posters, each submission was blind peer reviewed by at least two reviewers. Of the 205 paper abstracts, 118 were invited to the second stage, with 55 full papers finally accepted (an acceptance rate of 27%). Of the 47 poster abstracts, 33 were accepted to stage two, with six posters finally accepted. The contribution of the 10 track chairs and 108 reviewers worldwide highlights a thriving global community of design scholarship. We are indebted to them for undertaking this important work.

In addition, there were 10 working group sessions; eight-panel sessions, including a student panel on Sustainable Design in the Future; four cultural tours; one seminar on social innovation and building design for peace contexts; a Ph.D. networking event; a CCS student exhibition; one guest speaker; and two keynote speakers with Q&A sessions. Once again, much gratitude to all for their powerful contributions.

The College for Creative Studies was honored and excited to host the conference here in Detroit and, for only the second time in its 30-year history, in North America. With the world re-emerging from the COVID-19 pandemic, we were so happy to welcome 285 of the 400 delegates to campus, with 115 joining the conference remotely. Participants came from 37 countries representing 70 universities and colleges. We thank all for their attendance. We would also like to thank the Association of Independent Colleges of Art & Design (AICAD) for their collaboration. Please enjoy these proceedings from "Design for Adaptation" Cumulus Detroit 2022. We hope they give rise to further action and projects in bringing about change and advancing the global curriculum.

Dr. Ian Lambert
Conference Co-Chair and Submissions Chair
College for Creative Studies

CLIMATE APARTHEID



ARE TREES THE KEY TO PROMOTING THE ADAPTATION OF ENVIRONMENTALLY SUSTAINABLE ATTITUDES AND BEHAVIOR? A CASE STUDY EXAMINATION

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Abstract
Trees have historically forced a widening of the human timeframe to align with their extended existence. This paper's historical and contemporary case studies illustrate how interactions with trees or forests offer a powerful leverage point for systemic change. Engaging with the arboreal world can prompt temporal expansion and consideration of environmental and non-human stakeholders. Designers acting within this space could develop solutions that help shift society towards behaviors and mindsets considerate of the long-term and the natural world.

In the preindustrial era, a pattern emerged of governmental and administrative actions to ensure access to wood, timber, and forest resources. Given the markedly different span of arboreal lifecycles, governmental or legal actions were required for humans to expand and adapt their timeframes, often to three or more centuries into the future.

After the Industrial Revolution, trees emerged as islands of non-human life and the natural world within urbanized communities. The importance of this relationship and its potential to affect behavior and mindset is evident in recent events in Sheffield, U.K. Long considered one of the "greenest" cities in Europe, in 2012, an initiative began to remove many street trees. Facing the loss of six thousand trees in five years, concerned citizens became intensely engaged in the community, law, politics, and the natural world.

Individuals and neighborhood-based protest groups joined together as Sheffield Tree Action Groups (STAG). Members exposed the financial motivation for tree removal and its proposed extent. They organized, educated themselves in arboreal science, and became experts in civil disobedience, guerilla action, public relations, contracts, and the English legal system – many were arrested. Residents elected Green Party members to public office to preserve the urban canopy, changing the balance of power in the city. They forced rewriting of the city's tree maintenance guidelines and assessment process to favor preserving trees. Finally, a referendum led to a city government reorganization that favored direct representation.

The felling changed the landscape and undermined citizens' connection to Sheffield and sense of "home." While the drawn-out battle preserved only a few hundred of Sheffield's street trees, it acted as a leverage point for a more informed, environmentally aware community, the enshrining of environmental stewardship into legislation, and direct representation in the city government. Residents recognized trees as valued community members and became their advocates.

The discipline of design is at a crossroads. It is grappling with its role in stoking the economy that fueled the climate crisis. Simultaneously, it is considering how to contribute to a more environmentally sustainable future and mitigate the worst effects of global heating. Identifying and understanding leverage points to change human behavior is foundational to transition design. The relationship between members of industrialized societies and trees or forests may be critical for affecting mindset and initiating transitions to more sustainable ways of living.

Author Keywords
Transition design; environmental advocacy; trees; behavior change; more-than-human; leverage points; posture and mindset; living systems; public policy.

Introduction

Westernized civilizations have difficulty considering the long-term: the long-term in individual lives, the long-term of their economy and their governance, the long-term use of resources, the long-term consequences of their actions, and the long-term stability of the planet. The changing tides of popular sentiment and elective government often preclude a singular vision. So how does one shift society's gaze toward the far horizon?

Consideration of the long-term is foundational to the transition design[1] approach that has emerged over the last decade. Designers in this field draw from design, sociology, economics, anthropology, and ecology to catalyze socio-technical transitions towards more sustainable ways of living. It is fourth order design[2] writ on a global scale, and seeks to effect changes in mindset within industrialized societies. Is it possible for designers to help these people, these cultures, understand the ramifications of their actions beyond immediate consequences and consider the toll on the planet's future?

Convenience, cultural norms, and infrastructure created and perpetuated industrialized society's destructive patterns of consumption. This status quo makes it difficult to disengage from harmful behaviors even when an individual is aware of the consequences of their actions. Modern living reduces that nature to social media posts and computer desktops and provides layers of physical and conceptual insulation against any sense that an individual is a part of a local, regional, or planetary ecosystem.

Where has extended temporality and awareness of the natural world been incorporated into civilization? Historically, an acknowledgment of the long-term came when human needs were reliant on trees and forests. Because many trees exist on a different timescale than humans and forests may outlive governments or cultures, any silviculture requires a greatly expanded time frame. Julia Nordblad (2017) argues "that forestry offers examples of how long-termism can be conceptualized and institutionalized in ways that encourage continuous deliberation and reconceptualization" (p. 164).

Fertilizer and cultivation can only accelerate a tree's slower existence so much; the physical properties of wood result from its growth. If a load-bearing beam or a mast is required, the only acceptable timber comes from trees with time to build the appropriate density and mass. The forester may not have conservationist intentions, but they must have the patience for a tree to grow to the required specifications. Further, while finding the required timber in an unmanaged forest is possible, a predictable supply requires administration and care (Nordblad, 2017). This relationship forces long-termism onto human society and governance structures, resulting in environmental stewardship of a hundred years or more.

Historical Precedents in Forest Administration

Carta de Foresta

Situated in the twenty-first century, it is surprising that one of the cornerstones of English law during much of the last millennium was a document guaranteeing stewardship of the forest and access to the land for all subjects. The fact that the Carta de Foresta, or Charter of the Forest, is largely forgotten speaks eloquently to the changing relationship between Western societies and their forests.

The document was part of the 1215 Great Compact of Henry III. In 1217, the Compact was reissued in two parts – the Magna Carta, enshrining the socio-political rights of the ruled into law, and the Charter of the Forest, which codified access to the land and its resources. For several hundred years, the two documents were of equal importance. Indeed, the "Magna" title indicated the physically larger, not the more significant, document. Some scholars compare the Charter of the Forest to the International Declaration of Human Rights, guaranteeing access to many forest products necessary for subsistence.

To understand the document's significance, consider critical differences in the England of 1215. At the Norman Conquest, a "forest" had specific characteristics of soil, tree density, and game (Magraw & Thomure, 2017). Land meeting these conditions could be "afforested" for the king's use. Once afforested, it was illegal for anyone other than the king to enter. Peasantry, merchants, and lower royal classes were denied access, limiting firewood essential for heating and cooking and the timber necessary for building shelter. Additionally, hunting within the forest became illegal, removing essential protein and fat from the peasant diet. The forest floor and wild fields that provided essential livestock grazing were also off-limits. The springs and rivers running through the forest became inaccessible, denying access to drinking water, fishing, and shipping. In 1215, a third of Southern England and a quarter of the entire kingdom were afforested (Van Bueren, 2015) at a time when England was experiencing a population boom.[3] As a result, an increasing population relied on products obtainable only by trespassing onto afforested land at the risk of corporal punishment (Magraw & Thomure, 2017).

While the Charter guaranteed access to the forest and its resources, it also enshrined sustainable resource management into law. Trees could be harvested or coppiced, but only if enough of the stool remained for regeneration and to shelter wild game.[4] Further, the document permitted damming of waterways for mills, irrigation, and drainage only if it did not negatively affect others in the watershed.

The Charter of the Forest represented the importance of forests in the lives of the governed and set boundaries on the monarchy's ability to monopolize an essential resource. While it guaranteed access, it also ensured ecosystem resilience by preventing overuse. Further, it provided a recourse when those ecosystems were damaged and a check on overdevelopment within the commons. The Carta de Foresta codified long-term thinking in English law, being "re-confirmed" multiple times through the fifteenth century (Van Bueren, 2015). Some of its provisions remained active nationally until 1971, while others still govern the Forest of Dean, a rural area at the border of Wales (Magraw & Thomure, 2017). Legal challenges to environmentally damaging business, industrial, and governmental practices are prompting a rediscovery of the Charter of the Forest. As Western societies grapple with unsustainable practices and environmental degradation, the document provides an interesting example of more holistic and egalitarian resource management.

The Forest Administration of the Venetian Republic

Several hundred years later and thousands of kilometers to the southwest, the Venetian Republic implemented a more formal administration of its forests. The need for wood in Venice was grounded not only in subsistence but in production, trade, and the peculiar geography of the city. Built on the Venetian lagoon's unstable alluvial deposits, the foundation of the city's artificial islands is poetically known as the "Forest of Venice."[5] Further, naturally buoyant timber floated from the mainland was the building material of choice in the city. By the fifteenth century, Venice was one of the great sea-going powers in the world with a massive armada. Each galley constructed in the Venetian Arsenal required nearly 300 mature trees of various species,[6] yet no timber grew within the city.[7] As agricultural plains ringed the shoreline, the city-state had to obtain the required wood from the mountainous forest further inland. This process was lengthy as timber was harvested during the dry season and floated to the lagoon during the rainy season on flooded rivers. The delay added six months to a year to the procurement timeline. In his detailed study of Venice's system of forestry management, A Forest on the Sea, Karl Appuhn (2009) states succinctly, "supplying the Arsenal with oak was not merely a question of harvesting poles and floating them downstream; it also required a significant amount of advance planning" (p. 55). Such planning necessitated not only legal protections and guidelines, as seen in the Charter of the Forest, but a complicated system of surveys, management, procurement, and labor allocation by the Venetian State.

During its rise to power, Venice had no mainland holdings and little control of its timber supply. At the beginning of the fourteenth century, when war, brutal weather, the Great Famine, and the first wave of the Black Death arrived in quick succession, Republican legislators[8] described a scarcity of wood in Venice as a "famine of timber (that) threatens our liberty" (Appuhn, 2009, p. 55). The city attempted to legislate its way out of shortages, but this failed. When an uprising over firewood threatened stability, governmental representatives ventured to the mainland and discovered that the timber scarcity was not due to deforestation. Instead, it resulted from an unpredictable interplay of labor shortages, seasonal constraints on forest access and timber transportation, siltation of waterways from overharvesting timber, competition with mainland populations for firewood, and predatory pricing. By the end of the fifteenth century, the frustrated Venice government embraced the role of colonial power and took possession of the community forests within its domain. By the beginning of the seventeenth century, the city directly administered its mainland forest holdings.

The Venetians distinguished forests by their administration. Apphun (2009) notes "a particularly Venetian sense that the natural world required active protection from private interests that threatened to damage it, and that such safeguards could only come from republican institutions designed to protect the common good" (p. 251). "Selva" was a forest assaulted by humanity and in danger of destruction through careless overuse by the peasantry without consideration of the ecosystem or conditions needed to ensure a healthy forest. In contrast, "Bosco" was a forest administered with care and stewardship for the good of the Republic that allowed trees the time and conditions to reach maturity through selective cutting and an understanding of the forest ecosystem and regional watershed.

The classifications of "Bosco" and "Selva" speak to the city's colonial mindset and can seem dismissive of its mainland subjects' needs and situated knowledge. However, the reality was more complicated. As a Republic, the Venetians emphasized collective knowledge and decision-making based on surveys and studies of the forests rather than immediate needs and impulses. The government began to concertedly document woodland conditions at the beginning of the fourteenth century when it realized it incorrectly assumed deforestation was the cause of wood scarcity. It built its knowledge over many years and worked to ensure a continuation of this expertise through generations of bureaucracy. Further, an administrative structure made silvicultural decisions through consultation with experts ranging from woodcutters and foresters to Arsenal and citizen representatives.

While the Charter of the Forest protected the peoples' access to critical forest resources by placing limitations on the monarchy, Venetian actions were in service to the Republic. It limited the control and access of the city-state's mainland subjects. The city prioritized the needs and rights of its citizens over those it ruled on the mainland. However, its decisions were rooted in careful observation and consideration of the forest ecosystems' health. As a government concerned with the well-being and continuation of the state, it could enforce administrative long-termism. It emphasized the material needs of the collective rather than the immediate subsistence needs of the local population. However, it was also able to override the economic calculations of landowners and merchants and preserve the forests intact. Such control mirrors the intention of the Charter of the Forest in its attempt to ensure continuing stewardship of its forests and safeguard those critical resources to its people and the state for hundreds of years.

The Menominee

The forestry practices and administration of the Menominee Tribe of Wisconsin, U.S., offer a contrasting approach to the Charter of the Forest and the Venetian forest administration system. These two examples emerged from the needs, political structures, and ontology of a Christianized medieval Europe. Official structures backed by the weight of law and government-enforced stewardship were put in place to ensure forest resource yield. The Menominee's approach to forestry was grounded in, and nearly indivisible from, their spirituality. While they did not shirk harvesting timber, they believed their needs were subordinate to the health of their forests. This approach resulted in conflict with the United States government as it attempted to enforce forestry practices that maximized timber extraction.

The Menominee tribe was confined to their "temporary" reservation in 1848 (Herzberg, 1977). The Indian Bureau pressured these skilled hunters and fishers to become farmers.

The Menominee refused and sought to practice sustainable, selective-cut forestry on their heavily wooded reservation. However, the U.S. government repeatedly prevented the tribe from working their forests and forcibly clear-cut sections of the reservation (Trosper, 2007). Between 1854 and 1908, tribal representatives lobbied to administer their land according to their expertise and beliefs. These efforts bore fruit in 1908 when Wisconsin Senator Robert M. La Follette sponsored an act that gave the Menominee complete control of their land.

The Menominee were among many tribes who lost the recognition of their tribal sovereignty under House Concurrent Resolution No. 108 in 1956 (Valandra & Deloria, 2006). During the process of defining the terms of their dissolution, the tribe insisted that their administrative plan include as the first objective to "enforce the maintenance of sustained yield[9] principles in the care and preservation of the forest" (26 Fed. Reg. 3669 (1961), p. 3727). This provision allowed the Menominee to continue their sustainable practices through the Termination period. Upon restoration of tribal status in 1973, they founded Menominee Tribal Enterprise (MTE) to maintain this management approach. The stated goal of the Enterprise is to:

> Maintain the diversity of native species and habitats, continue to improve environmental and cultural protection, improve planning efforts, further develop economic opportunities, promote communication, and increase environmental education for the Menominee people, while maximizing the quantity and quality of forest products grown under sustained yield principles. (Menominee Tribal Enterprises, 2012, p. 15)

Despite formidable obstacles, the Menominee administered their woodlands according to their beliefs for over a century with impressive results. The reservation was established in 1865 and contained around 1.2 billion board feet of timber (Pecore & Nesper, 1993). The tribe has harvested 2.3 billion board feet since then, with 1.9 billion board feet available today. The tribe's sustainable forestry principles yielded 3 billion board feet over the 150 years of management (Mausel et al., 2017, p. 366). Among many other commendations, the United Nations recognized MTE for its sustainable forest management. It was also honored with the first President's Award for Sustainable Development in 1996 and received an FSC Stewardship Award in 2015 (MTE Sustainable Forestry Recognition, n.d.). The tribe also established the Menominee Tribal College and its Sustainable Development Institute to pass their forestry practices to tribal members and the outside world.

Start with the rising sun and work toward the setting sun, but take only the mature trees, the sick trees, and the trees that have fallen. When you reach the end of the reservation, turn and cut from the setting sun to the rising sun, and the trees will last forever - Chief Oshkosh. (Menominee Tribal Enterprises, 2012, p. 10)

This quote guides Menominee forestry practices and is often cited by foresters and MTE. While board feet and accolades are striking, visiting the forest that resulted from their practice is startling; it is an ecosystem teeming with life. Insects and bird calls abound. Trees range in age, and the ground, understory, and overstory are patchworks of different species. There are numerous plots of old-growth forest and massive white pine, a species harvested to extinction beyond the bounds of Menominee land, easily accessible near roads and rivers. After the nineteenth-century frenzy of timber harvesting and land clearing around the Great Lakes and into the Mid-Atlantic and New England, the forests have slowly regrown. Only after visiting the Menominee land is it possible to understand how these ecosystems are still damaged and that their regeneration is incomplete.

While the Charter of the Forest and Venetian bureaucracy acted to ensure yield, the Menominee fought the government to administer their woodlands, guided by a sense of stewardship. Through foresight, concern for the human and non-human community, and consideration of natural systems, the tribe has managed to preserve, and work, their forest. Their belief in reciprocity and relationship to their land defines their actions, their business, their government, and their personal and collective ontology.

Consequences and Conflict in the Urban Forest of Sheffield, Yorkshire, U.K.

Industrialization and Urban Forestry

The socio-technical transitions ushered in by the Industrial Revolution radically changed much of humanity's relationship with the natural world. Once directly responsible for raising or procuring the raw materials of our lives and sustenance, such tasks were out-sourced, and finished goods and materials were bought and sold. With the factory system came explosive growth in the population of industrial centers, and former farm workers left the countryside for urban manufacturing. No longer reliant on the natural world for farming, trees became background in our settlements and our cities – at their best, quiet companions and reminders of nature; at their worst, annoying or threatening forces interfering with our housing, our transportation, or our safety. Nevertheless, even in this reduced state, they have unanticipated importance and power.

Sheffield's Landscape and History

Sheffield, Yorkshire, U.K., is not a city that frequently enters the collective imagination. A nexus of the Industrial Revolution, it is grouped with "struggling former industrial centers" like Manchester or Liverpool or "Rust Belt" cities like Detroit, Pittsburgh, or Buffalo. However, sitting at the confluence of the Rivers Don and Sheaf, Sheffield's history is millennia old. At the time of the Domesday book in 1086 C.E., roughly 22% of the area was wooded (Jones, 2009). Sparsely populated until the Industrial Revolution, local timber was an essential building material, and charcoal and "white coal" processing was significant to the regional economy (Jones, 2009).

Trees are an important force in contemporary Sheffield. According to a recent industry-standard I-Tree report, the city's canopy coverage is 18.40%, and the total trees number 3,863,630 with annual benefits of £8.4 million (approx. US$10.26 million) (Rogers et al., 2020). This tally includes over 35,000 street trees[10] and 250 woodlands, gardens, and parks (Flinders & Wood, 2019). Additionally, the Peak District National Park lies partially within the city boundaries.

Many of these street trees were planted with specific purposes, including 43 trees by the former Western Road Council School memorializing former pupils lost in the war (WW1 memorial trees, n.d.). Later, as the effects of air pollution became apparent, the city made a concerted effort to plant trees and become a "Clean Air City." The latter half of the twentieth century saw the city implement a Countryside Commission and formulate a Nature Conservation Strategy in response to local initiatives and national bills such as the

Wildlife and Countryside Act (Rotherham & Flinders, 2019). Indeed, in a 2014 survey, 98% of the surveyed Sheffield citizens rated the outdoors important to their lives (Heydon, 2020, p. 4). This history of environmental engagement clashed with neoliberal economic austerity measures in the early 2010s, with the city's trees a casualty.

A Battle Over Priorities

In 2012, facing massive budget shortfalls, the Sheffield City Council (SCC) signed a £2.4 billion (approx. US$2.92 billion) private finance initiative (PFI) known as Streets Ahead. The 25-year contract engaged U.K.-based, Spanish-owned Amey Plc. to maintain the city streets and paved infrastructure, including care of street trees. PFIs are a Thatcher-era invention where a private company administers municipal services. The company bears the initial costs and then charges the government for reimbursement at a predictable agreed rate, often retaining local staff (Barton, 2018). This structure encourages cost-cutting measures to maximize the PFI's profits.

The streets and sidewalks in Sheffield needed attention and, according to Amey, that included the felling of 6,000 "dead," "dying," diseased," "dangerous," "damaging," or "discriminatory"[11] trees (known as the six Ds[12]) over the first five years of the contract. As Amey started to remove trees, residents became alarmed at the change to the city's canopy, and neighborhood groups formed to oppose the felling. Eventually, the smaller organizations united and coordinated their efforts under the Sheffield Tree Action Groups (STAG) umbrella.

The "Sheffield Street Tree Massacre" was fought street by street and tree by tree as residents battled on multiple fronts to save their trees. The specifics of what occurred in Sheffield between 2012 and 2018 are outside this paper's scope. The events are well documented in regional, national, and international press, a work of nonfiction, a documentary, and several academic papers.[13] After escalating conflicts between activists, Amey, and the South Yorkshire Police (SYP), the city paused the removals at the end of March 2018. The SCC issued a statement, saying, "the actions of a handful of people unlawfully entering the safety zones where tree replacement work is being carried out has meant that it has become increasingly difficult for Amey to complete the programme without danger to staff and members of the public" (Sheffield City Council calls temporary halt, 2018).

Following mediated peace talks, the former adversaries joined specialists and regional conservation groups to create a comprehensive street tree strategy for the city, presented in May of 2021. A year later, Sheffield was named A Tree City of The World,[14] recognizing a community for best practices of policy, care, propagation, and community involvement with its urban canopy. This designation indicates the conflict's end and the transformation of the city's attitude towards its trees.

The Consequences of Leverage

Before the implementation of Streets Ahead, in 2011 the Sheffield City Council was divided between 32 Liberal Democrats, 49 Labour Party, two Green Party, and one Independent (2011 Sheffield City Council election, 2022). By 2021, the balance of power changed to 29 Liberal Democrats, 41 Labour Party, 13 Green Party, and one Conservative Party member, with the Labour and Green Parties forming a ruling coalition (2021 Sheffield City Council election, 2022). The Green Party supported the tree campaigners and STAG from the outset, with counselor Alison Teal arrested and charged for her protest activities. In the aftermath of the most contentious disputes between the SCC and the tree campaigners, the unrelated group It's Our City! submitted a petition for a referendum in 2019, which was passed by a wide margin in 2021.[15]

While correlation does not equate to causation, Sheffield politics underwent a sea change over the decade, accelerated by the tree dispute. The campaigners' advocacy and self-organization reverberated through the political system. In addition to the referendum, the Sheffield Street Tree Strategy offers a new guidance[16] "for the city to collectively view street trees as an asset, helping us to improve air quality, reduce flood risk, support wildlife and store carbon. This strategy aims to learn from the past in order to deliver our vision for the future of Sheffield's street trees" (Sheffield & Rotherham Wildlife Trust et al., 2021, p. 4). The document acknowledges the difficulty of maintaining streets filled with trees, emphasizing the planting and maintenance of the city's urban canopy. It also addresses broader environmental sustainability issues and inclusivity of all parties – regardless of age or socio-political status – in caring for and making decisions about the city environment.

The battle over Sheffield's street trees also had a national impact. Michael Gove, U.K. Secretary of State for Environment, Food, and Rural Affairs, named Sir William Worsley as national Tree Champion in June of 2018. The appointed mission was to "bring together mayors, city leaders and other key players across local government to prevent the unnecessary felling of street trees." An additional consequence came with the 2020 Environmental Bill, which included a section known as "The Sheffield Clause." It requires "Local highway authorities in England to consult before felling street trees" in a legal "Duty to Consult" the public on any street tree fellings (Environment Act 2021, 115).

There is a paper trail of reporting and political consequences of the conflict over Sheffield's street trees, but what were the effects on those living there? After visiting Sheffield, meeting with campaigners, and reading extensive interviews, it is evident that as residents watched beloved trees felled from their windows, it challenged their sense of place. They recognized they valued the trees – the non-human – in their personal and collective histories and were willing to place themselves in harm's way for their arboreal neighbors. This realization leveraged the residents of Sheffield to educate themselves, organize, and act. They collectively investigated and monitored Amey, the Sheffield City Council, and the South Yorkshire Police. They developed a sophisticated network to inform, plan, and execute their non-violent direct action. Eventually, their efforts ensured a more environmentally engaged and sustainable future for their community and possibly for their country.

Conclusion
In each case examined in this paper, trees and forests acted as leverage points for change,[17] forcing individuals and societies – and especially their governments – to adopt environmentally beneficial behaviors and mindsets. While the Charter of the Forest and Venetian Forestry Administration emerged from extractive goals, the extended life of trees did force an expansion of societal and governmental temporal frames. Further, a duty of stewardship towards trees and forests arose organically from the anthrosilvian interface, shaping new systems and regimes that engaged with forests and safeguarded them for hundreds of years.

The Menominee engaged in forestry from a paradigm of responsibility and reciprocity. Their conviction that forestry must be practiced based on stewardship overcame the obstacles of conventional silvicultural approaches and a governmental system enforcing an extractive mindset. In the process, they exerted transformative pressure and became an international leader in forestry and sustainability.

The events in Sheffield, England show the differing approaches and attitudes governing urban, rather than traditional, forestry. The engagement with trees did not arise from a need for raw materials or the products of the forest ecosystem. Instead, the conflict was shaped by differing visions of trees in daily life and their importance to a community. The leverage points align with those Abson et al. (2017) argue are particularly effective in pushing systems towards sustainable practices and beliefs.[18]

> How people perceive, value and interact with the natural world fundamentally shapes the goals and paradigms underpinning many systems of interest. Although not always immediately apparent, the functioning of a

> system is influenced by the degree to which humanity's reliance on the natural world is acknowledged, and the extent to which a close relationship with nature is identified as essential to a "good life." (Abson et al., 2017, p. 34)

In Sheffield, the community was shocked into perceiving, valuing, and interacting with their street trees by the actions of a struggling government. The street tree campaigners realized the trees were ecologically, historically, and personally "essential" to life in their city. Their actions were able to leverage a new systemic paradigm for their community and beyond.

Why is the interaction between industrialized societies and trees or forests of any consequence? Design must change or it will die with the economic and consumptive systems killing the planet. Alternatively, design will utilize its unique position between disciplines and ontologies to identify and utilize opportunities for new engagement points and new ways of making and thinking that benefit society and the environment. Irwin (2019) has stated that "identifying lifestyles and everyday life as leverage points for change is central to the Transition Design process" (p. 167). The historical and contemporary examples discussed within this paper show how this interface, often overlooked in the industrialized Western lifestyle, may offer designers a potentially powerful way to shape a transition to new mindsets that consider the natural world and help society look toward future horizons.

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[1] Gideon Kossoff, one of the originators of transition design, calls on David Orr when he describes it as an effort to "reimagine and remake the human presence in the world" (Kossoff, 2019, p. 51). For further discussion, see Arturo Escobar's *Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds* and issue 73 of the bilingual publication *Cuadernos Del Centro de Estudios de Diseño y Comunicación.*

[2] Buchanan posited that design will address ever-larger scale solutions as it develops as a discipline. The first order is addressed in graphic design, focused on communication. Industrial design's creation of "things" is the second order. Designing for action or interaction is the third order of design. Finally, thought is designed through systems and environments in the fourth order (Buchanan, 2001).

[3] In his book *The Third Horseman*, William Rosen provides an interesting perspective on the socio-cultural- technical-environmental transitions that led to a population boom in Europe at the start of the second millennium, which then set the stage for the great famine of the fourteenth century.

[4] Magraw and Thomure's (2017) paper illustrates the shift in language and our understanding of forestry since the writing of the Carta de Foresta. They discuss the following citation:

> To ensure sustainable management of the commons, the Charter built on traditional forest law to prescribe limitations on harvesting and hunting within the commons. According to Thomson, "even the Chief Justice of the Forests cannot license a tenant cutting his own Woods, unless there be enough left to shelter wild animals" (Ralph Turner, 2014. supra note 1, ch. 12). In another example, Thomson notes that a freeholder's license "extends only to felling, not to destroying these woods, since the springs must be left in the ground that they may grow to be Coverts again" (Ralph Turner, 2014. supra note 1, ch. 12). Forest dwellers thus could harvest from tree branches, leaves, and nuts, but had to leave the tree itself for regeneration. (Magraw & Thomure, 2017, p. 4)

While Magraw and Thomure (2017) acknowledge that Turner's interpretation emphasizes sustainable resource use, they seem unaware of a historical connotation employed by the Charter and Thomson – they imply the practice of coppicing, which was widespread in England at the beginning of the thirteenth century.

In coppice forestry, trunks of tree species – such as hazel, ash, willow, and hawthorne – are cut off several inches above their roots, leaving the "stool," or the base of the trunk and the root ball, intact. Depending on the species and the desired diameter, the tree will quickly regrow a mass of smaller stems, providing staves, poles, firewood, basketry, and "green hay" for repeat harvest in five to twenty years. Additionally, coppiced tree stems regrow in greater density, creating a thicket or "covert" that was the ideal habitat for small game.

To those in the late medieval period, the description in the Carta de Foresta would have implied specific definitions and forestry practices in its language and context. Those practices fell out of favor in Europe with the Industrial Revolution. Additionally, coppicing was never widely spread in the densely wooded North American continent as it was a way of managing limited arboreal resources. Magraw and Thomure (2017) would have had few opportunities to encounter a once common forestry practice well known during the Carta de Foresta era, further evidence of the radical change in Western societies' relationships with forests and arboriculture.

[5] Archeologists and historians believe that the city of Venice dates to the fifth century, when groups fled the mainland and the instability of the waning Roman Empire. The first settlement clung to islands that were little more than sandbars. The builders developed systems of wood platforms that they overlaid to stabilize the shifting island surfaces. These "rafts" provided a solid base for constructing stone and wood buildings and public spaces.

As the city's population grew, it engineered its way around the physical constraints of the original islands and the instability of the lagoon's sand and silty soil by driving many vertical pillars or Tolpi (tree trunks) close together into the lagoon, hence the "Forest of Venice." These timbers were trimmed to an even height above the waterline, with horizontal beams (again, tree trunks) placed on top to form a platform for building. The channels between the original 118 islands slowly closed until the fifteenth century. The Tolpi also formed the massive breakwater that helped protect the lagoon from storms and other high-water events.

The island nature of the city also had an impact on the construction atop these platforms. From the perspective of an individual wandering through the paths and waterways of Venice, the city appears to be a labyrinth of stone walls. However, stone is heavy and hard to float from the mainland. Many buildings are clad in a fascia of the material or ingenious conglomerates, enclosing completely wooden structures within. Any construction or renovation requires large amounts of timber.

While it may be difficult to find, Franco Mancuso's (2014) fascinating little chapbook *Building on Water* provides an overview of the physical construction of the city.

[6] The scale of Venetian shipbuilding required an immense number of woods of specific scale and species. A single galley constructed in the Venetian Arsenal during the fifteenth century required over 200 mature oaks, 50 mature beeches, and three or four straight and mature fir, with miscellaneous fir, larch, walnut, and elm completing the decking and fittings of the ship. Much of this wood needed to be specially prepared to ensure a seaworthy final structure, necessitating submerging the oak logs in the lagoon for six to eighteen months before milling (Appuhn, 2009, p. 55).

[7] As trees require soil, it is possible to use the few growing within the city to locate the original islands.

[8] It should be noted that at the beginning of the fifteenth century, the Venetian Republic was ruled and administered by The Great Council, composed of the hereditary Patrician class of over 1,000 members. This group elected from its ranks individuals to fill all legal and governmental positions. Power was also held by the citizen class of 2,500 men who occupied the civil service. Other than these roughly 3,500 individuals, residents of the city were disenfranchised (Britannica, n.d.).

[9] Sustained yield is the practice of harvesting timber at a rate equal to, or less than, a forest's growth. This emphasizes the long-term productivity of the woodlands with MTE managing for an outcome 150 years into the future. It assesses stands every ten to fifteen years using Continuous Forest Inventory (CFI) measurements. These are paired with the Operating Inventory (OPINV) calculated for the same period and used to adjust management practices to support the MTE's long-term forestry goals (Menominee Tribal Enterprises, 2012).

[10] A street tree is loosely defined as any tree planted along pavements or public right of way and is usually maintained by the municipality. Although they are often planted during infrastructure development, some street trees are remnants of agricultural fields or orchards that predate the (sub)urbanization.

[11] Discriminatory trees are those that impede pedestrian traffic and have the greatest impact on individuals with different mobility.

[12] All assessment reports from external arborists noted that the 6D criteria were an Amey/SCC invention and not an industry standard. The musician turned street-tree campaigner Jarvis Cocker added a seventh D: "daft" (Thuring, 2018).

[13] *The Star*, based in Sheffield, has exhaustively covered the dispute over the city's trees and politics. *The Guardian* and *BBC News* gave the story extensive coverage at the national and international levels. *Persons Unknown; the Battle for Sheffield's Street Trees* offers extensive interviews with many protesters, personal diaries of protest actions, and a compilation of legal filings and arguments. The book was written by Simon Crump & Calvin Payne (with Julie Stribley), two of the protestors arrested and charged by the South Yorkshire Police.

*The Felling – An Epic Tale of People Powe*r by Jacqui Bellamy documents the conflict in a feature-length film using archival footage and contemporary interviews. "No Stump City: The Contestation and Politics of Urban Street-Trees – A Case Study of Sheffield" by Ian Rotherham and Matthew Flinders offers an excellent overview of the history of the city of Sheffield's environmental policies and commentary on the recent conflict.

"Ethnographic insights into competing forms of co-production: A case study of the politics of street trees in a northern English city" by Matthew Flinders and Matthew Wood provides additional interviews with protestors and documentation of meetings and actions. "Procedural Environmental Injustice in 'Europe's Greenest City': A Case Study into the Felling of Sheffield's Street Trees" by James Heydon explains the political actions of the Sheffield City Council and their consequences.

[14] Tree Cities of the World is a program from the Food and Agriculture Organization of the United Nations and the Arbor Day Foundation which recognizes cities that meet five standards (Standards for Recognition, n.d.):

1. *"Establish Responsibility:" City leaders have formally charged an individual or board with overseeing street tree care.*
2. *"Set the Rules:" Laws or policies for street tree maintenance exist and implement industry best practices with clear consequences for noncompliance.*
3. *"Know What You Have:" There is a current inventory and assessment of the city trees to facilitate care and long-term planning.*
4. *"Allocate the Resources:" The annual city budget has a dedicated line for tree maintenance.*
5. *Celebrate Achievements: An annual community-wide educational event and celebration of trees.*

[15] It sought to change City Counsel governance to direct representation rather than delegated administration to better reflect the city's diversity (Sheff Ref 21, n.d.). In the supporting Commentary and Evidence submitted to the Overview and Scrutiny Management Committee, many of the tree protesters' complaints – the SCC's unwillingness to listen to constituents or external experts, a sense that public listening sessions were ignored or held after decision-making – were echoed. One paragraph specifically stated, "people across the city mention things like street trees/Western Rd memorial trees...as examples of poor judgment and flawed decision making by an executive operating in an insular way" (It's Our City, 2019, 4.18).

[16] (1) Sustainably and carefully managing and maintaining our street trees in accordance with best practice. (2) Ensuring our street trees are more resilient through the type and age of trees we plant and also how we manage the current street tree stock. (3) Increasing the value and benefits that flow from our street trees. (4) Contributing to a more equal distribution of urban forest across the city. (5) Increasing street tree canopy cover. (6) Involving the wider community of all ages in caring for and valuing street trees. (Sheffield & Rotherham Wildlife Trust et al., 2021, p. 18)

[17] Donella Meadows defines leverage points as "places in a system where a small change could lead to a large shift in behavior" (Meadows & Wright, 2008. p. 145).

[18] As found in Abson et al. (2017), "(i) the role of institutions and institutional decline and failure in systemic change; (ii) people's connections to nature and their influences on sustainability outcomes and (iii) knowledge production and use in transformational processes" (p. 33).

DESIGN, STORYTELLING AND OUR ENVIRONMENT: CRITICAL INSIGHTS FROM AN EMPIRICAL STUDY WITH STORYTELLERS

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Abstract
In 2021, the U.K. Design Council published *Beyond Net Zero,* introducing its Systemic Design Framework to help designers address complex challenges such as climate change. The framework outlines the four key roles that designers can play in responding to systems-oriented challenges: by being systems thinkers, designers and makers, connectors and convenors, and finally, as leaders and storytellers. The relationship between the practice of design, the practice of storytelling and the role of narrative is receiving more attention from designers and researchers, whether as deployed by designers or by researchers in understanding design practices and design sensemaking skills (Beckman & Berry, 2010; Bleecker, 2009; Childs et al., 2013; Dillon & Howe, 2003; Lloyd & Oak, 2018; Lupton, 2017). Recognizing that storytelling is a fundamental mode of human interaction and knowledge exchange shared and employed by most everyone (Bruner, 1991; Polkinghorne, 1988), we suggest that existing design research involving storytelling may be finding and reporting on what is a naturally occurring activity in socially-oriented design practice contexts, but missing critical and nuanced perspectives on the types, forms and manner of stories that can address system challenges and foster change. In this paper, we discuss empirical work from a funded U.K. research project that examines the relationship between sustainability, environment and storytelling practices from the position of professional storytellers which may better inform both content and application of storytelling approaches for design.

Data collection methods involve a series of surveys, ethnographic observations in storytelling workshops relating to the environment and semi-structured interviews with professional storytellers. Preliminary analysis suggests that storytelling requires greater institutional support to foster the practice for younger generations; storytellers are enthusiastic about sharing their practice with other disciplines to construct new narratives for addressing climate change with wider audiences; and storytellers see themselves as “cultural caretakers” of collective stories and raised concerns regarding storytelling

approaches aligned to the projective nature of design practices. Our discussion here will focus on two preliminary recommendations: first, that storytelling as practice be formally included within higher education design curricula in partnership with storytellers themselves; and second, to facilitate new storytelling content that addresses social injustices and societal imbalances and that highlights the potential impact and courses of action to mitigate climate apartheid. We outline that these recommendations should also ensure that both disciplinary practices of design and storytelling are able to thrive, survive and deliver effective change through "shifting the narrative" associated with the complex climate challenges our communities are preparing to address.

Author Keywords
Storytelling; design practice; social justice; environment; climate change; systems thinking.

Introduction

Recently, the British Academy (BA) held an open call to academic researchers in the U.K. to propose projects addressing their theme of "Shared Understandings of a Sustainable Future."[1] An interdisciplinary team of researchers from the University of Edinburgh proposed to address this theme through the project entitled "Shifting the Narrative: Exploring the role of arts interventions in supporting communities in working across sectors to achieve place-based climate action" (StN), which took place between January and June 2022. The project was led by academics from the School of Health & Social Sciences, supported by colleagues from the School of Education and the School of Design. This paper describes the StN project, the methods undertaken and the analysis of findings holistically, but draws insights and recommendations regarding placed-based stories and storytelling relevant to design (practice and theory).

Background

A number of public and private sector institutions and thought-leaders have started to call for "a new story," seen as a fundamental requirement in societies' transition towards sustainable, carbon neutral and resource sensitive futures, addressing net-zero targets and mitigating the impact of the pending climate crisis. Within the fields of design, the U.K. Design Council (2021) has outlined that for this to happen, designers may need to adopt new frameworks and embrace new ways of working. In their 2021 publication *Beyond Net Zero: A Systemic Design Approach*, the Design Council acknowledges that work is required to transition towards a sustainable, environmentally positive society:

> For the most part, designers are not yet using their skills and knowledge to deliberately support the green transition in the way that they should and could.
>
> However, there are many individuals who are working – or who want to work – in this way. The designers we've interviewed here are working deliberately and systemically to help transition towards net zero or to support climate mitigation or adaptation. But, in the view of many of our interviewees, much design work is currently superficial, making incremental changes without tackling underlying issues. The practitioners we worked with agree that for the most part, even well-meaning designers have a limited conception of the tools and approaches

> necessary to design for sustainability and other important emerging issues. (p. 6)

Beyond Net Zero (Design Council, 2021) engaged in discussion with a range of academics, industry professionals and policy makers involved in various design fields to understand what barriers existed for designers attempting to work in and deliver sustainable transitions and futures, with seven key recommendations emerging to assist designers wanting to become "change-makers." Through observations and interviews, existing change-makers were understood to possess various competencies and characteristics, allowing them to be identified as either: 1) systems thinkers, 2) leaders and storytellers, 3) designers and makers or 4) connectors and convenors. In terms of projects involving systems change, the publication makes the following qualification about those who are encouraged to adopt a role as an agent of change:

> There are common features across these roles. Some projects may include people who can span different roles, while others may need experts to focus on a single area. For projects to be effective, all of these roles must be filled from the start of the process. (Design Council, 2021, p. 25)

Design and Stories

Blaylock (2003) outlines that the use of narrative in (architectural) design has a long history in the field, with a great number of established architects adopting the role of writer as a manner in which to construct and convey ideas involving prospective design propositions, but that "...the use of narrative as a method to explore the design process and to develop ideas about program, form, and space might not be commonly presented as an option for design development to students at the beginning design level." Childs et al. (2013) consider narrative, which they outline as being synonymous with story, as a helpful tool in design ideation, allowing for quick and rapid production of concepts during ideation development in a variety of postgraduate design projects with students. Lloyd & Oak (2018) also consider stories and narrative a methodological tool during design co-creation with stakeholder participants, whereby design propositions and prototypes are configured as "imagined particulars" within a story framing of design futures, contrasted and linked with "past particulars," involving stakeholder behaviours and systems of values uncovered in discussion between stakeholders and designers in earlier co-creation phases. In contrast, rather than stories and narratives being considered useful methodological tools during design development, Dillon and Howe (2003) consider narrative in design as an attribute of the objects and outputs of design practice, where these objects of design

> ... have power in social settings: they offer an interpretation of the story of their existence; they give back echoes of their past. To regard design objects as forms of text allows "readers" to interpret them within their own frames of reference.

This relationship between the practice of design and the objects and outcomes which are capable of telling stories, even on their own, is furthered by Bleecker (2009):

> They are things around which discussions happen, even with only one other person, and that help us to imagine other kinds of worlds and experiences. These are material objects that have a form, certainly. But they become real before themselves, because they could never exist outside of an imagined use context, however mundane or vernacular that imagined context of social practices might be. Designed objects tell stories, even by themselves. (p. 5)

Beyond the design studio, scholars of science & technology studies (STS) have begun to realise that much of their own work examining the relationships between science, technology, society and policy has failed to help non-scientific actors and institutions understand complex sociotechnical systems and their impact on society. This has led to a subfield of inquiry examining the "sociotechnical imaginaries" associated with technical adoption and progress and the varying impacts these may have on the different societies and cultures, all dependent upon particular framings of cultural narratives (Chateau et al., 2021; Jasanoff & Kim, 2009; Nucho, 2022). The imaginaries approach has also started to see adoption as a form of critical narrative methodology within some areas of speculative and critical design (Soden et al., 2022; Strand et al., 2018).

The Narrative Tradition

Though engagement with story and narrative in design is relatively new and gaining interest, scholarship in story and narrative itself already has a longstanding tradition, particularly within the social sciences, including the structure of narrative (Greimas, 1971; Todorov & Weinstein, 1969); the social use of narrative in identity formation and experience (Labov, 1972); the construction of social reality through narrative (Bakhtin & Holquist, 1981; Marcus, 1995); and narrative as a qualitative research method of inquiry (Clandinin & Connelly, 2000; Riessman, 2008). In these instances, a marked nuance is noticed between story and narrative which distinguishes between story as "a sequence of events" and narrative as "a sequence of events, told from a particular point of view." Though a story may be an outline of events, the act of storytelling presents a practice that requires a particular point of view from the position of the storyteller, and the implied presence of an audience to whom the story is being told and a particular meaning being conveyed. This distinction is crucial, implying that storytelling and narrative are generally understood as particular modes of discourse amongst others which include description, exposition and argument (Newman, 1846).

Considering narrative as a mode of discourse frames it as a communicative practice, which critics have challenged as underestimating the power and role of narrative. Bruner (1991), for instance, reframes narrative as a form of thought involving circulation of knowledge and meaning-making that allows individuals, communities and groups to socially construct their world. In this framing, narrative knowing is contrasted with logico-scientific knowing, and Bruner (1991) explains the difference in these modes of knowing-the-world:

> As I have argued extensively elsewhere, we organize our experience and our memory of human happenings mainly in the form of narrative – stories, excuses, myths, reasons for doing and not doing, and so on. Narrative is a conventional form, transmitted culturally and constrained by each individual's level of mastery and by his conglomerate of prosthetic

> devices, colleagues, and mentors. Unlike the constructions generated by logical and scientific procedures that can be weeded out by falsification, narrative constructions can only achieve "verisimilitude." Narratives, then, are a version of reality whose acceptability is governed by convention and "narrative necessity" rather than by empirical verification and logical requiredness ... (p. 4)

It is this view of narrative, as an epistemological position of knowing-the-world through shared experience and understanding rather than an ontological account of what the world might categorically be, that has formed the foundation of our Shifting the Narrative (StN) project. As social scientists engaged with environmental ecology, education and design studies, our project team holds a shared view that narrative is both a mode of discourse situated on exchanging information about actions and events whilst also being a mode of knowing which allows individuals to relate to actions and events, to construct relevant meaning and in turn allow individuals and communities to shape identities and systems of value. This view has implications and consequences, namely that simply telling "a new story" does not necessarily imply an equivalent shift in narrative held by individuals and communities necessary for adopting new systems of value and forming new approaches of interaction. To help uncover ways in which individuals and societies can "shift the narrative" to embrace ecological values, sustainable behaviour, planetary compassion and eventually adopt appropriate actions to mitigate the climate crisis, our team engaged those with considerable expertise in the practice and craft of storytelling as specialists in the ecologically motivated, relationally driven storytelling oeuvre.

Methodology

The StN project was a relatively short research exercise which took place over a period of six months between January and June 2022. Our methodological perspective for this project was aligned to those found in traditional social sciences, as described above, in place of the material constructivist methodologies more frequently employed in design-led research projects. The research programme comprised four distinct phases involving: 1) synthesising findings from precedent literature; 2) conducting global surveys and focus groups; 3) semi-structured interviews with "best practice practitioners" identified through relevant networks and situated field studies in community arts events; and 4) summarising and disseminating research findings and insights through appropriate channels. Phases 2 and 3 constituted the primary data collection phases where a qualitative, mixed methods approach was employed involving an adaptation of the Delphi Technique (Hasson et al., 2011a) with storytelling experts and professionals, focus groups and semi-structured interviews. The Delphi Technique is an accessible methodology that allows for quick and efficient data collection based on reported insights and experiences from identified experts in the relevant area of inquiry (Hasson et al., 2011b). Our modified approach involved deploying an iterative approach to survey development, where data from an initial survey was collected, coded and patterns identified, allowing the research team to refine lines of questioning and return to our expert pool of informed advocates (IAs) for clarification, corroboration and correction.

Iterative Survey Development

Phase 2 of our research project began with the development of an initial survey involving 12 questions. This was circulated through our U.K. network of IAs with returned responses coded through an in-vivo process (Saldaña, 2013) using relevant CADQAS software to assist in identifying preliminary patterns in respondent feedback across 12 predetermined questions. This preliminary coding activity was done by the core research team, with each member coding a particular set of questions independently. Upon completing the first-pass of coding, the lead researcher compiled all codes and, deploying practices of code aggregation, proposed a preliminary coding framework. This framework was shared with the rest of the research team for consideration, corroboration and negotiation in order to achieve an informal shared understanding across the team, allowing for greater intercoder reliability.

Concurrent to compiling our coding framework, a few weeks after our initial engagement with our U.K. networks, the same survey was circulated to our global storytelling network. These later responses were then coded following our preliminary coding process and framework and variations were noted in responses based primarily on national locations of respondents. Having compiled an initial codebook through in-vivo coding, the research team were able to identify gaps in lines of questioning through the emergent coding schemes and nascent framework, and through our iterative approach were able to nuance our survey questions with follow-on material which was again circulated to our networks, both in the U.K. and globally. These secondary responses were coded again in the same manner as above, and coding schemes and frameworks addressed accordingly.

Embedded Fieldwork and Expert Interviews

During Phase 2, surveys were able to provide general insights through questions and responses, allowing for the development of our preliminary coding scheme and identifying patterns and trends in a broad community. In Phase 3, the project team directly engaged in fieldwork and semi-structured interviews with identified storytelling practitioners (individuals and communities) to collect further data and material from primary experience in order to enrich our analytical framework examining shared understandings of sustainability and climate change through practices of storytelling. Operating as "embedded researchers" (Lewis & Russell, 2011), members of the research project team participated in five events in the U.K. between April and May 2022, ranging from a local storytelling workshop to a guided tour of an outdoor ecomuseum to an annual conference (online) established by a recognised international storytelling network. Supplemental data collected from these events helped to expand and enrich preliminary research findings through the addition of situated notes and memos generated by researchers in situ, as well as affording opportunities for informal discussion and conversation with those other participants in these events. Situated fieldwork also afforded opportunities to identify additional experts in the field – beyond our established IA network – who were willing to participate through semi-structured interviews, fully rounding out our data set generated through our mixed method, social sciences methodology.

Analysis and Discussion

Numerous findings were uncovered in the analysis of our data from surveys, interviews and fieldwork notes. In consolidating this data, our final project report outlined seven key recommendations based on insights uncovered. These insights are briefly outlined here, with a final discussion about the potential implications for disciplinary practices aligning design and storytelling.

Seven Insights

Storytelling Creates Community While Holding Diversity

A key determination of our project scope was that our teams worked and consulted with traditional storytellers, which constitutes a particular focus of "storytelling practice." Our project did not engage authors, scriptwriters, filmmakers, advertising, marketing or other creative industries where people and teams may be involved in alternative, perhaps more contemporary, forms of "storytelling practice." Our project scope involved learning from experts and specialists who operated in historical and traditional modes of performative oral practice often accompanied by deep knowledge of people and place, rather than engaging with those creative professions involved in the commodification and propagation of stories for general consumption. For most of our IAs, their practices of storytelling were done with live audiences in local settings as events to be experienced, not only as venues allowing for the exchange of stories and content. This approach implicates the need to establish a relationship between storyteller and audience, but also requires the storyteller to construct some ambiguity and uncertainty in the story being told rather than conveying particular facts to be consumed. This difference is comparable to Bruner's (1991) distinction between narrative knowledge and rational knowledge where the former mode of knowledge requires ambiguity and uncertainty to allow the listener to create meaning, whereas the latter requires certainty in order to convey factual information.

Storytelling Is Fundamentally Dialogical

Our second insight involved our IAs stressing the importance of dialogue as the foundation of good storytelling. Whilst strong storytelling involved tellers being able to "read" their audience and adapt their performances accordingly to deliver the story as best as possible, this was understood to be a form of dialogue between audience and teller. This, we suggest, is a similar distinction between storytelling and narrative as forms of discourse or knowledge. We argue that discourse may convey information and knowledge objectively, but storytelling and narrative as dialogue allow for exchange of perception and perspective, leading to exchange, meaning-generation and ultimately construction of a shared understanding.

Storytelling, Emotions, and Care

Historically, stories and storytelling did more than just entertain and amuse; through myth, folktales and parables, they also allowed individuals and communities to share experiences and build meaning collectively about difficult circumstances involved with life, although it can be said that a well-told story is an emotional experience for the listener, and this can be extended to all forms and mediums of stories. Many of our IAs, however, stressed the important nature of "the particular" as relating particular emotions and requirements to care through place-based storytelling, often outside in particular landscapes, allowing the audience to perceive and re-frame their understanding of the very place in which they are participating in the storytelling performance.

Reaching People Who Have Not Yet Been Reached

A key theme that emerged from our research involved reaching new audiences, particularly when the practice of storytelling is often situated and many people continue to believe that storytelling is appropriate for children, perhaps because it continues to be misunderstood as a form of knowledge and meaning-making considered inferior to rationalist ways of thinking. Our IAs outlined that many had much success in working longitudinally with particular groups that understood their aims and objectives as storytellers, whilst others found that there continued to be significant opportunities to work with children and young adults in schools. However, many agreed that climate action and sustainable transitions required a wider audience than just communities of young people in order for effective action and narrative shifts about climate adaptation to take hold more broadly.

Skills Needed in Working with Stories in This Way

Many of the IAs we worked with in our project are academics and published authors on storytelling practices and were able to clearly articulate a wide range of skills and attributes possessed by good storytellers. Notably, many of the skills and attributes outlined could be easily summarised as "attending to the audience": pace of delivery, language structure and word choice and body language/facial expression were key performative attributes, but understanding of story structure and composition (setting, character, plot, arc) was also entangled here, as adaptation required understanding the audience with whom storytellers were in dialogue. Notably, facilitation skills were considered important in being able to make an audience feel welcome and comfortable, particularly when complex and difficult subject matter was being addressed.

It is worth noting here that our project was unable to construct a taxonomy of stories that our tellers were telling, since there was no consensus on particular stories that needed to be told. Rather, the IAs seemed to suggest that context should continue to take priority over content where discussion of content seemed to create often contradictory insights, both across our group of IAs and sometimes with IAs contradicting themselves.

Sustainability of Storytelling, Traditional Environmental Knowledge (TEK) and Traditional Knowledge (TK)

Our project was established with a line of inquiry about the relationship between storytelling, sustainable living and achieving this through "shifting the narrative." In many instances, our discussions with IAs fluctuated between "storytelling for sustainability" and "the sustainability of storytelling." For many, the local communities in which they worked were small, and truly traditional approaches to storytelling no longer sustainable in a global context. It was also noted that "sustainable storytelling" also included requirements of travel and the associated economic costs of going to other places, particularly to national and international storytelling events, despite some IAs experimenting with digital technologies such as Zoom to address place-based constraints. Most significantly, in terms of "storytelling and sustainability," serious concerns were raised about the viability of maintaining place-based stories in lieu of appropriating stories from other cultures and communities and the tensions associated with telling stories that were not indigenous to local communities, however those might be defined. Through these discussions, some of our IAs suggested initiatives that allowed for "story re-appropriation" through working with local communities to uncover lost stories and narratives which might provide benefit from being retold and re-distributed in the local communities from which they come.

Support to Enable Storytellers to Expand Their Contribution to Making the Shift to Net-Zero Society

As with many segments of society, it would seem that storytellers would relish more opportunities to help make transitions towards a sustainable culture addressing climate mitigation. Support was identified in a number of different ways, with direct financial support seen as a surprisingly low-ranking priority. Our IAs placed highest support priorities on increased opportunities for storytellers to apply their practice, particularly in venues for performance and audience engagement. Many IAs also suggested increased support for collaboration with other experts, notably climate scientists and sustainability experts, in order to better understand complex content in context. A third support priority was to find ways to develop stronger intergenerational networks; it was felt that this might best be fostered through curriculum integration in schools and universities where storytelling might benefit from forms of critical practice in dialogue between practitioners and students.

Implications for Design

At the outset of this paper, we outlined that our approach to the Shifting the Narrative project adopted a social science methodology in lieu of more material constructivist approaches often employed in practices of design and design research. However, whilst our findings remain analytical, we believe that they can also serve as guiding principles for other disciplines hoping to engage in storytelling futures, notably here for the field of design. As highlighted in the introduction, the U.K. Design Council's (2021) *Beyond Net Zero* suggests that one of the characteristics of "change-agents" often involves adopting the role of leader and storyteller, with an implication that this is a role that designers themselves should embrace, despite a small caveat that in some cases and projects, specialists may be desired. In a similar way, where Manzini (2015) posits two types of designers (expert and diffuse) in a world where "everybody designs," our research analysis also suggests employing a similar typology of expert and diffuse storytelling practitioners may be helpful.

In doing so, through our distinctions of expert and amateur practices, we suggest that a majority of designers may benefit from training and development in storytelling through two particular approaches in line with our current project insights and analysis, namely: 1) through fostered training in collaboration with expert storytellers through formal design education, providing equal priority to this critical practice alongside more traditional, materially driven practices associated with design thinking and design knowledge such as drawing and making; and 2) working with experts to construct new approaches to "design dialogues" through associated, particular, material outputs. This may be best achieved in partnership with environmental scientists, humanities scholars and storytelling professionals in order to encourage citizens and audiences to participate in narrative thinking and knowing as climate citizens, leading to dialogical models of design that encourage audiences to construct collective meanings, leading to shared understandings about how such transitions may be addressed. Like our IAs, we suggest that the importance of local, Indigenous knowledge be maintained, allowing for communities to engage in effective action and develop new stories and narratives that can be shared and circulated with other climate-action towns and communities.

Conclusions and Future Work

Whilst our survey, fieldwork and interviews engaged a particular community of practitioners identified as professional storytellers and tradition bearers, we anticipate that future lines of work relevant to understanding storytelling networks and practices in other disciplines will need to include further participation from those disciplinary perspectives also. While it may be straightforward to suggest that designers are storytellers or that designers are experts at deploying storytelling methods, we would consider that this is a relatively small cohort of professionals who would be considered experts by respective peers in both communities of designers and storytellers. Rather than attempting to build case studies around this rare breed of expert designer/storyteller, we propose adopting further research perspectives following along two lines of recommendations outlined by our current Shifting the Narrative project: developing useful, professional storytelling training relevant to critical design practices; and fostering new methods for meaningful collaborations with disciplinary experts to foster dialogue with audiences, leading to local stories and narratives of knowledge and action. To that end, some of this work is already in planning with a few local design agencies, design schools and practitioners in Europe and the U.K., and we look forward to developing more insights from these nascent, design-led interactions, allowing our project team to continue to tell this story.

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DIGITAL LEARNING EXPERIENCES FOR CREATING SOLUTIONS FOR ADAPTATION

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Abstract
In this research paper, we discuss ways of teaching and consider how critical thinking and sustainability can be included in the design teaching model. The outcomes of a master's program on multidisciplinary service design are presented in this paper, which is based on three case studies regarding the development of learning models that focus on digital learning experiences. We present a theoretical framework in which the issues of design for sustainability (DfS) (Ceschin & Gaziulusoy, 2015), adaptation (Hoffmann & Sgrò, 2011) and critical thinking (Ennis, 1993) are used to evaluate the developed learning models. Our aim is to develop learning models that can support sustainable development goals and inclusive learning experiences.

This paper presents case studies of digital learning models that address adaptation and new solutions for a more sustainable and equitable society. These case studies are specific study courses included in the curricula of advanced project studies on service design: 1) digital service design, 2) story-based service design and 3) spatial-oriented service design. Through the three case studies, we examine how different forms of haptics can be transformed in a digital learning context, how the materiality of design practice can be transformed in a digital context and how this learning experience can be made uniform and not place-specific.

Author Keywords
Digital learning experience; learning models; design for sustainability; adaptation; critical thinking; sustainable service design.

Introduction
Over the past two years, teaching modes have moved into online and hybrid environments, hence new ways of concretizing service design practices need to be considered for design teaching. Design teaching has been impacted by the global pandemic, which

may be interpreted as one of the outcomes of the Anthropocene (Steffen et al., 2011). In this paper, we not only discuss ways of teaching but also consider how critical thinking and sustainability can be included in the design teaching model. The outcomes of a master's program on multidisciplinary service design are presented in this paper, which is based on three case studies regarding the development of learning models that focus on digital learning experiences. We present a theoretical framework in which the issues of design for sustainability (DfS) (Ceschin & Gaziulusoy, 2015), impact of the Anthropocene (Anderson, 2015), adaptation (Hoffmann & Sgrò, 2011) and critical thinking (Ennis, 1993) are used to evaluate the developed learning models. Our aim is to develop learning models that can support sustainable development goals and inclusive learning experiences.

This paper presents case studies of digital learning models that address adaptation and new solutions for a more sustainable and equitable society. In service design teaching, haptic learning experiences are present, especially in service prototyping and demo-making. This study explores service design practices, blended learning and flipped learning approaches through three case studies. These case studies are specific study courses included in the curricula of advanced project studies on service design: 1) digital service design, 2) story-based service design and 3) spatial-oriented service design. Blended learning builds a hybrid space that combines online and onsite teaching. Hrastinski (2019) maintained that blended learning is generally regarded as the combination of face-to-face and online instruction, and it increases the accessibility and flexibility of students. Meanwhile, flipped learning helps students to prepare for upcoming class activities by reading through the teaching material beforehand. This is a type of blended learning in which the traditional class setting is inverted, as classes do not fully comprise lectures but problem-solving or practical assignments through discussions and peer-to-peer learning (González-Gómez et al., 2016). This balances the power structure between the learner and the teacher. Through the three case studies, we examine how different forms of haptics can be transformed in a digital learning context, how the materiality of design practice can be transformed in a digital context and how this learning experience can be made uniform and not place-specific. As an outcome, we propose teaching models for sustainable service design teaching in a digital context by examining the forms of haptics, materiality and blended and flipped learning approaches. We also consider how to develop learning models that create service solutions to address the theoretical framework.

Theoretical Framework

In this paper, we discuss sustainable development and DfS. One of the most well-known definitions of sustainable development is the 17 goals proposed by the United Nations, called the Sustainable Development Goals (http://sustainabledevelopment.un.org). These goals represent sustainability challenges that need to be resolved in order to create a more sustainable and equitable society. DfS is part of a larger holistic view of sustainable development that addresses challenges such as climate change, famine, disease and poverty. It offers a new and broader context for design in which a designer considers the environment and society while designing (Bhamra & Lofthouse, 2016). Based on Birkeland's (2002) vision of design, Bhamra and Lofthouse (2016) concluded that it is important for designers to 1) take responsibility for redefining needs, social/eco equity and justice, 2) re-evaluate design conventions towards social transformation, 3) restore the social and natural worlds and 4) achieve eco-efficiency to increase the economy of energy, materials and costs, to name a few. This agenda is still current, although Birkeland's

(2002) vision dates back two decades. Ceschin and Gaziulusoy (2016, p. 145) discussed how the focus of DfS has expanded from addressing only single products to addressing complex systems. DfS does not only include technical aspects of sustainability, such as green design, ecodesign, biomimicry, cradle-to-cradle or the role of users in the context of sustainability, such as emotionally durable design, design for sustainable behavior or resilience of communities, such as design for social innovation. It is explained how the scope of DfS has expanded to address systemic design innovations. Thus, designers need to go beyond developing solutions to improve recyclability and product energy efficiency to develop innovations that are much more complex and require a stakeholder network (users, policy-makers, local administrations, non-governmental organizations, consumer groups and industrial associations) for their implementation.

Light et al. (2017) discussed the gloomy predictions for sustainability as some of the most powerful countries scaled down their sustainable development goals, despite this being the Anthropocene age in which people have more impact on climate and planet than all other factors combined. The authors addressed value-sensitive design (Iversen et al., 2012), in which focusing on the role of human decisions is a means by which responsibility and care for other people can be recognized. It is proposed that designers and design researchers could stimulate alternative narratives and visions that can be attentive, different, critical and compact. Further, they argue that "it is possible to pursue good qualities of kindness and self-respect and not to live on as a species and/or surrounded by fellow species" (Iversen et al., 2012, p. 2).

Auld (2008) described the rationale behind adaptation by design and proposed how to respond to extreme weather changes and climate change. These first actions could be categorized as 1) "no regrets," defined as actions whose implementation would benefit the society even if anthropogenic climate change did not occur. The climate impacts of 2) further actions would lie outside of existing experience and the coping ranges of the existing infrastructure. Auld (2018) proposed the need to develop adaptation science and solutions and to reduce uncertainties around sound actions within the next decade or two.

In this paper, we utilize a theoretical framework (shown in Figure 1) that acknowledges the need for both DfS and adaptation for designing alternative narratives and visions for a sustainable future.

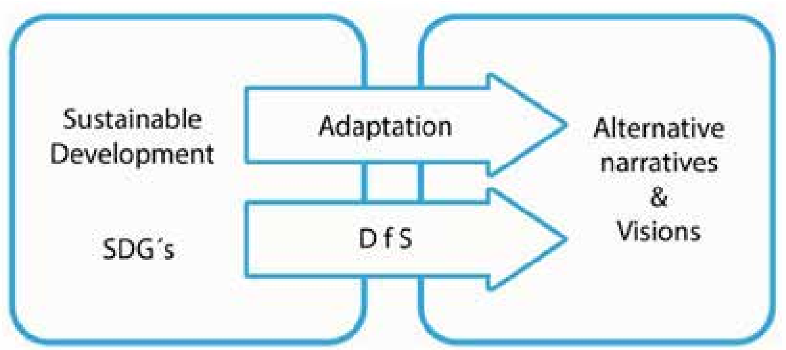

Figure 1. Theoretical framework.

Research Design

This research paper is based on case study research (Rule & John, 2011), where three different case studies – 1) digital service design, 2) story-based service design and 3) spatial-oriented service design – were documented and analyzed. The case studies were documented through participant observations (Spradley, 2016) and note-taking. Throughout the case studies, collective autoethnography (CAE) was used, as there were several researchers/teachers working with different courses and documenting their experiences. This method was very valuable as it enabled us to utilize the researchers' personal experiences and their understanding of the larger cultural context or phenomenon taught (service design, sustainability) and the adopted teaching medium (blended learning or flipped learning) (Adams et al., 2015). The benefit of CAE is its multivocal approach through discussion, knowledge-sharing, data interpretation and sharing of and reflecting on personal experiences (Lapadat, 2017). The case studies were analyzed using a theoretical framework to respond to the research questions. This research is also used as an exploratory study (Bontis, 1998) to develop learning models and hypothesize how these learning models would respond to sustainable development needs. In the case studies, both teachers and learners were encouraged to use critical thinking to evaluate the value and impact of the case studies. Lai (2011) described critical thinking as the "skill of analyzing arguments, making inferences using inductive or deductive reasoning, judging or evaluating, and making decisions or solving problems" (p. 1). Meanwhile, Norris and Ennis (1989) defined critical thinking as reasonable and reflective thinking that decides what to believe or do.

Digital Service Design

A learning goal for the digital service design course was to introduce a development process of digital services using service design methods. The advanced ten European Credit Transfer and Accumulation System (ECTS) credit course focused on both the comprehensive and holistic user experience of service and digital solutions that would create a service experience. The course was part of the study plan for the master's program on multidisciplinary service design. The students worked in teams of three to four, with each team having a client company to develop the service with. The project work done for the client included outlining the service objectives and user needs, developing the service concept, designing, prototyping and testing digital service elements and demonstrating the service concept using digital tools. Due to the Covid-19 pandemic, the course was fully delivered online during the 2020-2021 academic year. In the 2021-2022 academic year, the course was mainly delivered online and included three intensive two-day weekends for onsite, face-to-face team meetings for work. In addition to practice-based project work, the student teams utilized the flipped learning approach to share expert findings about selected topics, including, for example, the internet of things (IoT), agile development and digital public services. These lessons were delivered in a peer-to-peer manner, where the students led the lessons and the teacher supported them.

During the 2020-2021 academic year, the course classes were fully taught using the flipped learning approach. Since most of the students already had strong working life experience, the teacher wanted to benefit from their expertise. This had a significant impact on the power structure between the learners and the teacher. The students' roles also became somewhat flipped or at least more balanced, giving them an opportunity to share their insights and have wide access to learning within a vast company cluster. First, the students created small teams where they determined the lecture topics they were interested in and had insights about, based on their past working life experiences in service design cases, related to digitalization, artificial intelligence, IoT and so on. Second, they produced learning materials for others to study before class. Third, during the classes, the topics were discussed, and problems that arose were solved through practical tasks and assignments using Miro online whiteboard (www.Miro.com) in a workshop-like way. Thus, the classes were inverted from the traditional class setting into classes where co-creative problem-solving and practical assignments, including discussions and peer-to-peer learning, were at the core, following González-Gómez et al.'s (2016) study.

Feedback was collected from the students and their experiences with the flipped learning approach were assembled and carefully studied. One of the main discoveries was that the approach significantly increased the workload of the students. In the 2021-2022 academic year, the course was planned differently to balance the workload of the students. The number of flipped learning lessons decreased, and only three of the eleven half-day classes included flipped learning lessons during the academic year. Additionally, two teachers adopted traditional class settings through online teaching. The course also included expert guest lectures provided by digitalization and design experts working in the area of digitalization. Three intensive two-day weekend sessions for onsite, team-based work were also implemented during the 2021-2022 academic year. This enabled us to provide face-to-face learning experiences supported by teachers, supervise the students' work with the client companies' projects and support the teamwork practice of the students. Moreover, it offered the students an opportunity to visit the local companies in which they produced service design work.

The mixture of online classes and digital learning experiences, blended learning, flipped learning, expert lectures, traditional class settings and face-to-face project work provided accessibility and flexibility (Hrastinski, 2019) not only for the students but also for the teachers and expert lecturers. Online work provided an opportunity to invite experts nationwide without the need for them to travel; hence, it enabled more agile course arrangements. Moreover, location-based teaching was not required by either the students or the teachers. However, intensive two-day, face-to-face learning sessions onsite at the University of Lapland supported both the grouping and building of team spirit for the students' project teams. Furthermore, it contributed to relationship building between the students and teachers, as well as between the students and client companies.

Based on the feedback and teachers' observations of the course during the 2021-2022 academic year, there was a higher student satisfaction rate regarding the teaching methods and workload compared to experiences from the previous academic year. This was also evident in the course results, as the students achieved excellent results in their course-work, including the teams' project deliverables, flipped learning materials and classes produced by the students and individual essays. Hence, the mixture of blended and flipped learning approaches, combined with traditional class settings with online teaching, expert lectures and face-to-face intensive sessions, were highly appraised by the students and teachers. A combination of these methods will be used in the future implementation of the course.

In the course, sustainability was a cross-cutting theme in both the project work and teaching. The digitalizing world challenges students to design their digital service innovations through DfS, where the ability to consider, for example, the environment and society is emphasized (Bhamra & Lofthouse, 2016). In teaching, sustainable development should promote different approaches for inclusive, equitable and lifelong learning. Digitalization and online teaching provide a platform to test different digital solutions. These can include, for instance, different online tools for group work and speech-to-text translation as part of the accessibility of digital services.

Story-Based Service Design

The story-based service design ECTS credit course was held amidst the Covid-19 pandemic during the 2020-2021 and 2021-2022 academic years. A large part of the course in the 2021-2022 academic year was delivered through digital platforms, such as Microsoft Teams and Miro, for teaching and group work. Virtual learning platforms can become constructivist learning environments in design education, supporting team-based design and communication skill-building (Gül et al., 2012). Due to the pandemic, it was possible to organize only one intensive weekend during which the students worked onsite at the University of Lapland. During this weekend, the students and teachers had face-to-face meetings with one another. The learning goal of this advanced course was to introduce the ideas, benefits, methods and practices of storytelling in service design projects (Neuhoff et al., 2022; Olajuwon-Ige, 2020; Yamaoka & Sakamoto, 2015). The course was part of the study plan for the master's program on multidisciplinary service design.

The course included lectures, webinars and reflective discussions and utilized constructive (Gül et al., 2012) and project-based learning (PBL) (Kokotsaki et al., 2016) approaches, where students worked on assignments in teams. PBL supports student-centeredness in teaching, focusing on students' "autonomy, constructive investigations, goal-setting, collaboration, communication and reflection within real-world practices" (Kokotsaki et al., 2016, p. 1). On one occasion, a lecture was conducted by a student offering the same course as the other students. Other lectures were conducted by the teacher and guest expert lecturers from various design fields. This gave an interesting and sometimes critical perspective on storytelling. Having one occasion of peer-to-peer teaching as a flipped learning experience and a number of different expert lectures on the course were widely appreciated learning experiences among the students. The group assignments were supervised by the teacher and student peers, and this exercise was regarded as useful, as the groups shared and compared different approaches and cases. When a teacher conducted the supervision, it had a higher-level hierarchy, as the teacher had both industrial experience and seniority, yet it was important to induce a feeling of safety among the students and encourage them to open discussions and compare their opinions and experiences. Meanwhile, when student peers conducted the supervision, it included critical reflection, further innovation and peer-to-peer learning. In a similar vein, the lectures concentrated on discussions and introduced the concept of storytelling and its possibilities in service design.

In story-based service design, the focus is often on how intangible, abstract elements, such as values or brand identity, can be conveyed in a form that is easily comprehended and interesting for the user and/or client (Chang & Lin, 2020). It emphasizes the drama-associated elements in and during service, such as the straightforward stories brought to customers about service or following the dramatic arc from the beginning to the end of the service (Li & Chen, 2021). Based on the principles of service design methods, the students were first introduced to the client company and its service portfolio. This was conducted mostly by remote interviews and, in some cases, by service safari who experienced the service themselves. In a digital course setting, it was challenging for the students to transform this information into a format that could be studied and further developed. This transformation process is at the core of service design in general and is particularly emphasized here. Thus, communication with the entrepreneurs and background material from the companies were vital and recognized by the students.

The student groups sought and found ways to apply and benefit from the story-based service design methods to develop the case to which they were assigned. The majority of the students expected the methods to offer a quick and straightforward tool to develop a service. This course challenged the students' perceptions of classic classroom teaching. A more tutor- or mentor-like approach and encouragement towards experimenting was sometimes experienced as a more fuzzy and open-ended way of teaching. Changing these assumptions may require a change in one's beliefs and expectations as well as critical thinking, building of trust between the teacher and students and feelings of accomplishments when reaching milestones in learning journeys. Towards the end of the course, the students saw the complexity of service design. They learned the challenges of the fuzzy front end of a design or innovation process with companies in practice (Christiansen & Gasparin, 2016).

Stories are powerful means of conveying ideas and beliefs (Clementson & Beatty, 2021). Thus, it calls for responsibility from all stakeholders involved in the chain of adding value to clients and businesses alike. This chain could start from the education provider to the designer, the client company and its client, and ultimately to society as a whole and the world. When studying specific aspects of design, such as story-based service design, focusing on storytelling, narrative and theatrical methods adds holistic, critical and reflective perspectives to service design and can be utilized towards more sustainable service design.

Students could have engaged in a deeper reflection on the rationales or implications of story-based service design tools during or after assignments. As there is an eagerness to interpret service design as a simple toolset, the teacher's role is to encourage students to adopt the critical perspective inherent in the scientific approach and mentor them to challenge themselves beyond the borders of the simple toolset to find and develop novel and unique tools and solutions with and for the companies involved in the assignments. This, in turn, might enhance the feeling of safety and facilitate paradigm change for the students, often with working experience in the field.

The designers' role in enhancing sustainability as a responsible doer/maker was brought up by an expert lecturer and in brief discussions during lectures. Sustainability is a cross-cutting theme in all design teaching. Sustainability and critical thinking in service design need to be all-encompassing in the courses for the students to attain a comprehensive understanding of the topics. This might require a certain level of paradigm change and teacher training to create stronger momentum. It could be a productive way to stress knowledge- and thought-sharing between student groups to open up the possibilities of methods studied across the study plan. In addition, it could democratize and enhance the horizontality of the hierarchy in which "course-bubble" students are immersed. This was and can be conducted via applications, such as Teams, Zoom, Miro, etc. If social interaction in a world after an acute Covid-19 situation becomes more unlimited, it is still feasible to meet in digital venues and share information over the internet. Meanwhile, meetings in the digital world may have changed during this period of isolation such that they are not so formal in nature and students may be more at ease with video meetings. The way students can exert trust and feelings of safety with one another during meetings is perhaps one of the key elements that will be addressed in the future. De Vere et al. (2021, p. 6) discussed safeness by design as a specific lens of design practice that operates outside safety compliance networks. It uses a number of approaches, such as "human-centered design, experience and interaction design, social design and service design approaches, rather [than] risk management methodologies, to achieve actual or perceived safeness" (De Vere et al., 2021, p. 6). The authors propose safeness by design not as a design specialization but as a generalist approach all over designers' toolkits. The feeling of safeness would probably also enhance the critical thinking of students, affecting how they perceive service design tools and mindsets and eventually leading to new narratives and visions.

It can be argued that sustainability is affected by a critical, safeness-inducing approach to the behavior of clients, companies serving them and designers developing the services. The dimension making this possible from the education providers' perspective could be the safe mental space that changes how the world is seen and constructed using service design tools, such as story-based service design. This can partly be enhanced by blended and flipped learning, flattening the hierarchy, using a mentor-like approach and peer-to-peer learning, having students as lecturers, mentoring sessions with teachers and having groups give feedback to one another.

Spatial-Orientated Service Design

The learning goal for the spatial-oriented service design course focused on the different possibilities and dimensions of space using service design methods. For example, spatial-oriented service design can be used to improve the functionality of work environments, develop experiential interiors for travel and strengthen the business space brand. This ten ECTS credit course is part of the master's program on multidisciplinary service design.

This course was mainly attended by adult learners who were working simultaneously in different locations in Finland. This is why the course was designed to be organized using both contact and distance-learning methods. However, due to the Covid-19 pandemic, the course was delivered online in the 2020-2021 and 2021-2022 academic years using Microsoft Teams and Miro platforms. The online course teaching comprised lectures, assignments, group works and seminars. While the topic of the course remains the same, digital learning enables the effectiveness and productivity of teaching practices. The teaching and learning experience was improved using blended and flipped learning methods.

In this course, interior design and spatial design principles are applied when designing service environments. The course includes comprehensive project work focusing on service design, where service design processes and methods are applied in the design of the physical, social and mental spatial environment. Schon (1987) described how studio work supports students' ability to reflect in action or "reflection-in-action." Overall, when teaching service design in the studio, company briefs are the start for practical doing and learning. Some companies and organizations that were participating in the project for the master's program on multidisciplinary service design also gave design briefs for students as project assignments. The project work included the development of a service environment through user- and activity-based and visual spatial design. This kind of learning style in design is supported by Kolb's (1984) experiential learning style, in which knowledge is created through the transformation of experience. Demirbas and Demirkan (2007) revised Kolb's (1984) four phases of the learning cycle: concrete experience, reflective observation, abstract conceptualization and active experimentation, which have a strong relationship with the iterative manner of innovation and the design process. Because the teaching was online, companies and organization representatives found it easier to attend the course.

The students worked on the design projects in small groups, which allowed for better discussion and presentation of different perspectives than in large groups. In addition, teaching was more intensive when focusing on special design problems. Digital platforms enable the easy sharing of files and visual materials, which are an important part of learning spatial-oriented service design. Moreover, the online learning platform allowed students to dip in and out at times that suited them, depending on where they were. Course lectures were also recorded, which allowed students to return to them at any time.

In teaching, the blended learning method was broadly used, utilizing various teaching activities such as lectures, exercise sessions, workshop days and self-study. The course was taught by teachers and guest lecturers from different companies and organizations, and the aim was to utilize extended expertise to improve the students' work life understanding.

The course teaching was attended by adult students who already had other studies, career or work and life experiences. The flipped learning teaching method allowed the students to apply what they already had, complement it and bring it to one another's attention. The course assignments applied the flipped learning method, and it was called "Theme quarter" because its purpose was to prepare and present short information on the chosen topic. Each student was allowed to choose a topic that related to the concept of physical, social or mental space. These topics supported the understanding of the concept of spatial-oriented service design and created a source of important background information for the course. Through the assignment, the students made good use of their skills – such as their previous work and life experience – which motivated them to acquire more information about their chosen topic. The students could present the outcomes of the "Theme quarter" in the way they wanted; for example, as a visual presentation, video or using various web-based applications. This flipped learning method motivated the students and gave them interactive discussion, even though it happened online. Furthermore, it provided students with information they had never thought of considering when designing space-based service design environments.

Overall, the students reported a positive experience in studying the spatial-oriented service design course in an online context and using digital learning platforms. Most of the students reported that working in small groups when doing design projects was essential because of timetables. When working in small groups, the students felt supported and understood by their fellow students. The fact that the design project tasks embedded in the online course were group-based forced them to work together to achieve learning outcomes.

Throughout the course, the topic of sustainability was a cross-cutting topic embedded in the learning goals. Educating the students about the importance of sustainable development was reflected in the spatial design practices taught throughout the course. In addition, the use of digital platforms reduced the overall environmental footprint of the campus. The course also highlighted how to conduct insightful research on the challenges of sustainability with the companies and organizations at hand.

Conclusion

Collaborative ethnography with reflective and critical thinking enabled us to discover shared outcomes. One of the final outcomes shared by all three case studies was that in a blended and flipped learning approach, it is essential to apply democracy and open access to information between all parties. The open information flow from students with high respect for their work and life experience is essential, for example, even if it sometimes challenges the teacher's role. In this case, teachers should be open to feedback. Furthermore, the flipped learning model also challenges students' workloads, and this should be carefully managed so as not to exceed ten ECTS credits. Therefore, careful planning of the workload is needed, as well as good tutoring work with the students so that they understand the value of their input for the course. In addition, online teaching is now always inclusive, and it needs to be developed such that it becomes an increasingly viable and inclusive option for all. The benefits of onsite studio teaching are still quite evident.

The above figure is describing both a learning model for sustainable service design as well as the insights learned from the case studies. The two circles represent learning phases that project work with the company cases within the advanced ten ECTS credit courses (digital service design, story-based service design and spatial-oriented service design) create. Further, it introduces key concepts that are embedded in both sustainable service design and service design for adaptation. In conclusion, it is important to note that to create a framework for sustainable service design, a feeling of safety needs to be created, supported by high trust between the stakeholders, with the teacher and with one's abilities; this enables creativity. Critical thinking is essential in challenging one's own thinking patterns regarding sustainability. This is needed to create learning experiences that contribute to new alternatives. The learnings, reflection-in-action, working with company briefs in the studio and creating new services, empower the students who will learn new skills and competencies that will help them solve problems and create innovation. To use sustainable service design to create alternative sustainable narratives and visions, students need to be empowered with the mindset (Brenner et al., 2016; Groeger & Schweitzer, 2020) that enables individual learning processes while designing during studies and later in work life or both simultaneously. The mindset will increase their skills and tool sets and strengthen not only their sustainable service design but also their ability to service design for adaptation.

This study is a work in progress, and it has several limitations; all comments and contributions are warmly welcomed. These suggestions will be used to further develop sustainable service design teaching.

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ELDERLY USERS' SATISFACTION FROM SHANGHAI UNIFIED E-GOVERNANCE ON MOBILE TERMINALS: THE EFFECT OF THE DESIGN INTERFACE

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Abstract
The deterioration of the environment has accelerated the wave of social digitalization transformation from enterprise to government. However, the reform has also brought challenges and multiple forms of the digital divide to some people, especially among the poorest and the most vulnerable groups. Elderly users' satisfaction is important for the success or failure of the e-governance portal due to the aging society. This paper aims to identify the effect of design and usability on elderly users' satisfaction with e-governance systems by using empirical analysis in the form of a questionnaire. A total of 357 senior residents in Shanghai participated in the research and their data was processed by the software SPSS. The research contributes to several findings, indicating that elders with different gender and education levels appear to have different degrees of satisfaction with e-governance. Male elders and those with high levels of education have been proven to have better performance when using the digital, therefore these groups of the population have higher satisfaction. Among the five dimensions surveyed, structure design was rated high and found to be a critical factor for satisfaction levels with the e-government application while the entry guide and information design contribute insignificantly to the satisfaction level achievement. This study has a certain reference value for the development of government digitalization and low-carbon green development.

Author Keywords
Sustainable design; e-governance; interface design; user satisfaction; user experience; digital transformation.

Introduction
Climate change has a far-reaching impact on the sustainable development of the world. It is regarded as one of the risks in the process of endogenous development. To some extent, it can cause other, more prominent social problems such as poverty. At present, many of the poverty-stricken zones in China are located in places with relatively poor ecological environments. These places have fragile ecological environments, remote locations, and a lack of basic guarantees for economic development (Zhang et al., 2021). Some organizations emphasize the transformative impact of digital technology on achieving the 15% emission reduction target by the end of 2030 (Falk et al., 2019). The development of

digital technology brings offline government affairs online, which not only reduces carbon emissions to a certain extent but also helps to establish a real-time iterative and efficient sharing of the information base for the poor. The incidence of poverty in Xianyang city in China decreased from 10.53% in 2014 to 0.63% in 2020, in which the e-governance platform played an important role. Relying on big data and cloud computing, the government has established a mobile app for targeted poverty alleviation which can realize an "all-in-one net" for basic information, assistance, and project fund management for poor households (Shanxi Provincial People's Government, 2020). It promotes information sharing and the interconnection of different official departments. E-government in some areas of China has been extended to the village level, promoting the free flow of public resources between urban and rural areas and providing the authorities with accurate decision support for poverty alleviation.

Meanwhile, the digital emergency response to crises and online service capability of the Chinese government has been continuously improved during the pandemic. In 2018, China's global ranking increased from 65th to 45th in e-government management. In particular, the online service index jumped from 34th to 9th in the world, which indicates China is becoming a leading nation in e-governance (United Nations, 2020). Some cities established online government portals, so the matter handling capacity of the system across regions and departments has been continuously optimized. By July 2019, China built 31 provincial government service applications (Chinese Academy of Cyberspace Studies, 2019).

As for Shanghai, the program of unified e-governance was initially built in July 2018, and the reform was recognized as a classic case in the UN's (2020) *E-Government Survey 2020*. The digital platform provides comprehensive services and contains the richest local government information resources. As shown in Figure 1, the homepage of the app displays five main modules – QR code scanning, green health code, license collection, online customer service, and a personalized page. Shanghai e-governance had more than 58 million registered users by 2021, and 1380 government affairs and public services have integrated into the program (State Information Center, 2021).

Figure 1. The Shanghai unified e-governance mobile application (credit: author).

However, the reform has also brought challenges and multiple forms of the digital divide to some people, especially among the poorest and most vulnerable groups. There is a gap between the rapid development of technology and an aging society. Digital reform has an impact on senior citizens' lives. In 2021, the registered resident population reached 14,953,400, with 5.42 million residents aged 60 and above, accounting for 36.3% of the total, far exceeding the internationally recognized standard of aging society (Shanghai Municipal Bureau of Statistics, 2022). This indicates Shanghai is a city with a high degree of aging as well as digitization.

Public satisfaction is an important indicator in assessing the success of e-government, especially for vulnerable populations. Therefore, this research conducted an empirical study to analyze the acceptance and usage of Shanghai elderly users of the e-governance application. In the end, the research findings and implications are discussed, and some suggestions are put forward.

Literature Review

User Satisfaction

User satisfaction is an important criterion to judge the quality of an information system. It is a critical index because it has been examined in connection with many important variables in systems and design.

Researchers have constructed various models from different points of view to interpret user satisfaction. Researchers discovered that the dimensions underlying website user satisfaction can be expanded to eleven constructs, based on previous literature on user satisfaction (Muylle et al., 2004). Some studied the influence of overall website design (Tandon et al., 2018), some explored particular aspects of interface design (Ant Ozok & Salvendy, 2000), and others analyzed the impact of website quality on user satisfaction. There are researchers who measured user satisfaction with e-government services

(Alkraiji, 2020). A few researchers attempted to identify the important elements that determine user satisfaction with e-government services which are security and privacy, trust, accessibility, awareness of public services, and quality of public services (Alawneh et al., 2013). U.K. researchers examined the impact of information quality, system quality, trust, and cost on user satisfaction with U.K. e-government services (Weerakkody et al., 2016). However, those research papers have not discussed the influence of e-governance on the satisfaction of the elderly.

Interface Design for the Elderly
Some researchers have studied the use of digital products by seniors. Due to the decline of physiological function, the acceptance of digital products by the elderly will be lower than that of the young (Hall et al., 2001). Although they still have the ability to learn, they will inevitably suffer from behavioral disorders and cognitive impairments such as slow response, memory degradation, hearing, vision, and degradation in both hands. The ability to learn and accept digital devices is lower for elderly people than that of young people (Craik & Salthouse, 2011). The aged people might have problems with digital interactions because of inappropriately designed interfaces, products, and systems, among other reasons. De Barros et al. (2013) pointed out in their study that the elderly prefer to click the icon button, so it is suggested that designers should operate the icon or text as a single element button. Zhang and Lin (2015) conducted a study on mobile phone interface design for the elderly and discovered that the elderly preferred to use an easy and concise interface, therefore unnecessary elements should be avoided in design for visual identification consideration. Ho and Tzeng (2021) proposed that the interface design for the elderly should pay attention to font style and line spacing to meet the needs of their low vision. Therefore, for a humanized design, we should take into account the special needs of the elderly for text, pictures, buttons, line spacing, background, and colors, reflecting the design principles of simplicity, clarity, and ease of use.

Considering the authority of the theoretical model and its correlation with the content of our research, this study is based on Steve Muylle et al.'s (2004) theoretical model and questionnaire to examine elderly users' satisfaction with the Shanghai unified e-governance from five dimensions: information design, ease of use, entry guidance design, structure design, and layout design.

Methodology
Based on the literature review and previous works, we empirically investigated the effect of design and usability on user satisfaction from the Shanghai e-governance portal. To this end, a survey questionnaire was assembled based on previously reported dimensions for measuring user satisfaction. After sorting and classifying, the data was processed by the software SPSS for Mac 26.0. Independent t-tests and analysis of variance (ANOVA) were used to measure and analyze the demographic statistics and the related variables.

A total of 357 Shanghai elderly users with experience using the app participated in this study. The research was conducted over one month, between May and June 2021. Elders older than 60 years in Shanghai were considered research subjects. A total of 380 copies of questionnaires were distributed online and offline, with 365 returned, of which 357 were valid.

The questionnaire included two parts with a total of 21 questions. The first part was collecting demographic information data, including gender, age, education level, and occupation. In addition, information on use frequency and the main purpose was also collected. The second part was the measurement of user satisfaction; using a five-point Likert scale (from 1 – very low, to 5 – very high), respondents rated their reactions to the online service.

The user satisfaction constructs applied the well-established questionnaire developed by Steve Muylle et al. (2004). It should be noted that we focused on five dimensions of user satisfaction with a website interface from Muylle et al.'s (2004) questionnaire since the portal research does not involve specific hyperlinks or language choices. Two to four questions for each dimension were set up. The five dimensions we focused on included:

- Information design: the extent to which the user can comprehend, discern, and perceive.
- Ease of use: the extent to which the website is perceived to be user-friendly.
- Entry guidance design: the user's understanding of the homepage in guiding them to the right page on the website.
- Structure design: the extent to which the different parts of the site are connected.
- Layout design: the appearance of the website in terms of colors, fonts, and images.

Data Analysis

Descriptive Statistics

A total of 357 elders were investigated (Table 1). The number of men and women in the research was almost equal (50.1% men, 49.9% women). 210 respondents (58.82%) were in the 60-65 years old age group and 129 were in the 66-70 years old age group (36.13%), with only 18 elders over 70 years old (5.04%). The majority of respondents were well educated, with 56.0% of the elders holding at least a bachelor's degree and 13.4% holding a master's degree. 30.5% of people held a high school level education or below. It is notable that 41.74% of the respondents used the service three to four times a week and 22.41% used it every day, while 35.85% of them used it only one to two times a week. Elders used the service for querying information (34.45%), handling personal matters (28.29%), showing green codes to move around the city freely (25.21%), making an appointment with a doctor (6.72%), or other purposes (5.32%).

Demographic object	The valid items	N	Percentage
Gender	Male	179	50.1%
	Female	178	49.9%
Age	60-65	210	58.82%
	66-70	129	36.13%
	>70	18	5.04%
Education level	High school and below	109	30.5%
	Bachelor's degree	200	56.0%
	Master's degree and above	48	13.4%
Occupation	Farmer	37	10.36%
	Laborers	101	28.29%
	Employees of enterprises	157	43.98%
	Others	62	17.37%
Frequency of use	1-2 times a week	128	35.85%
	3-4 times a week	149	41.74%
	Use it every day	80	22.41%
Main purpose of use	Travel green code	90	25.21%
	Personal matters	101	28.29%
	Query information	123	34.45%
	Make an appointment with a doctor	24	6.72%
	Other	19	5.32%

Table 1. Demographic data of the survey (n=357).

Reliability and Validity Verification

The original version of the questionnaire has been published and therefore has established reliability and validity. For our research, the reliability of the measurement on a sample of 357 participants was also found to be good. The Cronbach's alpha for the data we collected was 0.940, which indicates the questionnaire has high reliability.

Difference Analysis of User Satisfaction

Table 2 shows the difference analysis between elderly men and women in various dimensions. If sig. is greater than 0.05, there is no significant difference; otherwise, if sig. is less than 0.05, there is a significant difference. It can be seen from Table 2 that both men and women rated structure design highly among the five dimensions. The difference is elderly men rated the information highest while women rated the entry guide highest. For all dimensions – including information design, ease of use, entry guide, structure design, and layout design – the mean scores rated by men were all higher than those rated by women, with all the T values greater than 1.96 and all significance values at or less than 0.01, which indicated there were significant differences between men and women in all dimensions. In other words, women's satisfaction in the five dimensions was lower than that of men.

Dimension	Gender	N	Mean score	Standard deviation	T	Sig.
Information design	Male	179	3.981	0.586	3.34	0.001
	Female	178	3.706	0.932		
Ease of use	Male	179	4.134	0.582	5.069	< 0.001
	Female	178	3.702	0.977		
Entry guide	Male	179	3.997	0.686	3.646	< 0.001
	Female	178	3.643	1.100		
Structure design	Male	179	4.397	0.482	4.791	< 0.001
	Female	178	4.017	0.942		
Layout design	Male	179	4.133	0.542	3.549	< 0.001
	Female	178	3.830	1.001		
Overall	Male	179	4.128	0.425	4.611	< 0.001
	Female	178	3.780	0.916		

Table 2. Data for gender difference analysis.

As we can see in Table 3, it shows the different tests for the elderly population with different education levels in each dimension. The elderly groups with different educational backgrounds had different degrees of satisfaction in five dimensions. The highest mean score by those with a master's degree was structure design, at 4.625, and the well-educated elderly individuals rated the entry guide the lowest, at 3.642.

The average value in five dimensions of the respondents with a master's degree was higher than those with a bachelor's degree or below, followed by the elderly with a bachelor's degree; the elderly an education level of high school or below had the lowest score. The significance of the five dimensions was all less than 0.01, indicating that senior citizens with different educational backgrounds had different satisfaction levels in the use of the program.

Dimension	Education level	Number	Mean score	Standard deviation	F	Sig.
Information design	High school & below	109	3.654	0.912	7.365	0.001
	Bachelor's degree	200	3.872	0.730		
	Master's degree & above	48	4.160	0.599		
Ease of use	High school & below	109	3.685	1.032	23.013	< 0.001
	Bachelor's degree	200	3.883	0.679		
	Master's degree & above	48	4.597	0.481		
Entry guide	High school & below	109	3.642	1.091	6.110	0.002
	Bachelor's degree	200	3.828	0.881		
	Master's degree & above	48	4.198	0.581		
Structure design	High school & below	109	4.000	0.940	11.689	< 0.001
	Bachelor's degree	200	4.220	0.704		
	Master's degree & above	48	4.625	0.297		
Layout design	High school & below	109	3.775	0.971	8.779	< 0.001
	Bachelor's degree	200	4.006	0.761		
	Master's degree & above	48	4.349	0.449		
Overall	High school & below	109	3.751	0.914	13.362	< 0.001
	Bachelor's degree	200	3.962	0.654		
	Master's degree & above	48	4.386	0.242		

Table 3. Data for different education levels analysis.

Discussion

To explore the satisfaction level of Shanghai elders with the local e-governance platform, this study constructed a survey to examine five indicators: information design, ease of use, entry guide, structure design, and layout design. The survey led to the following points.

First, male users from Shanghai have been proven to have a better performance in the usage of the local e-governance application. Table 2 shows men marked higher mean scores in five dimensions – as well as the overall score – than women did (male overall mean score=4.128, female=3.780) and the sig.<0.001, which indicates males were more receptive to information technology and better at using it.

Specifically, the male elders gave a relatively high assessment of structural design (male mean score=4.397), but a relatively low evaluation of the information design (male mean score=3.981). According to the survey, 34.45% of all the respondents used it to search for information. A clear structural design can lead users to find information with little effort. In addition to clear visual and dynamic design, the app classifies the government service items by topic, department, and district level from a multidimensional perspective, and has also established multiple functions such as recommending public affairs offices and word-of-mouth services in each district, which is convenient for users to search and quickly find the corresponding functional services.

Second, the elders' performance in digital usage was associated with their levels of education. Based on the experiment results of table 3, the respondents with master's degrees and above had the highest mean score (mean score=4.386) of the five dimensions, followed by those with bachelor's degrees (mean score=3.962), and then those with high school education levels (mean score=3.751). The significance of the five dimensions was all less than 0.01. The results were consistent with previous research that the well-educated elderly in big cities pay attention to interpersonal communication, physical condition, social networking, rich life interest, and harmonious relationships with their children; thus, in some conditions, their physical and mental health will be relatively better than those with low literacy (Chen, 2003). That can lead to more efficient usage of digital products by the group with high education levels. Education level and age independently affect the cognitive ability of the elderly. The effect of education level is positive while the influence of age is negative (Wang et al., 2005). Different levels of education have different degrees of effects on elders' attention, memory, language ability, visual perception, movement, executive ability, and so on (Ardila et al., 2000).

In addition, in the analysis of differences in the satisfaction of people with different levels of education, those with master's degrees had the highest score in structure design – 4.625 – followed by ease of use and layout design. The lowest mean score was information design, which indicates that some guidance information displayed on the app interface is not clear enough, resulting in misjudgment by the elderly group. Due to the limited size of mobile phones, the length and size of the content are limited. The vision and reading abilities of the elderly decline significantly, so it is difficult for them to understand lengthy and complex information. Therefore, improper icon design and button design will cause repeated operations and cannot lead them to the target interface. What is more, the app's homepage has five core modules while the fuzzy information design will lead elderly users to confusion in module switching.

Third, different people had different perceptions of digital interfaces. Even the elderly group also showed different satisfaction levels due to discrepancies in gender and education levels. From the perspective of dimensional data, the elderly of Shanghai were relatively satisfied with the structural design of the platform, with both men and women rating it the highest among the five dimensions.

This indicates that the elderly group pays more attention to the practicability of the interface. A well-designed interface can reduce the strangeness of digital and technological products for the elderly.

Unified e-governance is a widely used and multi-functional application. It should follow a special design for specific individuals, which is more suitable for the operation and usage needs of elderly users. Considering the cognitive characteristics of the group, navigation design should be emphasized as a key requirement; simple and efficient navigation is more convenient to navigate information, reduce operation mistakes, and guide the elderly to proper operation (Li & Xu, 2016). This, in turn, will influence citizens' usage behavior, satisfaction evaluation, and positive feelings towards the continual use of the e-government program.

Conclusion

Our study empirically investigated the effect of design and usability on elderly user satisfaction with e-governance systems by using empirical analysis in the form of a questionnaire. The survey results contribute to several findings, indicating that elders with different gender and education levels appear to have different degrees of satisfaction with e-governance. Male elders and those with high levels of education have been proven to have a better performance in usage, therefore these groups of the population had higher satisfaction.

According to the results of the analysis, from information design, ease of use, entry guide, structure design, and layout design, the five determinants have different degrees of influence on satisfaction levels in which structure design was rated highly and found to be the critical factor for satisfaction levels with the e-government portal, while entry guide and information design contribute insignificantly to the satisfaction level.

With the intensification of population aging and the maturity of mobile Internet technology, the elderly user experience of the app is of importance in digital service. The associations of elderly characteristics consideration and user satisfaction is of importance and suggests the application design should focus more on disadvantaged group attributes so it can be applied to more individuals. This study has a certain reference value for the development of government digitalization and low-carbon green development.

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GUIDELINES FOR ICT TO PROMOTE INCLUSION, EQUITY, AND SOCIAL JUSTICE IN THE BRAZILIAN HEALTHCARE ECOSYSTEM

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Abstract

Environmental change has worsened global economic inequality. Specifically, climate issues have driven social, cultural, and economic disparities. Thus, it should be noted that vulnerable people are even more affected by these problems. The challenges faced by them are evidenced in their access to quality healthcare. Despite health being a human right, there are many barriers in terms of inclusion for these people in the Brazilian context, harming their well-being and quality of life. From this perspective, it is important to think about strategies that minimize the problems related to the lack of inclusion in health contexts while contributing to climate-related events. Therefore, this paper aims to develop guidelines for information and communication technology (ICT) in order to enable a healthcare ecosystem that stimulates access and provides resources to promote inclusion, equity, and social justice and reverse the impacts caused. As a research method, first, Bohn et al.'s (2022) systematic literature review, inclusive design principles (Fletcher, 2006), the four key features discussed by Eriksen et al. (2021), and the UN (2022b) Sustainable Development Goals were considered. For the second stage, a case study which included non-participant observation in an out-patient oncological service of a Brazilian hospital was carried out. As a result, five guidelines that have to be considered in order to develop ICT were proposed: community engagement; support networks; shared knowledge; respect for differences; and public policies. For these guidelines, we have considered not just putting people first, but respecting concerns related to human and planetary health, ensuring social justice, wellbeing, and rights for marginalized people. Thus, this study would like to present intersections between the areas of planetary health, human health, and inclusion. From the proposed guidelines, it is expected to encourage new ICT propositions in order to minimize inequalities and reverse the impacts caused by environmental changes.

Author Keywords

Climate change; information and communication technology (ICT); inclusive design; vulnerable people; Sustainable Development Goals (SDGs); inclusion.

Introduction
Environmental change has worsened global economic inequality. Specifically, climate issues have driven social, cultural, and economic disparities (Beck, 2010). According to the United Nations (UN) (2022a), climate change means long-term shifts in temperatures and weather patterns. However, warmer temperatures are just the tip of the iceberg. Climate change involves severe fires, rising sea levels, intense droughts, catastrophic storms, declining biodiversity, melting polar ice, flooding, water scarcity, etc. Furthermore, these issues affect human health (UN, 2022a).

Vulnerable communities are even more affected by these problems because of their exposure, sensitivity, and adaptive capacity (Paavola, 2017). Adger (2006) points out that "climate change impacts will substantially increase burdens on those populations that are already vulnerable" (p. 273). In that regard, the elderly, for example, would be more sensitive to climate change impacts, and isolated people with reduced mobility or disabilities would also face limited adaptive capacity in cases of climate catastrophes (Paavola, 2017). Furthermore, people in poverty are more negatively impacted by the changing climate (Diffenbaugh & Burke, 2019).

According to Gaskin et al. (2017), there are specific situations which particular climate phenomena could influence. For example, intense heat waves and wildfires increase mortality, injury, and risk of developing diseases. In addition to increasing mortality, high temperatures affect work capacity and productivity, which is particularly damaging to vulnerable groups; decreased food production in poorer regions causes undernutrition; and the spread of food-, water-, and vector-borne diseases causes infections. Thus, climate change "affects human health through the exacerbation of existing health conditions, which means the most vulnerable are those with the weakest health protection systems and least adaptive capacity" (Gaskin et al., 2017, p. 4).

The challenges faced by these people are also evidenced in their access to quality healthcare. This is explained by the fact that disadvantaged population groups struggle to come to health services, sometimes struggling to access and use them (Wang & Tang, 2013). The Brazilian Public Healthcare System (SUS) was designed to cover primary and clinical care in all country regions. SUS has policies of inclusion and equity. However, due to the territorial extension and inequalities, it ends up not reflecting its principles in practice. Sometimes, the standardization of processes without considering particular characteristics of the population reverberates as unequal relationships that do not promote inclusive actions and end up driving marginalization (Garnelo et al., 2020). Furthermore, according to Zitkus and Libânio (2021), some factors such as gender, race, educational level, social class, income level of the population, and geographical distribution of health services in Brazil contribute to lack of access.

This context relates to social inclusion, which impacts even healthcare access, and was exacerbated by the Covid-19 pandemic, which has more severely affected people facing vulnerable conditions (World Bank, 2021). In this perspective, Rocha et al. (2021) explain that in the Brazilian context during the pandemic, "multiple layers of vulnerability and risk have overlapped and amplified existing structural inequalities to produce worse outcomes in socioeconomically vulnerable regions" compared to less vulnerable ones (p. e790). Given this scenario, we could start to think of ways to decrease exclusion, inequity, and injustice. The systematic review performed by Pérez-Escolar and Canet (2022) found that digital inclusion projects can achieve social inclusion of vulnerable groups. Njoki and Wabwoba (2015) also found that information and communication technologies (ICT) are playing an important role in enhancing inclusion. Thus, we must consider this scope in designing inclusive solutions in healthcare.

This whole context is directly related to the United Nations' (UN) Sustainable Development Goals (SDGs) (UN, 2022b). These goals are part of *Agenda 20*30 which represents a call to action for all countries regarding peace and prosperity for people and the planet. The SDGs try to achieve solutions to improve human and planetary health as connected parts of a great ecosystem. In general, they are related to issues such as poverty, hunger, education, health and well-being, gender equality, sanitation, energy, economic growth, employment, infrastructure, inequalities, sustainable cities and communities, responsible consumption and production, climate, and peace and justice (UN, 2022b). Inclusion is an important topic discussed in the SDGs to the extent that the vulnerable are the target population of the solutions considered.

In this context, the principles of inclusive design are also relevant. Inclusive design (ID) is a philosophy of design that aims to propose solutions seeking to include as many people as possible. In light of this, dominant and minority groups are considered, and vulnerable groups are included in the use of products or services (Pattison & Stedmon, 2006; Gomes & Quaresma, 2018). For the purpose of this study, we will consider the five principles of ID as stated by the Commission for Architecture and the Built Environment (CABE) (Fletcher, 2006): placing people at the heart of the design process; acknowledging diversity and difference; offering choice where a single design solution cannot accommodate all users; providing flexibility in use; and providing environments that are convenient and enjoyable for everyone to use. Considering inclusion, equity, and social justice when accessing healthcare, these principles are significant in the sense that they recognize that not all people require the same type of care. There are many conditions and needs that should be taken into account, especially when we think about vulnerable groups (Hashemi et al., 2017).

In this same perspective, Eriksen et al. (2021) discuss four key features for climate-resilient development, considering vulnerable groups (in the specific case of their article, disabled people). These features embrace human diversity, allowing human well-being and planetary health. They are: 1) social justice and equity as normative goals; 2) ethical underpinnings of social choices; 3) addressing the inequitable relations that drive marginalization; and 4) navigating uncertainty through inclusive and contestatory policies (Eriksen et al., 2021).

Climate change, diversity, and inclusion can lead to better decision-making and improve outcomes for vulnerable people (World Economic Forum, 2021). Thus, it is important to think about strategies that minimize the problems related to the lack of inclusion of vulnerable and marginalized groups in health contexts, as well as respect and contribute to climate-related events. The use of technologies in this context might be beneficial, as long as the right technologies are designed for the right contexts. If this is not well thought out, a new form of exclusion can occur: digital exclusion (Njoki & Wabwoba, 2015). Regarding that, the theoretical gap explored in this study is the involvement of ICTs in solving the problems mentioned.

Therefore, the study aims to identify gaps and, based on them, develop guidelines for information and communication technology (ICT) to enable a health ecosystem that encourages access and promotes inclusion, equity, and social justice.

Method

This research followed an exploratory approach divided into two stages. For the construction of the first stage, the systematic literature review (SLR) by Bohn et al. (2022), ID principles (Fletcher, 2006), the four key features discussed by Eriksen et al. (2021), and the UN SDGs (UN, 2022b) were considered.

For the second stage, a case study which included non-participant observation in an out-patient oncological service of a Brazilian hospital was carried out. Non-participant observation is a data collection technique in which the researcher uses observation to seek to understand the world, interactions, and relationships. In this technique, the observer does not have any human involvement or interaction in the research field (Ciesielska et al., 2018). The observations took place for eight days, during different shifts, according to the availability of the service and prior arrangements with the staff. A field diary was used to guide data collection and the researchers sought to observe issues related to patient inclusion in the service, looking for characteristics of vulnerability. For data analysis, thematic analysis was performed (Braun & Clarke, 2014), considering gaps of inclusion, resources necessary to promote inclusion, and impacts caused. Finally, guidelines will be proposed for information and communication technology (ICT) to enable a health ecosystem that encourages access and promotes inclusion, equity, and social justice.

Results and Discussion

In this section, we present the results and discuss our research.

First Stage

In this stage, the SLR by Bohn et al. (2022), ID principles, the four key features for climate-resilient development proposed by Eriksen et al. (2021), and the UN SDGs (2022b) were reviewed and discussed.

The analyzed SLR (Bohn et al., 2022) prompted a discussion about human and planetary health. The study evidenced that most of the reviewed papers were related only to human health, without considering planetary health. For example, design of products/services was prototyped and applied only considering the human perspective and needs, while planetary issues were not mentioned or were left in the background. However, the review shows that some papers, although in smaller numbers, evidence concern with human and planetary health in the design of products or services. These papers, in particular, are important for our analysis since our purpose is to help solve human problems that have increased because of planetary problems.

The materials related to human and planetary health promote reflection about ending hunger, improving food security, reducing pollution, ensuring sustainable consumption and production patterns, sustainable constructions and environments, saving energy, addressing poor air quality, greenhouse gasses, water quality, epidemics, socio-ecological systems, and others. These articles deal with the UN SDGs (2022b). All of them present relationships with SDG 3 (good health and well-being) and each presents one or more relationships with other SDGs involving planetary health.

In other words, we reflect that design with a focus on both human and planetary health can reduce environmental impacts, consequently reducing climate damage that affects social issues and especially vulnerable groups. Indirectly, all actions in favor of the planet, even though not directly linked to human health, will reverberate in improvements to human health, especially for those who already face more complex conditions, whether poverty, adverse socioeconomic conditions, the elderly, or people with disabilities and reduced mobility. However, we have observed that the analyzed SLR did not review the perspective of inclusion. For this reason, the key features of Eriksen et al. (2021) were also reviewed. They bring to the fore the concern about human and planetary health while trying to achieve inclusion, equity, and social justice for vulnerable groups. In other words, the discussed key features give us a new paradigm, beyond what we have observed in the SLR: human inclusion in addition to harmony between human health and planetary health.

The first key feature – "social justice and equity as normative goals" – concerns a change of mind regarding people in vulnerable conditions. We should look past the vulnerability itself and think about society's responsibilities to these groups, allowing their participation in social activities and decisions. More than that, we should recognize these people, empowering them to make their own decisions and ensuring their human rights (Eriksen et al., 2021).

The second key feature – "ethical underpinnings of social choices" – is related to equal social choices. In other words, climate decisions that discriminate against vulnerable groups contradict the ethical principle. In climate change, vulnerable populations should be considered not as victims or incapable, but as people who have rights and should have accessible participation (Eriksen et al., 2021).

The third key feature – "addressing the inequitable relations that drive marginalization" – focuses on systemic inequalities that require transformative actions. Ableism, racism, sexism, ageism, and adultism represent prejudices against some vulnerable groups. The authors point out that inequity and marginalization should be perceived through the rights of vulnerable groups, promoting inclusion and diversity through the lens of climate-resilient development (Eriksen et al., 2021). Differences should be understood and respected in order to promote inclusion, well-being, and better ecosystems.

Lastly, the fourth key feature – "navigating uncertainty through inclusive and contestatory policies" – concerns the need for changes in governance so that uncertainty can be better managed. Including contributions from vulnerable groups in political decisions is fundamental for more equitable, just, and inclusive plans (Eriksen et al., 2021).

In this sense, it is possible to relate ID principles (Fletcher, 2006) with the key features of Eriksen et al. (2021). The principle of placing people at the heart of the design process deals with the aspects brought by the features of allowing vulnerable groups to contribute to policies, make their own decisions, and have accessible and equitable participation. The principle of acknowledging diversity and difference is particularly connected with the third key feature, which handles understanding differences. The principles of offering choice where a single design solution cannot accommodate all users – allowing for flexibility in use and providing buildings and environments that are convenient and enjoyable for everyone – are also related to the third key feature, in the way that differences are perceived in planning better, equitable, and inclusive solutions. However, if we look at all the key features discussed, all of them sought vulnerable groups' participation.

Considering the above, we highlight that the studies reviewed in the SLR by Bohn et al. (2022) do not take a holistic approach. In other words, most of the articles propose solutions considering solely human health; a few articles explore human and planetary health but, in general, do not design solutions based on ID principles. So, we have perceived gaps regarding inclusion in the analyzed studies that could be better explored if ID principles – the key features for climate-resilient development – and the UN SDGs were taken into account jointly.

Second Stage
In this stage, the results of the case study were analyzed and discussed in light of the literature and reviews done in the first stage. Observations occurred throughout service, accompanying users all through their journey, from their arrival to consultation, until their departure. Vulnerability issues could be observed through dialog with professionals and among patients, as well as over the perception of each patient's personal characteristics and their physical, cognitive, social, and other conditions.

The main results of non-participant observation in the institution and during service – the basis for this discussion – were: the socioeconomic status of most SUS patients (who arrived at the service by public transportation, complained about their situation, and were unaware of many basic health processes. These patients depend on the public system and in several situations showed concern about their situation due to fear of financial expenses, dependence on family, etc.); the existence of a support league for patients in situations of economic and social vulnerability (the hospital hosts a league against cancer that plays a very important social role in the city); and difficulty communicating with patients due to the perception of different user profiles, sometimes with physical and/or cognitive limitations (some patients observed, for example, were elderly and needed to face treatment alone. An elderly person with cancer and in a situation of social vulnerability presents a series of weaknesses that are complex to manage in a health service).

These observations revealed that social issues are prevalent among SUS patients – poverty, hunger, and transportation difficulties. This is related to the social condition of patients since SUS is a system that aims at universal and equitable access to health services. Patients in disadvantaged socioeconomic conditions are the majority. They struggle to move between their residence and the service due to the limitations of transport and cost. This displacement involves the cost of transport, food, and other additional costs, applied to the patients and their companions. In many cases, it was observed that patients are the family's income providers and have limited income, which exposes their vulnerability even more. They report that coping with the pandemic has made this scenario even more complex, pushing socially, culturally, and economically driven disparities (Beck, 2010). This context presents an inclusion gap in addition to impacting the patient's ability to maintain their treatment.

Support networks such as the Brazilian leagues against cancer help oncological patients in vulnerable conditions in a variety of ways, such as providing support for health problems as well as financial, emotional, and social issues. More than that, leagues cooperate for the inclusion of cancer patients in aspects not covered by health services or public policies. In addition, it was noted that patients are treated as a whole, considering all their characteristics, their context, their mental health and well-being, and, in some cases, by extending that support to patient companions. This support network provides access to the most vulnerable patients (Eriksen et al., 2021), aligning specifically with SGD 3 (good health and well-being), SDG 10 (reduced inequalities), and SDG 13 (climate action), where the form of production and use depends on individual and collective behavior, affecting human and planetary health (UN, 2022b). It is also related to the principles of inclusive design (Fletcher, 2006), where users are included considering all their needs and specificities, being placed at the heart of the design process.

It was also noted that the social condition affects the patient's ability to communicate with the service since many are illiterate. The health condition and treatment of cancer patients themselves expose the patient's vulnerabilities in terms of communication and interaction with the service. It is related particularly to SDG 4 (quality education). This goal is determined to provide inclusive and equitable quality education for all. If the healthcare service has illiterate patients, it is a problem that goes beyond purely health and environmental issues: it is a problem of education. So, ICT strategies need to address a vast and diverse profile of people, including those who cannot read (as well as those who cannot see or who cannot hear).

In the case study, some critical aspects that limited patient inclusion were observed. These aspects relate to the lack of alternative communication resources. When patients arrive at the service, they must get paper tickets to wait for a nominal verbal call from receptionists, as well as for the doctor/healthcare professional's call (e.g., for consultation, exams, or chemotherapy). We observed patients leaving the doctor's room with questions about the next step, even though the doctor had just given them instructions. From the health service perspective, it lacks effective action in this case, limiting itself to the provision of the service. Furthermore, vulnerable communities are even more affected by these problems because of their exposure, sensitivity, and adaptive capacity (Paavola, 2017), where public policies also fail to contemplate these aspects.

It can also be observed that the oncology services are structured in a generic way, considering the characteristics of the majority of patients, focusing on technical issues aimed at the diagnosis and treatment of the disease. In this sense, considering the multiple needs, deficiencies, age groups, and social and economic statuses of patients, it can be concluded that the service does not offer conditions to include all patients who access the service, confronting ID principles (Fletcher, 2006) with the key features of Eriksen et al. (2021).

Guidelines

Based on our findings, we propose guidelines for information and communication technology (ICT) to enable a health ecosystem that encourages access and promotes inclusion, equity, and social justice. It is important to mention that we will not propose actual technologies, but rather an important point to be observed before proposing ICT solutions for vulnerable groups that will promote inclusion, social justice, and equity in healthcare. Another point we will consider in the propositions is not just putting people first, but respecting concerns related to human and planetary health, ensuring social justice, wellbeing, and rights for marginalized people.

After all the points analyzed from the literature and the case study, we propose five guidelines which should be considered so that ICT solutions are developed in order to reduce inequalities, inequities, exclusions, injustices and, at the same time, that climate drivers be controlled. These guidelines can be used to conduct ICT propositions in solving inclusion problems in healthcare ecosystems. We emphasize that these guidelines are not limited to the proposition of ICTs. Other solutions for the context can be thought out, using them as a stepping stone. However, in this study, we understand that it is through technologies that we can propose better inclusion. The proposed guidelines are community engagement, support networks, shared knowledge, respect for differences, and public policies.

Community Engagement

For each solution, the target public must be involved. This is not different for ICT propositions. As pointed out by Njoki and Wabwoba (2015) and Pérez-Escolar and Canet (2022), technology represents an opportunity to promote inclusion, as long as it is well planned and implemented. Therefore, community participation in the process is fundamental. If users who currently already face inclusion barriers because of their vulnerability do not participate and do not have the opportunity to collaborate and understand a new tool, more exclusion will probably be generated.

New technology needs to make sense for vulnerable groups. Thus, an imposition is not the right way to develop and implement something like that. For this engagement, we suggest coordinated actions, co-creation processes, and the opportunity/ability to make decisions and participate with all and for all. In the case of vulnerable patients, as observed in the case study, this is even more crucial because some of them are not able to manage technologies (probably the elderly and people with impairments caused by previous disease or by cancer treatments).

ICTs would solve many problems in the observed service, increasing inclusion, equity, and justice. For example, the nominal verbal call could be replaced by call screens. However, it is fundamental to think about all the possible vulnerable patients, including all the disabilities, conditions, needs, and existing characteristics. Hence the importance of engagement. For engagement to happen, firstly, the target public must be known. This is necessary from the perspective of ID (Pattison & Stedmon, 2006; Gomes & Quaresma, 2018), especially regarding the principle of placing people at the heart of the design process (Fletcher, 2006). It is also related to the key features, which propose vulnerable groups' participation (Eriksen et al., 2021), and to the SDGs. All goals depend on community engagement to make them work and generate harmony between human and planetary health (UN, 2022b).

Support Networks
As observed in the case study, support networks are crucial for the inclusion of vulnerable groups, especially regarding social aspects which go far beyond the disease, but are decisive for the treatment and the cure. Support networks are great opportunities to act in favor of both the community and the climate. Leagues, for example, are important institutions to show pathways for change by proposing ICTs. People in vulnerable conditions are used to seeking help in these institutions and, for this reason, usually follow their lead.

The proposed technologies should increase the adaptive capacity of vulnerable people, increasing and strengthening individual and collective opportunities (Manzini, 2015). Support networks could be a support for the joint construction of technologies with users, which would make health services more inclusive and accessible to all people, while helping to mitigate the climatic causes that are sometimes a reason for inequalities. An example of this would be to use support networks as drivers of planetary sustainability which, according to the SDGs proposed by the UN (2022b), are in line with aspects of human health, and aspects of inclusion, equity, and social justice. Thinking about technologies that include and at the same time spread good practices for the planet: these would help, both with the inequality already generated and in the prevention of future inequalities and social exclusions.

This is an immense challenge, but it is the future. The proposition of any solution in the reality that we have been living in needs to go through points that are important, both from a human and planetary perspective, and social support networks need to be inserted and used in this process.

Shared Knowledge
Considering that health and well-being are closely related to individuals and the environment in which they are inserted, it can be said that human health depends on the health of the planet. Likewise, it is understood that health is a sense of care, both individual and collective. This is because if human beings do not observe the actions they exert on the health of the planet, they are also not observing the actions the health of the planet exerts on their own health. Climate issues and social and economic inequalities are some of the reflections of this relationship. These reflexes marginalize people, especially the most vulnerable. In addition, evidence of health risks from heat stress and climate-related infectious diseases, mitigation of urban climate extremes by vegetation, and other forms are examples of other effects of climate on human and planetary health. This was also observed in the study by Bohn et al. (2022).

In this sense, the understanding of this relationship involves shared knowledge that needs to be socialized among the individuals that are part of society. Available and consistent education is an alternative that should be explored to enhance the collective sense of these facts. Furthermore, these features embrace human diversity, allowing for human well-being and planetary health, according to Eriksen et al. (2021). Shared knowledge is also related to ID principles because for people to be in the center of the design process and use the solution without difficulties, with flexibility and accessibility, they need to be part of the knowledge in order to contribute effectively.

However, the way this action will be operationalized must consider the characteristics of the individuals involved, their vulnerabilities, and limitations as predicted by the first key feature of social justice and equity as normative goals and the second key feature of ethical underpinnings of social choices (Eriksen et al., 2021). These strategies can help minimize the problems related to the lack of inclusion of vulnerable and marginalized groups in health contexts as well as respect and contribute to climate-related events.

The need for changes in governance for uncertainty to be better managed, including contributions from vulnerable groups in policy decisions, is critical for more equitable, fair, and inclusive plans (Eriksen et al., 2021) and can be built on ICTs.

Respect for Differences

This guideline is particularly close to the fundamentals of ID. When we think about designing for as many people as possible, we are considering all of the existing diversity (Pattison & Stedmon, 2006; Gomes & Quaresma, 2018). From the perspective of ICT for inclusion in healthcare ecosystems, we highlight the need to understand different publics, respect them, and design for them. In the oncological service observed, technologies proposed should consider easy and accessible language (for example, signaling systems to include visually impaired, illiterate, and deaf people, and the elderly), error tolerant systems that consider context, situation, and particularities, and offer opportunity for accessible participation to all.

This guideline deals especially with the key feature "addressing the inequitable relations that drive marginalization," which defends the idea that differences must be taken into account and respected in order to promote inclusion and well-being. Furthermore, respecting differences is something advocated by the SDGs, especially those who seek empowering, inclusive, and equitable opportunities, and safe and sustainable environments for all (SDGs: 4 – quality education; 8 – decent work and economic growth; 10 – reduced inequalities; 11 – sustainable cities and communities; and 17 – partnerships for goals) (UN, 2022b).

Public Policies

When designing ICTs in a health ecosystem, it is important to observe two main issues within the scope of public policies: adequacy to local public policies, mainly for health policies; and the perspective of target community participation in policies.

Regarding adequacy to local policies, each proposed ICT solution should take into consideration regulations and policies, as well as respect ethical issues. In the case of Brazil, the proposition of ICT should consider SUS principles anchored by law 8080/1990: universality; integrality; equity; decentralization; regionalization; hierarchy; and social participation (Brazil, 1990). Furthermore, other regulations and laws that focus on vulnerable people, such as disabled people, should be consulted before proposing an ICT solution. The law 13.146/2015, for example, aims to ensure and promote, under equal conditions, the exercise of fundamental rights and freedoms by disabled people, with a view to their social inclusion and citizenship (Brazil, 2015). ICT solutions for these people should take into account the rights guaranteed by their specific regulations.

Concerning the perspective of target community participation in policies, we highlight that the public policy cycle presents criticisms related to the modus operandi since its establishment has an implicit (top-down) approach where the role and existence of individuals or groups in society in general are disregarded. In Brazil, the formulation of strategies involves both deliberate (prior) and emergent (unforeseen) strategies. This process makes it possible for intended strategies to be deliberated and carried out, but it is not limited to them alone, as it opens space for the emergence of emerging strategies which are formed during the process and result in the strategy being carried out. For this dynamic to occur, the existence of social actors is necessary as the engines of change whose definition is related to the capacity for action and collective weight.

This fact is especially in accordance with key feature four by Eriksen et al. (2021), which discusses the importance of vulnerable groups being included in political decisions, as well as their contributions being a crucial part of public policy construction. Only by understanding their reality can better policies can be formulated and, consequently, more solutions will be aligned with real needs. Furthermore, this is also connected with ID principles, because it is only by including marginalized groups in social decision-making that they can be part of inclusive solutions, important from a human and social point of view, as well as from a planetary point of view.

Conclusion

Climate change has worsened global economic inequality, driving social, cultural, and economic disparities, which have impacts on inclusion issues, especially in the health-care context. Thus, this study aimed to identify gaps and, based on them, develop guide-lines for information and communication technologies to enable a health ecosystem that encourages access and promotes inclusion, equity, and social justice.

Based on a discussion of a systematic literature review, the United Nations Sustainable Development Goals, key features for climate-resilient development, the principles of inclusive design, and a case study, five guidelines were proposed in order to direct pathways for the development of an enabling health ecosystem that provides resources to promote inclusion and equity, as well as reverse climate impacts, considering ICT solutions. The proposed guidelines were community engagement, support networks, shared knowledge, respect for differences, and public policies. Our proposal intends to encourage an adaptation to reduce vulnerabilities and inequalities and foster resilience in communities. In addition, we intend to propose ICT guidelines in order to decrease divides between social, cultural, and economic groups.

We highlight that all guidelines must be considered together to develop and implement better solutions. Together they emphasize concerns, both with aspects of human and planetary health and also the inclusion of vulnerable groups, which was the research focus. In addition, we understand that this study brings an anthropocentric view of the planet since nature would find its way with or without the existence of humans. However, our discussion considers the existence of humans and, nowadays, how much human and planetary needs are a reflection of human actions.

The limitation of the study is the usage of only one data collection technique in the case study. For future studies, we recommend the research be carried out in other institutions and healthcare services, as well as other data collection techniques, such as interviews and surveys, be used in order to understand patient perspectives.

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SUSTAINABLE SMART PRODUCT DESIGN DECISION-MAKING AND EVALUATION SYSTEM

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Abstract
With the climate change and energy crises, sustainable development has become an important theme of social concern and how to promote sustainable development by means of design has become an important topic for the design field. With the development of information technology, such as artificial intelligence, the internet of things (IoT), and cloud computing, smart products like smart robots, smart wearables, and smart homes have appeared (Nunes, 2017; Tomiyama et al., 2019). There will be an increasing number of smart products in the foreseeable future. As such, this study focuses on smart product design that is conducive to sustainable development. The aim of the study is to answer the question: How can smart products be designed in a way that minimizes the conflict between society, ecology, and the economy? The characteristics of the paradigm of smart products are deconstructed by means of a literature review, including the definition of smart products, their constituent elements, and product life cycles. Then, life cycle design (LCD) design theory (Vezzoli & Manzini, 2015; Vezzoli & Sciama, 2006) and triple bottom line (TBL) theory (Zink, 2014) are introduced to build an evaluation system and design decision-making mechanism for smart products from a sustainable perspective, taking into account the characteristics of smart products. It aims to promote sustainable design and innovation of smart products, which can provide decision guidance for sustainable design of such smart products; it can also provide an evaluation model for smart products from a sustainable perspective.

Author Keywords
Smart product design; sustainable design; design decisions; design evaluation system; technological innovation.

Introduction

With industrial development, the climate and energy crises, water pollution, and other environmental issues are becoming increasingly serious; therefore, sustainable ecological development is receiving increasing attention from people. How to promote eco-sustainable development through design has received attention from the design community since the second half of the last century (Liduan & Hanhan, 2013). In 1971, American design theorist Victor Papanek published the book *Design for the Real World – Human Ecology and Social Change* and emphasized that design should recognize the limit to earth's resources and serve to protect the environment. This book promoted the concept and values of "green and ecological design" (Drukker et al., 2010; Glantschnig, 1994; Liduan & Hanhan, 2013). In 2015, the United Nations identified 17 Sustainable Development Goals (SDGs), which include ecological, economic, and social aspects of sustainable development. The design community has thus expanded its focus on sustainability to include ecological, economic, and social sustainability (Thatcher & Yeow, 2016b; Zink & Fischer, 2013). Promoting such integrated sustainability through design has become an important topic for the design community (Lange-Morales et al., 2014; Thatcher & Yeow, 2016a).

Every technological revolution brings new possibilities for design, and society is currently on the eve of the fourth industrial revolution (Zhou et al., 2018). Promoting sustainable technological innovation through design has become increasingly important and, thus, is the subject of this paper. With the development of information technology such as artificial intelligence (AI), the internet of things (IoT), big data, and cloud computing, a class of artifacts with certain autonomous behavioral characteristics – smart products – have begun to emerge, and consist of both material entities and information-encoded programs such as smart robots, wearable devices, smart cars, etc. (Nunes, 2017; Tomiyama et al., 2019). Smart products are emerging as a new design paradigm that differs significantly from traditional products. The function of a traditional product is entirely determined by the material structure of the product; however, the function of a smart product is determined by both the structure of the material and a program encoded by information. Therefore, the design method of smart products differs significantly from that of traditional products.

Guiding designers and engineers to develop sustainable smart products is of great importance in this technological revolution. The main questions of this research are: How can ecological, economic, and social sustainability factors be integrated into the design decisions of smart products, and how can smart products be evaluated from a sustainability perspective? The main goal of this study is to construct a sustainability assessment system and design a decision-making mechanism for smart products. The research methodology of the study is as follows:

1. Define smart products clearly through extensive literature research and analyze their constituent elements and life cycle characteristics.
2. Introduce triple bottom line (TBL) theory (Zink, 2014) to construct a sustainable evaluation system for smart products based on their characteristics.
3. Construct a decision-making mechanism for smart product design and introduce product cycle theory (Vezzoli & Sciama, 2006).

Smart Products

The basis of smart products can be traced back to mechatronic systems, which consist of a simple mechanical device and an electronic unit; an example is the automotive brake system. Later, intelligent mechatronic products were introduced, and simple braking systems were improved with the addition of electronic stability control. Then, cyber-physical systems (CPSs) were introduced, which consisted of embedded systems, actuators, and sensors with the ability to communicate with other systems (Tomiyama et al., 2019). With the development of CPS, IoT, AI, and other technologies, many smart products have emerged in our lives. Common smart products include smartphones, smart speakers, smart cars, smart robots, smart wearables, smart homes, etc.

Miranda et al. (2017) consider smart products to be physical products equipped with embedded systems, sensors, and actuators. Smart products connect physical and digital products and allow embedding digital product information into physical products (Miranda et al., 2017). Porter and Heppelmann (2014) state that smart products have three core elements, namely, physical components, smart components, and connected components. Abramovici (2015) defines smart products as “CPS that additionally use and integrate internet-based services to perform the required functions.” Scholars such as Tomiyama et al. (2019) consider smart products part of a complex business ecosystem that includes different stakeholders, the physical environment, and other connected product devices.

Smart products are equipped with a variety of technologies, including cyber-physical systems, the internet of things, artificial intelligence, and others. These technologies have paved the way for the evolution of traditional products to smarter products (Qutb, 2020), becoming the main enablers of smart products (see Figure 1).

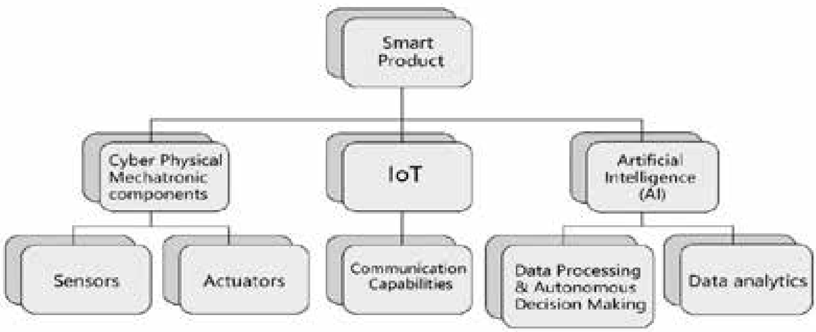

Figure 1. Smart product enablers (source: Qutb, 2020).

From a reductionist perspective, everything in the world is made up of basic constituents of three types: matter, information, and energy (Li Yingchun, 2017). Traditional products are mainly composed of matter; however, smart products are composed of both material structures and information-encoded programs. By combining the above scholars’ views and the characteristics of smart products relative to traditional products, this study defines smart products as products that are composed of material entities (e.g., mechanical hardware, electronic components, and communication hardware) and software programs (e.g., system programs and applications), and have a certain degree of autonomous behavioral capability to provide systematic services to users.

Life Cycle of Smart Products

In the late 1990s, the environmental requirements of industrial products started to become clear, and the concept of life cycle design (LCD) was introduced (Vezzoli & Sciama, 2006). It is widely used in the design and development of products. From a macro perspective, the traditional product cycle is generally divided into five phases: preproduction, production, distribution, usage, and disposal (Vezzoli & Manzini, 2015).

However, because of the differences between the basic composition of smart products and traditional products (Zhang et al., 2019), their life cycles show different characteristics. The most significant feature of a smart product is the disintegration of its hardware, which does not mean the end of the life of the smart product. When the hardware of a smart product is disintegrated, its software programs and previously accumulated data can continue to run after the hardware is replaced; it also retains the previous user usage data and habits, thus continuing its vitality. For example, when the hardware part of a Huawei smartphone is degraded, the applications and data of the old phone can be transferred to the new Huawei phone through phone cloning. The hardware and software parts of a smart product have different life cycle characteristics. The life cycle of the hardware part is no different from that of traditional products, which go through the preproduction, production, distribution, usage, and disposal phases. However, the software part is upgraded and iterated continuously after entering the usage phase, and there is no clear end to the life cycle; only when the product is eliminated by the market, or users give up using the product, does it mean the end of the product's life. The life cycle of a smart product can be analyzed in two dimensions, hardware and software, and its life cycle model is shown in Figure 2.

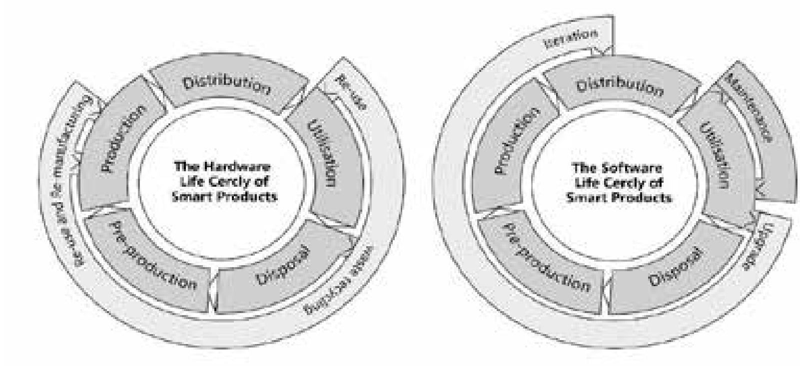

Figure 2. The life cycle of smart products.

Smart Product Evaluation System and Decision-Making Mechanism Based on TBL

It has to be recalled that the realization of sustainability is not free of contradictions or paradoxes. Therefore, the process of introducing such concepts needs the idea of balancing between different approaches and objectives. Inspired by sustainability goals, Klaus J. Zink (2014) proposed the triple bottom line (TBL) model in 2014, emphasizing the need to simultaneously integrate ecological, economic, and social sustainability goals into design decisions during the design process. However, Zink did not propose specific indicators for these three dimensions. Ananda Samudhram et al. (2016) proposed the holistic TBL model based on this model and fleshed out its specifics.

This study proposes a sustainable TBL evaluation system model and index system for smart products based on the characteristics of smart products. Then, the model of the design decision-making mechanism for sustainable smart products is proposed based on the life cycle characteristics of smart products.

Smart Product Evaluation System Based on TBL
This study adopts the framework of Klaus's (2014) TBL; at the same time, it refers to the evaluation system for a sustainable working environment proposed by Ananda Samudhram et al. (2016), the sustainable evaluation system for sustainable production proposed by He et al. (2019), and the sustainability assessment system for the chemical industry proposed by Tabone et al. (2010). Finally, this research proposes a sustainable evaluation system for smart products from the three dimensions of ecology, economy, and society, shown in Figure 3.

The eco-sustainability of products was the first to receive attention from the design community, and different scholars have proposed different models for the ecological assessment of products for various types of design tasks and scenarios (Vezzoli & Manzini, 2015; He et al., 2019; Tabone et al., 2010; Vezzoli & Sciama, 2006). In general, the ecological assessment of products is an assessment system established from two dimensions: the input of energy and materials and the output of waste gas, wastewater, and waste materials. Therefore, this study summarizes the assessment aspects of ecology into the following four elements:

- Reducing the use of nonrenewable energy sources and maximizing the use of renewable energy sources;
- Reducing emissions of waste gasses and wastewater;
- Using environmentally friendly materials as much as possible; and
- Reducing the generation of solid waste.

Due to the needs of social development, the connotation of sustainability has expanded from ecological sustainability to ecological, economic, and social sustainable development (Hanson, 2013; Thatcher & Yeow, 2016b). Economic development is an important indicator of sustainable development, which means the improvement of people's quality of life. However, it is not possible to pursue economic growth at an excessive cost. The following two relationships need to be weighed in product design:

- Balancing costs and benefits and
- Balancing short-term economic benefits with long-term economic benefits.

The design community has long considered human factors in product design to reduce safety hazards and their impact on human physical and mental health (Wilson, 2014). In recent years, the design community has begun to recognize that design may also have an impact on social justice and human rights (Lange-Morales et al., 2014; Lopez-Sintas et al., 2020; Thatcher & Yeow, 2016a). This research summarizes the assessment aspects of society in the following four elements:

- Preventing safety hazards;
- Minimizing the impact on human health;

- Fair use of power; and
- Responsible production and consumption mechanisms.

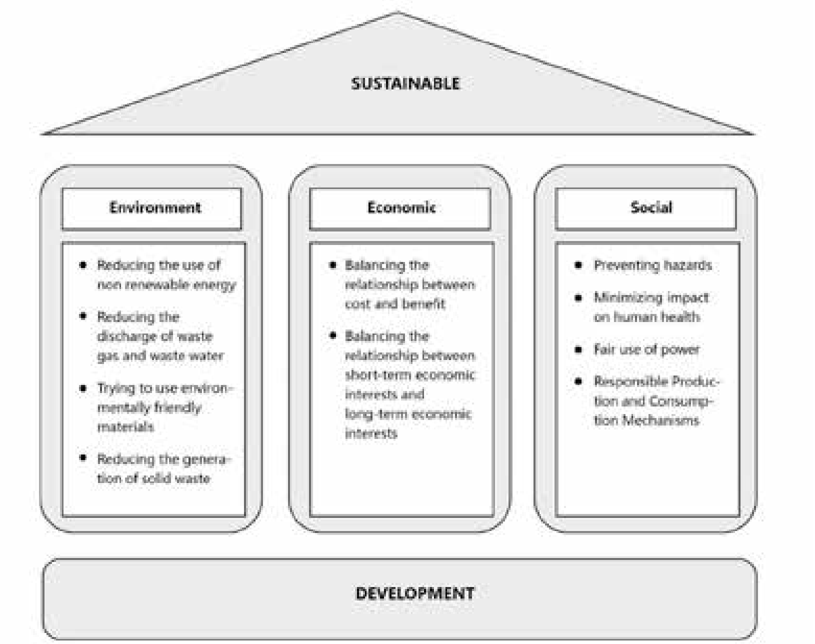

Figure 3. Comparison of the life cycle of traditional products and smart products.

A smart product consists of both matter and software programs. Compared with traditional products, it is not only a physical entity in physical space but also connected to cyberspace. Therefore, sustainable factors related to digital space should also be included in the evaluation of smart products, such as the stability of software programs, the security of private information, fairness of information access, software maintenance costs, and stability of network links. Based on the characteristics of smart products and considering both hardware and software dimensions, this study proposes a TBL evaluation index system for smart products, shown in Table 1.

Considering the economic dimension, there is not much difference between the evaluation indices of hardware and software of smart products, and both include production cost, revenue, price, fixed assets, operation cost, maintenance cost, etc. Considering the environmental dimension, it is more closely associated with the hardware of smart products. The hardware of smart products is directly involved in the exchange of material energy with the environment, which needs to be balanced by indicators such as energy consumption, water consumption, material consumption, material recycling rate, waste gas emission, wastewater emission, and solid waste. The software is dependent on the hardware and does not directly exchange material and energy with the ecological environment.

Considering the dimension of society, it is necessary to assess the indicators of the safety of smart products, the degree of impact on human health, the fairness of use rights, and the reasonableness of the accountability mechanism. In the case of hardware, it is particularly important to focus on the assessment of the potential security risks and the impact on human health. For software, the focus must be on assessing information security. Today, information has become an important asset. As such, the main goal of information security is to properly protect information from unauthorized access, use, disclosure, destruction, modification, and damage, thus avoiding the possible harm caused by information (Masso et al., 2020; Mesquida & Mas, 2015). Therefore, sustainable factors related to digital space should also be included in the evaluation of smart products, such as the stability of software programs, security of private information, fairness of information access, cost of software maintenance, stability of network links, etc. This evaluation system can be used as a reference system for the evaluation of smart products and in practice, designers can develop specific evaluation plans based on this evaluation framework according to specific project needs.

	Environment	Economic	Social
Hardware	▪ Energy consumption ▪ Water consumption ▪ Material consumption ▪ Material recovery rate ▪ Exhaust emissions ▪ Wastewater discharge ▪ Amount of solid waste	▪ Cost of production ▪ Income ▪ Sale price ▪ Fixed assets ▪ Operating costs ▪ Maintenance costs	▪ Safety ▪ Impact on human health ▪ Fair use rights ▪ The rationality of the accountability mechanism
Software		▪ Software development cost ▪ Income ▪ Sale price ▪ Fixed assets ▪ Operating costs ▪ Software maintenance costs	▪ Program stability ▪ Security of private information ▪ Fairness in access to information ▪ The rationality of the accountability mechanism

Table 1. TBL-based sustainable evaluation index of smart products.

The Design Decision-Making Mechanisms of a Smart Product Based on TBL

Vezzoli and Manzini (2015) combine ecological sustainability theory and product life cycle theory to propose a strategic decision-making mechanism for product design based on product life cycle theory to guide designers to develop environmentally friendly products. Due to the nature and life cycle characteristics of the hardware and software of smart products, this study proposes the consideration of the design decision-making mechanisms of sustainable smart products from both hardware and software dimensions. This study proposes a design decision model for smart products (shown in Table 2) for the characteristics of smart products, with the TBL evaluation model proposed above for smart products.

The Design Decision-Making Mechanisms of Smart Product Hardware

The hardware part of the smart product is an important part of the smart product, including mechanical hardware, electronic hardware, and communication hardware. Hardware is the operating carrier of the software and in actual use, it and the software are mutually exclusive. Hardware is composed of matter, and its life cycle is similar to that of traditional products. In the design and development of hardware, the sustainable factors of its various life stages should be taken into account, with a detailed description included below.

The preproduction stage entails preparing the necessary resources and components as part of the final product manufacturing. Resources are divided into renewable and non-renewable resources; nonrenewable resources are mined from above the ground, while renewable resources generally come from the biosphere. With similar economic factors, environmentally friendly materials should be selected as much as possible. At the same time, stakeholders associated with the product need to be considered at this stage, and a clear mechanism for the allocation of responsibilities and rights needs to be developed.

The production phase involves material processing and assembly of the final product. This process involves a variety of processing techniques and procedures. While ensuring production efficiency, renewable energy and production methods with low environmental impact should be used. At the same time, the safety of the production process should be guaranteed to avoid accidents or affecting the health of those involved in the production.

The sales phase includes packaging, transportation, and storage. Packaging is an important way to promote sales. Overpackaging should be avoided, and environmentally friendly, economical packaging materials should be used. At the same time, product advertising that may negatively affect users should be avoided in the marketing process. Goods must be transported to each point of sale, and transportation methods include trains, trucks, ships, airplanes, pipelines, etc. Energy consumption is required, not only for transportation, but also for the production of transportation means and resources for storage facilities. Under the control of transportation efficiency and cost, transportation methods that use less energy and have low consumable utilization should be chosen.

The usage phase involves the utilization of the product and after-sales service. The possible risk factors in the use of the product should be taken into account, and safety hazards should be avoided. A clear accountability mechanism should be developed so that relevant responsibilities can be pursued in a timely manner when various risks emerge. At the same time, the rights of the household of the product's stakeholders should be considered to avoid unreasonable distribution of rights due to technical factors or infringement of power over others. The product will be consumed or damaged in the process of use. Therefore, the product may face repair or replacement parts. The design should consider making the product easy to disassemble and replace for maintenance.

The disposal stage is the termination stage of the product life cycle. After the product is damaged, the original parts can be replaced to continue the product life cycle. After the product is completely disposed of, it should be recycled to avoid negative impacts on the environment. Recycling can be divided into two cases: one is to recycle the whole product, and some of the parts can be directly used in the next round of production; the other method is to recycle some of the materials in the product as materials for the next round of production.

The Design Decision-Making Mechanisms of Smart Product Software
Software for smart products is dependent on hardware and includes two categories: system programs and applications. It is the development of the system programs that must be considered. The life cycle of software is different than the life cycle of hardware, and the software part has a certain degree of independence from hardware in actual development. The basic building block of software is information, not matter; therefore, it has less impact in ecological terms. The software is connected to the network, which involves the privacy of the user's information, the fairness of the user's access to information, and the security of the network. The sustainability factors involved in the software life cycle differ from those of hardware; therefore, different design decisions need to be made.

The predevelopment phase of the software requires consideration of the stakeholders associated with the product and the development of a clear mechanism for the allocation of responsibilities and rights.

The development stage of the software is performed by the product manager, IT engineer, exchange designer, and other professionals. The stability of the developed system needs to be considered in this stage to ensure that the developed program can run in a stable and orderly manner. At the same time, the access rights of each user should be set fairly to ensure the rights of users. During the development process of the software, the safety of the relevant staff should also be ensured to avoid harming their health.

The sales phase should avoid product advertising that may negatively affect users. It should also ensure that each user has fair access to information.

New data are generated during the usage phase of the software. These data often involve information such as the privacy of the user or the business secrets of the company. Therefore, protecting these data becomes a very important task. Information security breaches that lead to information leakage should be avoided as this can have dire consequences for companies and individuals, negatively impacting their revenue streams, reputation, and trust. Access to information by stakeholders should also be guaranteed. In the process of using smart products, users may find some problems in the software; therefore, a reasonable user feedback mechanism should be set up. When problems are identified, the software can be maintained and optimized in a timely manner.

After a certain amount of time, software needs to be iterated as market demand changes. The life cycle of software is much longer than the life cycle of hardware. Hardware must be scrapped due to the disintegration and damage of its physical structure caused by the time factor, but software programs do not have this problem and their life cycle can theoretically be extended indefinitely. However, market needs may change, so software needs to be iterated from time to time according to market needs. This phase is similar to the development phase in that it requires an integrated consideration of all aspects.

The above design decision-making mechanism includes ecological, economic, and social considerations, and the focus of sustainability factors varies in each stage of the product life cycle, so in practice, all factors affecting the decision need to be systematically considered and weighed. The above proposed sustainable design decisions for smart products correspond to the product life cycle stages shown in Table 2.

	Hardware	Software
Preproduction	▪ Choosing environmentally friendly and economical materials ▪ Developing a clear responsibility and rights mechanism	▪ Developing a clear responsibility and rights mechanism
Production	▪ Choosing a production method that has a low impact on the environment ▪ Using renewable energy wherever possible ▪ Choosing safe production methods	▪ Ensuring system security and stability ▪ Ensuring the security of the development process
Distribution	▪ Trying to use environmentally friendly and economical packaging materials	▪ Establishing equitable access to information
Usage	▪ Using easy-to-remove and replace originals for easy maintenance ▪ Reducing security risks ▪ Establishing a fair user right to use ▪ Developing a clear responsibility and rights mechanism	▪ Protecting user privacy information ▪ Ensuring equitable access to information ▪ Ensuring reasonable user feedback mechanisms
Disposal / iteration	▪ Repairing and maintain products to extend product life cycle ▪ Recycling waste product materials	▪ Maintaining or optimizing software programs to improve operational efficiency

Table 2. TBL-based sustainable evaluation index of smart products.

Conclusion and Development

The study clearly defines the concept of a “smart product,” an emerging design paradigm, and analyzes its components and characteristics. Based on the traditional product life cycle theory, the life cycle characteristics of smart products are analyzed in two dimensions: hardware and software. TBL theory is introduced, and the evaluation model and indices of smart products based on TBL are constructed by combining the characteristics of smart products. The continuous evaluation criteria of smart products are combined with life cycle theory, and the design decision-making mechanism of smart products is proposed.

This research provides a theory of sustainability for the design and development of smart products and guides smart production to make composite sustainable design decisions in all stages. At the same time, this research can provide a set of evaluation systems for the sustainability of smart products. At the current stage, this research constructs a sustainable evaluation and decision-making system for smart products. In future research, the theoretical framework needs to be optimized and improved in design practice.

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TRAINING A NEW GENERATION OF BIODESIGNERS FOR A BETTER SOCIETY

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Abstract
The following research presents a first approach to the study of the relationship between biotechnology and design. This relationship might not be new to the field but the approach in teaching experience is still challenging for teachers and facilitators. This approach seeks to help designers understand and join the debate on this relationship. Additionally, they should propose systemic product-service solutions that benefit humanity in a comprehensive and ethical manner without detriment to the environment. The article makes a brief review of several key concepts such as biotechnology, bioeconomy, and biodesign. Moreover, it describes the exploratory project work carried out by a group of students (bachelor's degrees in industrial design and postgraduate degrees in design) derived from the object of study. These types of experiences contribute to preparing a new generation of bio designers capable of dialoguing with other disciplines to seek the best applications of biotechnology to society's problems.

Author Keywords
Biodesigners; Sustainable Development Goals (SDGs); sustainability; biotechnology.

Introduction

The United Nations (2020) declared that by the end of 2020, 3,000 million people in the world lacked the supply to wash their hands and scarcity of water could displace 700 million people by 2030. There is increased loss of biodiversity, reduction of forest areas to increase agricultural expansion, and the fact is that most of the business models world-wide continue to use natural resources in an unsustainable way. As testimony to this is the increase in subsidies to fossil fuels and the 38% increase in electronic waste – a possible consequence of planned obsolescence – to mention just a few examples that give us guidelines to urgently seek new ways to innovate in new models that allow us to move to a preferable and desirable future.

At its simplest, biotechnology is technology based on biology. Biotechnology harnesses cellular and biomolecular processes to develop technologies and products that help improve our lives and the health of our planet. We have used the biological processes of microorganisms for more than 6,000 years to make useful food products such as bread and cheese, and to preserve dairy products. Modern biotechnology provides breakthrough products and technologies to combat debilitating and rare diseases, reduce our environmental footprint, feed the hungry, use less and cleaner energy, and have safer, cleaner, and more efficient industrial manufacturing processes.

In this context, biotechnology is identified as one of the transforming forces of society due to the impact that biology is having in areas such as industry, health, or agriculture. Biotechnology is not only helping us to build things in a more ecological way or to generate more sustainable materials, however. It is also allowing humans to understand how to become a functional part of the ecosystem instead of only trying to dominate nature. As educators and cultural agents, there is a need to make a shift of perception, a new paradigm where humans find a natural place in the ecosystem and collaborate actively with it, an evolution from the Anthropocene to a future of collaboration between species, or as Donna Haraway (2016) puts it, the Chthulucene, a multispecies flourishing instead of the Anthropocene and the Capitalocene.

The interest in biotechnology in design is not only in practical terms. It is also an understanding of the ecosystem that we inhabit and learning how to collaborate with it. For far too long humans have been trying to dominate nature, and nowadays the relationship with it is reduced to productivity and capitalization. Considering nature only as a resource will lead to the extinction of humankind and the planet along with it. Donella Meadows (1970) explained in the *Limits of Growth* how we already achieved a point of no return in the use (abuse) of natural resources. Haraway (2016) explains from a biologist's perspective how nature works, sharing resources and negotiating them. She calls it a sympoietic system, where everyone in nature is "making-with" (Meadows, 1970). Nothing makes itself; nothing is really autopoietic or self-organizing. "Sympoiesis is a word proper to complex, dynamic, responsive, situated, historical systems. It is a word for worlding-with, in company. Sympoiesis enfolds autopoiesis and generatively unfurls and extends it" (Haraway, 2016). Based on this perspective, biodesign is not about teaching designers how to work with recycled materials or organic stuff, it is about a shift of their perspective to "make-with" nature.

According to experts, innovation driven through biotechnology is capturing the attention of different players involved in the industry. Little by little, it is beginning to be used in fields other than health care, and its application is expected to grow in the coming years in sectors such as services and consumer products, materials, energy, etc. From an economic perspective, a higher benefit is also expected from it (Iyer & Bezamat, 2021). It is not strange therefore that concepts such as bioeconomy arise.

Even though biotechnology has made great advances, the need to better prepare professionals who can take advantage of and make the industry around them grow in the best way is also recognized (Biotechnology, Innovation, Organization, n.d.).

In the case of design, interest in biology is not new. In fact, the term biodesign has been used for a long time to refer to the application of biological principles during design activity. Specifically, two other concepts emerge from biodesign that are very familiar in the field of industrial design: bionics and biomimicry (Egido, 2004). To this extent, it can be inferred that it is necessary for industrial design students to deepen their understanding of biotechnology and its applications, going beyond reproducing the forms found in nature and applying them to discrete artifacts to build better environments, for example, that adapt to a more sustainable future for human beings (Salingaros, 2019).

This situation also challenges design education, as has been stated in the "Future of Design Education" (2019) project, because designers more and more often address more complex problems and they must know the implications of new technologies like biotechnology. Thus, It is fundamental to understand it to ensure its correct application without detriment to humans and the environment.

Based on what has been said, the aim of this document is to present a first approach to the study of the relationship between biotechnology and design, mentioning some fundamental theoretical concepts and the methodological characteristics of the work completed, to present at the end some projects developed by students that can be exemplify an approach to biotechnology. The question to answer is: what can we learn from this first approach to prepare future generations of biodesigners? To answer this, the contents of this paper are organized into three main themes: the first exposes concepts such as biotechnology, bioeconomy, and biodesign, then the methodological teaching approach is described. Finally, three student projects are presented to illustrate some dynamics, processes, and learning strategies that are encouraged to deepen the understanding of biology and design.

Key Concepts of Biotechnology

In simple terms, biotechnology can be understood as the application of living organisms to create products in industry or other sectors. According to experts, modern biotechnology appeared in the 1970s, particularly in the field of health. However, little by little, it has been used in other industries such as food – also understood as agricultural biotechnology – with the purpose of feeding a global population that is growing more and more (De Lorenzo, 2018). Biotechnology is also being used to find more friendly ways, ecologically speaking, to build things or materials (World Economic Forum, n.d.).

For Dyson (2007), the twenty-first century will be the century of biology because of its economic consequences on people's well-being but also because of the ethical implications of its application. The fact that biotechnology is becoming more and more present in various domains of society, as mentioned above, makes this author suppose that the next step is its domestication, in such a way that it is easily used by people, or the users. Therefore, it is not unreasonable that more and more frequently one can find on the market, for example, materials with activities to understand biotechnology – aimed at children and adolescents – which function as if they were putting together Legos, but in this case cells are manipulated (AMINO Labs, n.d.).

In the field of industrial design, one of the possible interests of biotechnology is the application of biomaterials, already produced. Some of these biomaterials are synthetic polymers or bio polyesters which in fact are already found in some products that we consume such as packaging or electronic devices. In short, with biotechnology, innovative ways of advancing in different areas of our society are created and therefore studying and understanding them is necessary.

Bioeconomy

In recent years, the term bioeconomy has emerged; however, this concept, authored by Nicholas Georgescu-Roegen and developed in 1975, has evolved over time. The most acknowledged concepts have in common the transformation of biological or natural resources which foster a business and economic model oriented towards the circular. According to the European Parliament (2015), the circular economy refers to "a model of production and consumption that implies share, rent, reuse, repair, renovate and recycle existing materials and products as many times as possible to create added value."

According to the German Bioeconomy Council (Bioökonomie DE, n.d.), the sectors that have incorporated biotechnology in their production processes are chemistry, pharmaceuticals, mechanical engineering, textiles, consumer goods, food and beverages, energy, agriculture and forestry, construction, and automotive.

In the Economic Commission for Latin America and the Caribbean report *Bioeconomy in Latin America and the Caribbean* (Rodríguez et al., 2017), Latin America has eight of the 17 countries with the greatest biodiversity, including Bolivia, Brazil, Colombia, Ecuador, Peru, Venezuela, Costa Rica, and Mexico. Therefore, the bioeconomy could become a form of development for the region, but it requires the incorporation of strategic actors such as the government, businesspeople, and citizens, not only in the prevailing need to promote, design ,and implement public policies towards bioeconomy and innovation, but to adopt sustainable and accessible consumption habits that generate actions for development and attention to climate change, an issue that cannot be postponed.

Biodesign

Ettore Sottsass, cited in Antonelli (2011), stated that design "is a way of discussing society, politics, food and even design itself. In the end, it is a way of building a possible utopia or figurative metaphor about life" (Myers, 2014). Designers envision utopias, explore alternative behaviors, and imagine new ways of living.

Design transcends traditional borders and points directly to the core of the moral sphere, playing with the most deeply rooted beliefs. In the ability of designers to build scenarios and prototype interactions lies a power that should be appreciated in greater depth and that will be even more important in the future: the power to change habits and behaviors.

Biodesign presents an emerging and often radical approach to design that is based on biological principles and even incorporates the use of living materials in structures, objects, and tools. As Egido (2004) has documented, the most accepted meaning of this concept is that which refers to biology applied to design, through bionics and biomimicry. The first concept refers to "the application of the results of biological evolution and/or its principles to design" (Egido, 2004); that is, to imitate the forms that we find in nature. For its part, biomimicry seeks to additionally incorporate the functions and synthesis routes of biological structures to incorporate them into artificial systems (Egido, 2004).

This unifying purpose is driving greater collaboration between designers and biologists, an essential ingredient in many of the projects that offer exciting new forms and functions. Sometimes this unexpected collaboration explores the limits of each discipline and erases the epistemological frontier of each field. The important thing is not that the problem is tackled with design, biology, or some other disciplinary methodology; what remains important is the solution of the problem. A transdisciplinary approach will not only be open to diverse knowledge but also will set people free from the limits of their own discipline.

Biodesign goes beyond other biology-inspired approaches to design and manufacturing. Unlike biomimicry, cradle-to-cradle, and the popular but frustratingly vague "green design," biodesign refers specifically to the incorporation of living organisms as essential components, enhancing the function of the finished work (Myers, 2014).

Recently, architects like David Benjamin are teaching and practicing how to handle life as a design tool, insisting that "this is the century of biology" (Myers, 2014). We can notice processes that deepen the understanding of how nature works, as in neuroscience, which seeks to understand in-depth the way the brain works to bring more natural processes to human instinct and intuition. Other processes are more literal and seek to integrate strategies that we observe in nature into spaces, such as the oxygen generators by designer Mathieu Lehanneur, which, through the living algae of Spirulina Platensis, regularly produce oxygen in the spaces where its object "O" lives, thus balancing air quality (Klanten, 2012). Similarly, industrial processes can be designed to resemble ecosystems in which each waste product becomes a feedstock for another process.

Systemic Design

This is how the work of design has been expanding, even though there is still an excessive tendency to consider the object as an end. It is therefore time to consider the problems in their complexity and support the claim that, from an ecological point of view, there are no products: there are only systems. It is important to give up looking at isolated objects and begin to review how they are connected to the world around them. It is primarily by replicating natural ecosystems in terms of their ability to cooperate, as well as opening space for communication and debate that effective approaches to biodesign will be developed and implemented, and a readable formal language will emerge.

Today there is an urgent need to reduce the environmental impact of human activities, use fewer materials and less energy, and consider the entire design life cycle, from conception to manufacturing to disposal. It is necessary to understand in this perspective the continuous development in materials technology, less materials that impose their existence on nature and more that adapt to connect and be part of it.

For much of history, performance and quality were measured by the degree to which a designed material, object, or structure addressed a set of needs only once it was completed and delivered to the user. This primacy and narrow definition of function is no longer valid. In the twenty-first century, it is being replaced by a new and more sophisticated understanding of factors, such as the impact of carbon emissions, the product life cycle, and resource scarcity. Additionally, new dimensions of function have become increasingly important, such as an object's ability to restore a sense of human connectivity, enable new forms of interaction, or make critical observations about the future trajectory of technologies and behaviors.

The purpose of this brief introduction to biodesign concepts is to prompt discussion and careful consideration of its potential unintended consequences, something too often overlooked in the breathless optimism that characterizes discussion of the field today.

The spread of biodesign promises to be much like mechanization in the twentieth century, as historians such as Sigfried Giedion (1948) describe in *Mechanization Takes Command*: changing accepted practices, extinguishing traditions, toning down natural beauties, and shaping a way of life, strange life. The future that biodesign envisions is one of humanity integrated with nature, where people live in balance and symbiotically with natural processes and systems.

Methodology

The international contest Bio Design Challenge (BDC) served as a basis to define the projects to be carried out. In general terms, the BDC seeks to contribute to the training of future designers who deeply understand the debates around biotechnology and who can design in the best possible way when they are required to use this technology, being aware of its ethical part.

During the creative process, a biodesign approach seeks to promote greater collaboration between designers, biologists, artists, etc. Likewise, it promotes the training of biodesigners, but above all contributes to the public dialogue on biotechnology and its application in our society. The problems of a community are complex and cannot be solved only with a new object that appears in its environment; that is why it also needs a strategic approach. The proposals appear as a tactic plan where objects can exist but they do not appear out of the blue: some take time to develop, others are built by the community, some are supported by a service, others need to be surrounded by a space that enables them, lighting, signage, etc. These different tactics are brought together in a compilation that we call *Playbook* which contains an analysis of the context as well as possible strategies to follow and improve the conditions.

Product-service systems are a way of solving complex problems within a societal context. If problems were simple, perhaps the solution could be just as simple, but when a series of interrelated problems arise in an ecosystem of people, artifacts, emotions, and identities, the solutions cannot be simple. Different tactics are needed for each moment, like the way that the basketball team's coach has a playbook which he shares with the team and invites them to play along according to how he reads the game. This is the way to read the social context and develop a book of emergent strategies for situations that may arise in strategic design.

In an effort to coordinate our universities' traditional model with the human-centered design methodology and so-called design thinking, we made a diagram of our own mix of methodologies. This diagram's purpose is to compile topics and tools that guide the industrial design student in the exercise of new professional roles.

Specifically, the above methodology is defined by the following stages: *Case (caso)*, *Problem (problema*), Hypothesis (hipótesis), *Project (proyecto)*, and Realization (realización). Tools grouped into seven moments were incorporated into this methodological model to accompany the process step by step: (1) define the intention, (2) understand the context, (3) understand people, (4) frame the findings, (5) frame the concepts, (6) frame the solutions, and (7) execute the solutions.

Designers nowadays also take on roles that seek social welfare and the transition to a better society. That is why, convinced by this vision, this approach is shared with the students. They become challenged by the change of focus from object to subject but quickly set to work on a wider approach, one that would consider the collective context and the interactions within it. Following this methodology, they dedicate most of the course to researching the context and people, arriving at a greater understanding of it. As facilitators, we have seen that people become more creative when they have more intellectual resources. Specifically, during the design project courses, students become more creative when they can connect a wider variety of elements. Therefore, they will only have more pieces of this puzzle if they can spark more insights during their research. Consequently, it is easier for them to confront a white canvas. When they are requested to brainstorm with the tool called KJ Method, ideas flow easily. In a common session of two hours, each time students would easily arrive at 50 ideas. Selecting the ones with more potential is easier, especially when they are clear about the problem. Ultimately, they start to connect these ideas into systems and arrive at a final strategy that allows them to define the identity, vision, and mood of the proposal.

Results

The most rewarding result is to achieve a shared vision with the students, one where they are convinced about their approach and the impact that it can have. There have been projects that evolve from a proposal of designing new trash cans to a proposal of a certification on how to handle the residues.

The course requests that students take on a biodesign challenge. This commonly means that students will experiment with organic materials and transform them into viable products. However, the vision that inspires us and the students is one of a symbiotic collaboration with the environment, also known as sympoiesis. Under this conviction, problems are not solved by just proposing a new product or recycling some organic waste. Life cycles, long term impact, local resources, and local production, among many other considerations, should be considered. Sometimes design solutions require a lighter touch, just applying the right leverage. This in practice means that students might come up with services, experiences, and intangible proposals and be more conscious about the behavior that they can inspire with their proposals. They now start to consider design as an *applied behavioral science*. We are convinced that behavioral changes are what will lead humankind towards a more sustainable future, towards finding our place in the ecosystem and collaborating with other species.

The two cases presented here were randomly selected to exemplify the work done to delve into the relationship between biology and design from the study of biotechnology. Next, the essential approaches of each project are presented, as well as pictures of each. Finally, even though only two from twelve projects have been presented here, there are other cases where students worked on topics like the application of chitin, a do-it-yourself (DIY) kit for creating homemade biomaterials, a biocultural center, production of biomaterial-based fruit waste, architectural panels made of biomaterials, and so on.

Case 1. Güit: An Alternative Food Distribution Store Model
This case started originally as an educational tool for nutrition at home, a project that shows a team of students that constantly challenged themselves to find the root of the problem. In the other project explored in this paper, students take the challenge of designing a certification for waste management in the largest marketplace on earth.

Güit seeks to activate families, tribes, and community city dwellers into a new food identity where, through the integration of learning solutions and accompaniment, new emotional bonds are awakened with a *bioconscious*, nutritious, and sustainable diet in all its dimensions. In the context of a globalized world, both transnational companies and supermarket chains have contributed in the last 30 years to what they call a food or nutritional transition, which has been characterized by the adoption of an industrialized, processed, and homogeneous diet. This diet has permeated consumption patterns and habits due to its accessibility, comfort, and time savings that the lifestyles of Mexican families demand today.

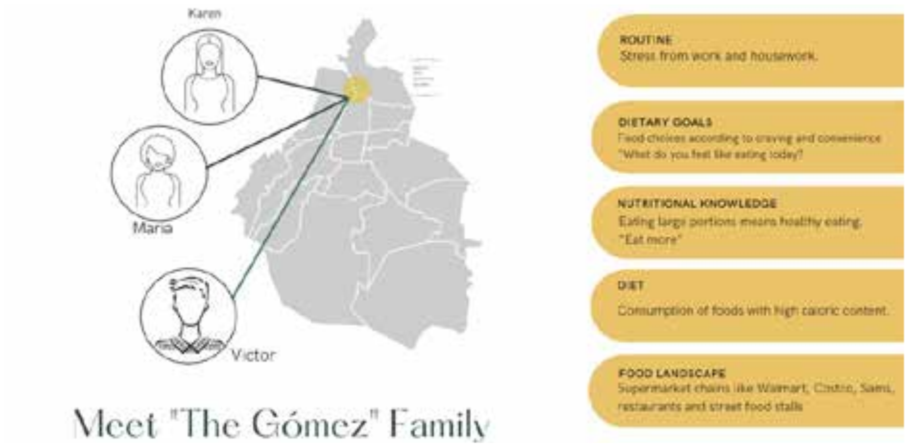

Figure 2. Contextual analysis, Güit Project (credit: K. M. González, A. P. Nandayapa, E. G. Vega, & M. A. Aznar).

The problem: Interest in researching the role of biotechnology in food led this team to consider the following research question for their project: *How could we guide families towards beneficial food decisions for the health of the body and nature in their daily consumption routines?*

The design approach: Under this context they proposed first *Achi Kuali*, a bio-educational platform where people would get to know their inner microbial world through a technological "mat" that collects saliva to test it and processes the information via an app in order to have a better understanding of the relationship between our food decisions and our health.

Finally, they came up with an alternative proposal to the food distribution store model, with the objective of activating a food culture based on awareness, reconnection, and revaluation of food by educating and promoting beneficial consumption decisions for the health of the body as well as nature. They called this educational food consumption model "Güit."

Figure 3. Spatial design proposal, Güit Project (credit: K. M. González, A. P. Nandayapa, E. G. Vega, & M. A. Aznar).

As a conclusion, the shift in this team was remarkable. They went from conceptualizing nutritional bacteria, designing plates to divide portions, and conceiving an online platform to an educational model that can improve food consumption culture and mitigate wicked problems in the local context like diabetes and obesity.

Case 2. Orbe: Use and Management of Organic Waste in Mexican Markets

The second case study that would be interesting to show is the project *Orbe*. Inspired by living systems, the students had the realization that organic waste should not only not end up occupying space in landfills but that its management should seek to make the most of it in the community. Attracted by its cultural richness and the life that exists in its ecosystem, they chose the following community: typical Mexican markets – and not a random market but the biggest one in the world, the *Central de Abastos*.

The *Central de Abastos*, located in Iztapalapa, Mexico City, is not only the largest retail and wholesale market in the world, but also the main supplier of food consumed in the city. Approximately 80% of what is consumed in the city comes from this market. To get into the scheme of this large community that is the Central de Abastos, the students used the different design tools available during the course in order to get a more accurate picture of the inner workings. They analyzed the participation of each of the actors and users involved in keeping this great system afloat.

In Mexico, the agricultural sector is vital for the country's development, whose main distribution centers are the markets. In Mexico City, the highest concentration of food products is found in the Central de Abastos thanks to the direct contact with farmers; however, there is a discrepancy between the high production and the lack of management of waste produced in their daily tasks, which makes it difficult to take advantage of one of the largest producers of organic waste in the city. Unfortunately, this overproduction of waste has consequences that directly affect the internal community and has general repercussions on society, causing serious impacts on the environment and the inhabitants' health.

The problem: As in the above case, the exploration between biotechnology and food led this team to the following research question: *How could we leverage community participation to improve the collection and management of organic waste?*

The design approach: To answer their question, they conceived of *Orbe,* which consists of a voluntary program for consumer product markets that seek to certify the use and management of organic waste in the public and private sector to manage waste from food and vegetables and take advantage of technology to democratize good environmental practices. The objective is to create a natural cycle where organic waste prevails in different ways and helps the community.

Orbe seeks to generate social recognition from users who come to purchase the variety of products and approve of the commitment to reduce the environmental impact and care for the safety of the ecosystem. Imagining a less polluted Mexico is possible; food and vegetable marketing companies will become unified in view of the social and environmental responsibility involved in obtaining the Orbe certificate. Replicating this model in most of the region will have a direct impact on society's actions in a positive way and will finally take advantage of those resources that today are considered "garbage."

Figure 5. Certification proposal and strategy map, Orbe Project (credit: A. S. Valencia, J. Larios, & E. Jaramillo).

Conclusions

In the making process, it is important to challenge the students to explore the boundaries and go beyond the limits of the discipline. Industrial design education does not normally propose certifications and strategies for cultural agency, mainly because it is a profession that is still focused on mass production and proposing commercial products. However, we believe that the shift that arises in the discipline towards social innovation processes and transition design casts new light onto the focus of creative professions. Nobody said it better than Adolfo Natalini (1971): "Only when design activities are aimed at meeting primary social needs is when it should exist, meanwhile it should disappear, it is possible to live without architecture."

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The cases presented in this paper were randomly selected to exemplify the work done to delve into the relationship between biology and design from the study of biotechnology:

Güit Project (2021) was developed by Karen Montserrat González Castillo, Ana Paula Nandayapa Robles, Elizabeth Geraldine Vega Franco, and Miguel Alejandro Aznar Sánchez.

The *Orbe Project* (2022) is developed by Ana Sofía Valencia Palacios, Jacqueline Larios Orozco, and Emiliano Jaramillo González.

USING STEAM TO POWER EQUALITY AND DEMOCRACY IN VACCINATION DECISION MAKING IN THE FACE OF CLIMATE APARTHEID

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Abstract
Technology and science are often promoted as the answer to the climate crisis, but changing human behavior from a user-centric position requires a humanistic and design thinking approach (Brown, 2009). If climate apartheid is to be challenged to decrease the divides between social, cultural and economic groups, then a participatory and democratic design approach needs to be found. One such challenge of inequality that will increasingly become more acute is the spread of viruses and disease, old and new, as the Covid-19 pandemic has shown. Our study aims to demonstrate how science, technology, engineering, arts, math (STEAM) education can bring together diverse groups for a common understanding and empower them to have the confidence to advocate for change in human behavior from peer-to-peer rather than top down by government.

Our study focused on human papilloma virus (HPV) vaccines which are proven to save lives and eradicate associated cancers, but the uptake of the vaccine among first-year second level schoolgirls in Ireland, to whom it is offered for free, has dropped in recent years (ICS, 2020). Building on the experience of a previous pilot study with biological science and design students, this project aimed to validate the findings of the authors (2022) with these questions: In what ways can STEAM engage and motivate students to learn about immunology and vaccination? And in what ways can STEAM help them develop the competence and confidence to communicate their understandings about immunology and vaccination? It brought together a team of academics from education, design, biology, the Irish Cancer Society (ICS), and Irish post-primary students in an interdisciplinary, intersectoral, and international collaboration.

Twenty 16 to 17 year-old students, from three post-primary schools, participated in a weeklong series of on-campus STEAM workshops, facilitated by the team. These involved dialogical peer-to-peer teaching and learning (Topping, 2009) amongst the participants to co-create localized, culturally inclusive, and scientifically informed stories around HPV vaccination and immunization. Using the principles of active learning (Bransford et al., 1999) the students constructed their own knowledge and understanding through drama improvisation and storytelling through scripts and storyboards in an iterative process of presentations and idea selection in a visual thinking methodology (Averinou & Pettersson, 2020).

A qualitative arts-based research methodology was adopted. The impact of the workshop series was evaluated on three key criteria: students' knowledge of immunology, their confidence in expressing their knowledge about immunology, and their confidence in advocating for vaccination and countering misinformation. Thematic analysis of the data was employed (Clarke et al., 2015).

The project highlights key insights that have wider application to combating climate apartheid: a STEAM approach is successful in engaging students in active learning and changing their attitudes towards the HPV vaccine from passive to positive; the use of a STEAM approach enabled and encouraged students to become more confident in their understanding of the HPV vaccine and immunization and more confident advocating for the HPV vaccine to peers; and combining creative learning and teaching approaches with scientific content can lead to meaningful changes in human behavior.

Author Keywords
STEAM; immunology; drama improvisation; storytelling; advocacy.

Introduction

The global Covid-19 pandemic and recent vaccination program roll out has prompted a lot of research into vaccine hesitancy and public messaging (De Figueiredo et al., 2020; North Carolina State University, 2021; ONS, 2021; Murphy, 2021), and has changed the priority and focus away from other diseases. The World Health Organization (WHO) (2021) has backed up the claim of many developing countries that they have not had an equal share of Covid-19 vaccines and have been left behind, despite pledges of generous support by the world's richest countries in the Northern hemisphere. As our climate changes, new diseases will occur and others will migrate to new warmer climatic conditions, exposing populations to further social inequity and economic disadvantage (Roberts & Parks, 2006).

> The effects of climate change on public health will be substantial as there is already a disproportionate distribution of risk in our society based on socioeconomic factors, such as education level, ethnicity, and poverty level. Thus, we can anticipate that climate change will only perpetuate these disparities in health (Frumkin et al., 2008). (Sandhaus et al., 2018, p. 260)

Many diseases are preventable with vaccination programs, but not everyone has access to enough information to make informed decisions, even if they have access to vaccines. Climate apartheid exposes the most vulnerable and disadvantaged to the risk of disease through changing climate and lack of education. If only we could design a democratic way to challenge the threat of disease that is exacerbated by the inequalities of climate apartheid; how might we empower communities to educate and better inform themselves in order to confidently challenge the inequities in disease prevention created by climate apartheid?

Climate justice seeks to remedy this by providing a platform for disadvantaged voices to be heard and to create community-based solutions (Cox & Pezzullo, 2016). Participatory approaches to health education are supported by extensive research (Haldane et al., 2019; Brear et al., 2019; Schroeer et al., 2021) following the Ottawa Charter for Health Promotion (WHO, 1986). Our study aims to demonstrate how science, technology, engineering, arts, math (STEAM) education can bring together diverse groups for a common understanding and empower them to have the confidence to advocate for change in human behavior peer-to-peer rather than top-down by government.

Our study focused on human papilloma virus (HPV) vaccines, which are proven to save lives and eradicate associated cancers, but the uptake of the vaccine among first-year second level schoolgirls in Ireland, to whom it is offered for free, has dropped in recent years (ICS, 2020). Building on the experience of a previous pilot study with biological science and design students, this project aimed to validate the findings of Macdonald et al. (2022) with these questions: In what ways can STEAM engage and motivate students to learn about immunology and vaccination? And in what ways can STEAM help them develop the competence and confidence to communicate their understandings about immunology and vaccination? It brought together a team of academics from education, design, biology, the Irish Cancer Society (ICS), and Irish post-primary students in an interdisciplinary, intersectoral, and international collaboration.

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Context

The European Centre for Disease Prevention and Control's (2017) catalog of interventions addressing vaccine hesitancy and the European Cancer Organization's (ECO) *Umbrella Review of Interventions Improving HPV Vaccine Uptake in Children, Adolescents, and Young Adults* (2022) explain that HPV causes about 5% of all cancers worldwide, and a significant proportion of the cancers caused by HPV in Europe are in men. HPV vaccination is probably the single most effective means of cancer prevention in the medical arsenal. Hence, Europe has set a 90% vaccination rate across all its states in order to succeed in eliminating HPV cancers as a public health problem in the region by 2030. Amongst the richest countries in the world, such a high vaccination rate has particular challenges:

- An important part of the explanation for sub-optimal vaccination rates is low vaccine confidence among parents and carers as well as young people themselves.
- This can be caused by insufficient information, a lack of trust in health authorities and vaccine manufacturers and concerns about vaccine safety.
- We know, however, that vaccine confidence can be improved and vaccine uptake increased if the right policies and programs are put in place (ECO, 2022, p. 1).

This review identifies face-to-face as the most effective means of improving vaccine uptake, but there is no "magic bullet" and other multimodal interventions such as videos, print, and online resources are also effective at making a difference in terms of intention to be vaccinated and uptake rates for HPV vaccination (ECO, 2022). Imagine then the added challenge of climate apartheid in developing countries where accurate data gathering and health information and education can be scarce.

Research into community participation in the developing African countries of Burundi (Falisse et al., 2012) and Swaziland (Brear et al., 2019) concluded that "participatory, dialogue-based methods can be effective techniques for enabling participation in learning, reflection and decision-making activities" (Brear et al., 2019, p. 68) in health education. Further support for community participation in health promotion and prevention activities highlights the benefits of new insights and a broader perspective on issues shared within the group, in addition to a sense of inclusion and community building (Schroeer et al., 2021).

Within the design community, Manzini (2015) argues that "the role of design experts is feed and support these individual and collective projects – and thus the social changes they may give rise to" (p. 1). Designers have had to respond to a change in their role as experts dictating a process or solution. Today everybody designs, so designers have had to adapt to use their own initiatives to assist other "social actors to design better" (Manzini, 2015, p. 2). There are also two paradigms that we operate in which are in conflict: the "limitless world" and "another that recognizes these limits and experiments with ways of transforming them into opportunities" (Manzini, 2015, p. 2). Through collaboration with others in multidisciplinary teams bound by shared values, design can work in both diffuse and expert roles: working together on diverse problems facing society and demonstrating its "specificity...where, more than any other discipline, it can bring its most original contribution" (Manzini, 2015, p. 3). Sustainable and scalable local applications of an idea of well-being, and in our study of health education, are possible if based on a new ecology of relationships between people.

Vignati et al. (2022) argue that teaching design in a blended and community-led approach – as in a train-the-trainer methodology – in emerging countries can move away from a concrete framework of Western design and instead provide a scaffold to create a local bespoke approach. This has the added advantage of decolonizing emerging countries from Western approaches. Diffuse design approaches leverage ground-up solutions and "social change through increased empathy developed by the adoption of human-centered design approaches" (Vignati et al., 2022, p. 62).

STEAM

Art-based intervention has been part of bringing climate change to public awareness for some time (Lippard, 2007; Volpe, 2018; Baztan et al., 2020). Baztan et al. (2020) argue that community art-based action groups not only stimulate awareness of climate issues, but they generate capacity to mobilize public opinion that help realize empowerment and greater social justice. The benefits of art and science integration are "helping to engage multiple senses and emphasizing social interaction within research practices...rearticulating politics and knowledge (Latour 2017); offering more effective approaches to multiple publics in climate-compatible behavior change..." (Baztan, 2020, p. 3).

Combining arts-based approaches with STEM (science, technology, engineering, math) to STEAM education is argued by many in education as an essential pedagogical development (Verran, 2019). "Indeed, as technology and the human species continue to symbiotically evolve, STEAM approaches will be crucial to facilitating acute and long-term insights into possible social and environmental interactions, impacts, benefits and consequences for our human condition" (de la Garza & Travis, 2019, p. 2).

> Our incapacity to address wicked problems has been traced to the compartmentalization of scientific and professional knowledge, to the sector-based division of responsibility in contemporary society and to the increasingly diverse nature of the social contexts in which people now live (Lawrence 2011). Transdisciplinary research and practices offer an avenue for the STEM disciplines, the arts, humanities and social sciences (STEAM) to overcome these obstacles and tackle these truly vital issues. It also introduces a model of accountability to society and promotes innovation as previously separate fields are brought into contact with one another. Transdisciplinary models of knowledge production are a necessary response to demands that academic life becomes more integrated with society and the economy. (de la Garza & Travis, 2019, p. 144)

Further, communicating scientific principles – in our study, immunology – through visual arts such as drama, storytelling, and video opens dialog and encourages unorthodox and innovative creative communication. According to McKeown (2019, p. 108),

> ... the arts can also disseminate STEM knowledge in a more accessible manner by 'making connections between diverse ideas and provok[ing] unexpected conversations' (Wellcome Trust, 2017, para. 3) ... In STEAM education, learning occurs at the intersection of the five fields, transforming how we know and investigate the world. As a pedagogical innovation, the STEAM agenda offers an approach to teaching and learning 'that encourages and facilitates unorthodox methods and strategies' (Rose & Smith, 2011, p. 8).

Following recent studies that have sought to establish best practices for integrating "interdisciplinarity" into higher education and research methodologies (Power & Handley, 2019; Tobi & Kampen, 2018; De Greef et al., 2017), this study explored new methods of communicating and learning the principles of immunology at a time when the concept of a pandemic was real and present. We will argue that interdisciplinary co-design workshops (Steen, 2013; Steen et al., 2011; Kleinsmann & Valkenburg, 2008) are an effective means of mitigating climate apartheid by creating opportunities to develop a pathway of communication through empathy and reflective practice (Schön, 1992).

Methodology

We established two research questions:

- In what ways can STEAM engage and motivate students to learn about immunology and vaccination?
- And in what ways can STEAM help them develop the competence and confidence to communicate their understandings about immunology and vaccination?

Our study was intersectoral, involving Maynooth University, Edinburgh Napier University, the Irish Cancer Society, and three post-primary schools. It was interdisciplinary involving academics from education, design innovation, product design, and immunology. Involving collaboration between colleagues in Ireland and Scotland, it was also international.

Having achieved ethical clearance and police vetting, we invited post-primary schools from the Maynooth area, twenty kilometers west of Dublin, to participate. Twenty 16 to 17 year-old students from three post-primary schools participated in a week-long series of on-campus STEAM workshops, facilitated by the team. These involved dialogical peer-to-peer teaching and learning (Topping, 2009) amongst the participants to co-create localized, culturally inclusive, and scientifically informed stories around HPV vaccination and immunization. Using the principles of active learning (Bransford et al., 1999), the students constructed their own knowledge and understanding through drama improvisation and storytelling through scripts and storyboards in an iterative process of presentations and idea selection in a visual thinking methodology (Averinou & Pettersson, 2020).

After receiving an information briefing to entire year groups, ten boys and ten girls self-selected and volunteered. Information sheets and letters of consent and assent were signed. They attended approximately eighteen hours of workshops on campus over four days. Two of the research team facilitated the on-campus workshops with some extra input from a postgraduate student teacher. Our colleagues from Edinburgh Napier University and the Irish Cancer Society participated in the workshops remotely online due to Covid-19 travel restrictions at the time.

As the students were from different schools and did not know one another, the emphasis on the first day was on establishing a collaborative environment. These activities were mainly education-based drama and, in addition to building a sense of community, they focused on facilitating learners to reflect on what they already knew about immunology, vaccines, and in particular, the HPV vaccine. We used a mix of self-reflection and group reflection with thoughts and opinions being shared in small groups initially and then collaboratively to the larger groups. We encouraged learners to incorporate a multimedia approach to presenting their thoughts and opinions, so they used storyboarding, posters, improvisation and role play, pictures, diagrams, movement, and sound, among other modes (see Figures 1 and 2).

Figure 1. Students present in front of the camera for online facilitators and in-person peers and facilitators.

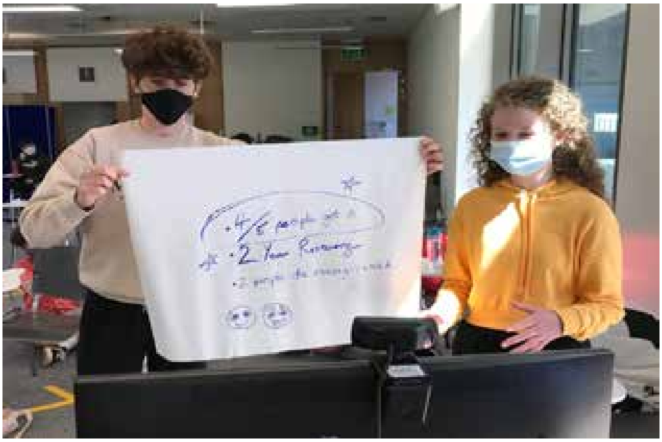

Figure 2. Students present in front of the camera for online facilitators and in-person peers and facilitators.

Planning and Reflection

We had planned the sessions in advance and collaboratively honed them each evening based on our reflections on the day's events. As researchers, we also engaged in reflection in action and altered our planned activities and tasks and the sequencing of these according to perceived levels of student engagement and interest. Observation grids were used to record and identify what engaged learners, what motivated them to learn, what helped their competence, and what helped to develop their confidence to communicate their knowledge and understandings. These were reinforced by ongoing requested feedback from the learners about what worked for them, what they found most helpful, and what they found most enjoyable. At the end of each session, we held focus groups with the learners for further feedback and discussion. Research team members also recorded daily entries in reflective journals.

Activities and Tasks

Following a design thinking (Brown, 2009) approach, journey – and empathy-mapping exercises encouraged learners to reflect on and discuss their personal experiences with vaccination, others' experiences, and what they have heard and read about vaccination. This helped them to collectively identify gaps and ambiguities in their knowledge and understanding and to prepare questions for the immunologist. Drama in education activities such as "line-of-life" enabled the team and the learners to reflect on their knowledge and understandings and to articulate them and – as time went on – to see their progress. Activities such as "angels and devils" enabled them to express both sides of the argument for and against vaccines, particularly the HPV vaccine. This enabled them to express disinformation that they had heard or found on the internet and to counter this so that they expressed a rounded understanding of issues. Design activities such as storyboarding allowed them to express understandings visually and to scaffold the planning of their videos.

They used the storyboards to present their plans to the whole group, including the facilitators. Peers asked questions when the narrative was unclear. Subject discipline experts were available for drop-in sense checking and advice, whether it was for creative and technical suggestions for improving the plans, challenging incorrect scientific information and giving feedback on how this could be corrected, or providing advice on videoing and scenes and props or input on improvising the storyboard content (see Figure 3). The planning and presenting of their plans enabled them to express and improve their scientific understandings and to collaboratively engage in artistic creation, collaboration, and communication (see Figure 4).

Figure 3. Online tutorial with facilitators.

Figure 4. Student participants shoot their video.

Baseline
One of the first activities on day one was to establish how confident the learners were in their knowledge and understanding of vaccines using a line-of-life drama in education activity. This showed that learners had very little knowledge and understanding. Typical responses were:

> What do you know about vaccines? (I know all I need to know about vaccines)
> 3.M.a: "I know about them but not the ins and outs."
> 1.F.f.: "I've heard of immunization so I'd probably know but can't quite remember."

Asked about their understandings of how immunization works, most indicated that they had no understanding or a basic or vague understanding. Just one indicated that they had a good idea of how it works. Asked how confident they would be to talk to peers about the HPV vaccine, typical responses indicated that they would not feel confident as they did not have the facts and did not have confidence in their knowledge.

Science Input
Having heightened their awareness of what they did and did not know about immunology, vaccines, and the HPV vaccine, we had input from team member Dr. Eva Malone, an immunologist, on how vaccines work. The presentation was live streamed and included colorful visuals and a short video. As with the workshops, a collaborative team-based approach was used in the preparation of the science input. Working on advice from colleagues in the Education Department, Dr. Malone created a presentation which was broken into short segments and included opportunities for learners to discuss their understandings and list questions which were then brought back to Dr. Malone. In order to ensure that the language and terminology used was suited to the learners, Dr. Malone collaborated with two of her university students who advised her on language, terminology, and slide content. The science input was followed by interactive activities where students shared their understandings and established further questions they had. Dr. Malone and her students stayed online and learners approached the laptop to pose questions and seek clarifications.
Students engaged with the new science learnings and incorporated them into drawings and improvisations. They were given input on storyboarding and design using a blended approach, with Dr. Iain Macdonald onsite and Dr. Richard Firth online.

Further science input on the HPV vaccine was given by Dr. Robert O'Connor from the Irish Cancer Research Society. Learners used the information gathered as a basis for discussion in small groups for further self-directed online research. In small groups, they discussed and planned freeze-frame tableaux and improvisations for showing and communicating their understandings to peers. Having shown them to the full group, they continued to adapt them and make TikTok-style short videos. With feedback on these and input on technical issues around making videos, the groups scripted, storyboarded, and rehearsed short videos for presentation to 12 to 13 year-old students (pre-vaccination target audience), telling stories carrying facts about the HPV vaccination process. Each group presented their story with their "storyboard" prior to having it screened on the big screen for all to see (see Figure 5).

Figure 5. Stills and end captions from student videos.

Findings

Data Analysis

A qualitative arts-based research methodology was adopted. The impact of the workshop series was evaluated on three key criteria: students' knowledge of immunology, their confidence in expressing their knowledge about immunology, and their confidence in advocating for vaccination and countering misinformation. Thematic analysis of the data was employed (Clarke et al., 2015) and an interpretive description of meaning was used (Thorne, 2016).

Analysis of our participant observation grids highlighted that learners showed signs of being most engaged and motivated when involved in tasks in which the outcome was clear, where they had agency over how they engaged with the task and how they demonstrated their understanding or knowledge – where they were able to collaborate. This was particularly evident in their planning, developing, and creation of videos around HPV vaccination. These encouraged them to bring all their learning and interests to the process, a holistic approach which encouraged and supported learner autonomy.

The STEAM approach successfully enabled learners to develop their knowledge and understandings of immunology, and especially of HPV vaccination, and to develop their competence and confidence to communicate this to peers and to counter misinformation through creative output.

Feedback from the students in focus groups and last day line-of-life activities showed that they had internalized the scientific facts and information and felt confident about communicating these to others. They were more confident because they believed they were better informed. Typical statements were:

> 1.F.f.: "I'm definitely more informed about how vaccines work, and how to promote it to other people."
> 3.M.d.: "and it spread awareness about the virus we didn't know beforehand "
> 1.F.f.: "and we were able to talk to experts, work with immunologists, like it just really reassures you about most of the doubts surrounding the vaccine are usually just caused by like, conspiracy theorists, that's not very grounded in the reality, like actual science of vaccines."

The STEAM approach enabled them to develop their science knowledge, but also to develop other transferable skills such as working collaboratively, public speaking, and being creative. Indicative comments:

> 3.M.a.: "also we learned a lot of skills like public speaking and working in groups together, which was very useful."
> 3.M.e.: "teach you how to work in groups as well, learning social skills."
> 3.M.a.: "get to show our creative side."

Learners enjoyed the holistic approach which encouraged them to be actively involved in their learning. Indicative comments:

> 3.M.g.: "it was a good fun way to learn about a serious topic, so it was easy to participate, taking the information and making something cool."
> 2.F.b.: "I really liked the call with the professor, I thought that was really fun and it was interesting, and that a lot of the activities were very much like umm...they were more practical, you were doing that and not just writing stuff down. "
> 2.M.e.: "yeah it was fun how it wasn't just like, we learning about vaccines, but it incorporated other things like, they had an expert in design there, and it incorporated that into it. So it wasn't just about vaccines, it was a lot fun. "

Learners regarded communication of HPV vaccine information to be important. Indicative comments:

> 2.M.e." "get the HPV vaccine...because before I didn't really know anything about it, I never...they talked about vaccines in general at school, but nothing specific about the HPV vaccine, so I feel it was important to learn about
> something that is that important."
> 1.F.b.: "you only get to hear of it like 2 weeks before you get it in first year, and that's it, and then it's gone again."
> 4.F.b.: "I don't think they do enough to stop the rumors, they just don't address it, and that makes people think that they are true."

The learners showed the essence of their learning around science, communication, collaboration, and creativity in their final outputs and their videos. The learners brought their understandings of life and culture into the making of these videos. They brought their knowledge of science, storyboarding, improvisation, music, videoing, dramatic effect, and advertising: a cross-curricular approach to showing their understanding and communicating their message.

Discussion

Insights from our data analysis reaffirmed that STEAM education provides a holistic learning experience, but moreover it can enable participants to communicate their understandings about vaccines, and in our case HPV, with peers and others, particularly those who will be offered the opportunity to be vaccinated and their parents. It is a powerful way to engage dialog, build empathy, and deliver science in a manner that is in the culture and lived experience of its audience, whatever their age or wherever they live. Could this approach be transferable to other scientific principles and concepts such as climate change? In highly-industrialized nations, people protect themselves from their culpability in furthering global climate change, often leading to an everyday denial of climate change (Norgaard, 2011). Stapleton (2019) argues that a collaborative participatory design approach can build empathy amongst the privileged through personal connection with those who are impacted directly by climate change.

Perhaps this is the way out of the problem Norgaard (2011) poses where emotions can be a roadblock to engaging in climate change, leading people to denial. Here emotions are used for connection; through connection to real people affected by climate change, youth become tangibly linked to what can otherwise seem a complex, amorphous, abstract problem. (Stapleton, 2019, p. 745)

In our study, as facilitators, we also learnt from each other's disciplines and STEAM-enabled collaborative inquisitiveness through the participants' playful learning. Future workshops may bring to light facilitators with skeptical or even opposing views, and yet as an interdisciplinary and collaborative process it could be a viable democratic methodology for discussing climate apartheid through empathy building.

Our study showed how readily teens wanted to interpret scientific concepts and personal stories around immunization into visual form, and more often, if drawing was not their first choice, it was through their phone cameras to capture performance and enact scenarios. Stories that are visual and about solutions rather than warnings appeal to underrepresented communities (Wenzel et al., 2016). Dahmen et al. (2019) found that "solutions-orientated photos also led to greater levels of narrative engagement with the story, which then facilitated significantly positive outcomes for interest, self-efficacy, and behaviour intentions" (p. 284).

As climate apartheid exacerbates the disparities between the hemispheres, it is local solutions that will have most impact. The 2021 United Nations Conference on Trade and Development (UNCTAD) (2021) reports that least developed countries suffer a digital divide in mobile connectivity: not only is network coverage much lower, but their data usage is significantly more expensive. "This situation perpetuates existing inequalities – rural vs. urban, poor vs. rich – that intersect with micro-level disparities across gender and ethnicities" (UNCTAD, 2021). Global charity networks know the importance of nurturing relationships on the ground; to be sustainable, any healthcare intervention needs to involve training and resourcing local stakeholders. Haldane et al. (2019) affirm that community involvement is key to driving improvement in healthcare as it provides a contextualizing learning phase and allows organizational relationships to build trust with stakeholders and communities. "Health improvements do not happen in a linear progression, but rather consist of complex processes influenced by an array of contextual factors" (Haldane et al., 2019, p. 21). As the ECO (2022) umbrella study of HPV interventions reports, there is no one single "magic bullet."

Conclusion

Our study provided space for dialog that challenged misinformation, and it offers a scalable template of peer-to-peer communication to positively impact the health trajectory of others across intergenerations within schools, families, and as future parents. As part of a multimodal strategy, this could educate and protect many that participate in such workshops, not just from the cancers prevented by HPV vaccination in our case study, but in any health context across the globe. This is an example of how to also help insulate these communities from the growing tide of health misinformation.

The project highlights key insights that have wider application to combating climate apartheid using STEAM to power equality and democracy: a STEAM approach is successful in engaging learners in active learning and changing their attitudes towards the HPV vaccine from passive to positive; the use of a STEAM approach enabled and encouraged students to become more confident in their understanding of the HPV vaccine and immunization and to be more confident to advocate for HPV vaccine to peers; and combining creative learning and teaching approaches with scientific content can lead to meaningful changes in human behavior. While our case study focused on HPV vaccines, we argue that this is a multidisciplinary template that could be used for other vaccination programs to power equality and democracy.

In order to challenge climate apartheid to mitigate the forces that divide people economically, culturally, and socially, such as access to vaccines to combat the spread of viruses and disease, then a participatory and democratic design approach is required. STEAM education can bring together diverse groups for a common understanding using empathy, creativity to communicate science that empowers them to have the confidence to advocate for a positive change in human behavior peer-to-peer.

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CLIMATE CITIZEN

A COOKBOOK FOR PLANETARY HEALTH: SITUATED AND DISTRIBUTED LEARNING TO ADDRESS NON-TRIVIAL ISSUES THROUGH DESIGN FOR COLLECTIVE ACTION

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Abstract
This paper reports on the Common Design Studio (CDS), a distributed intensive design sprint that introduces design students and staff to transnational and transcultural practices and collaboration and facilitates pluralistic ways of designing together whilst exploring complex problems at the local and planetary level.

The CDS grew out of INTERACT, an academic and student intercultural exchange project between four major institutions in Europe and Australia that explored the futures of design in a global context. The CDS adapted the key benefits of INTERACT into a formula that could be scaled to include a greater number of staff and students without the monetary and environmental expense of a physical exchange, making the learning experience more inclusive and accessible.

For the last two years, the CDS has brought together students and staff from design schools in Melbourne (RMIT University), Barcelona (ELISAVA) and London (London College Communication) to work on complex design problems with localised symptoms and planetary significance.

These recent iterations have focused on the documented risks to our interconnected ecologies that affect planetary health. The themes explored include specific material-based issues such as: microplastics; how to survive and thrive through catastrophic ecological risks; and radical social and ecological action in urban greenspaces. During the last two iterations of the CDS, students have been encouraged to create design proposals in the form of “recipes” that can incite positive collective action and encourage creative resistance. The recipes are designed to be oriented toward community-level activations and be accessible, adaptable and transferable across location, language and culture. The

student groups work on the same issue from various locations and therefore benefit from each other's diverse experiences.

The nature of the studio engages students in radical adaptation; they are asked to quickly develop strong relationships with their group members and take responsibility for their current and future roles as designers as change-makers. The adaptability required to address our critical climate issues is modelled in the studio where students must quickly learn to collaborate fluidly; to generate concepts based on sharing diverse experience and knowledge; to open themselves to innovation; and to assemble fast-paced research to share with the whole cohort in order to produce extensive future-orientated knowledge maps.

Students are encouraged to enact proposals in their local communities, then bring this highly localised experiential knowledge back to help generate a globally translatable outcome. While the outcomes are quick sketches for innovation, the studio experience itself provides a "recipe" for enabling adaptation-orientated designers.

This paper will discuss the organisation and adaptable framework of the studio, as well as show selected recipes as outputs of the studio. Furthermore, we will propose valuable next steps: the structure of the CDS is flexible and adaptable and can be re-created across different institutions, times and contexts, and even beyond. We would value the opportunity to create further connections in order to find ways of adapting the CDS for greater accessibility and reach, working in common and creatively on the complex problems that face us.

Author Keywords
Commons; situated practice; planetary health; design for collective action; collaboration; transcultural; design pedagogy.

Introduction

Over the last four years, design educators and students from major higher educational institutions in various countries have worked together annually on a two-week intense design studio for transnational and transcultural collaboration, out of which the Common Design Studio (CDS) has emerged. The CDS is a distributed and transferable model for transnational and transcultural co-design, and each year produces a new iteration of the "Planetary Health Cookbook" for distributed and situated design actions.

The evolution of the Common Design Studio has included a variety of institutional partnerships with the Royal Melbourne Institute of Technology University (RMIT) and the London College of Communication (LCC) as constant partners. During these partnerships, tools, processes and methods have been adopted or created to enable collaborative activities, addressing themes that are urgent, situated (local) and distributed (global).

The last two iterations – in 2021 and 2022, the focus of this paper – involved twenty to forty students from RMIT, LCC and ELISAVA, Barcelona, and two to four staff from each institution, with a thematic focus on planetary health (2021) and radical urban gardening (2022).

The project evolved from a four-year European-funded exchange programme between the institutions called INTERACT (full title: INTERACTive Studios & Innovative Networks for Future Design Careers) which proved to be a productive catalyst for each institution to challenge its approach to design and teaching methods as well as exposing participants to broader global contexts for design. INTERACT facilitated forty student and twenty staff exchanges between the European and Australian institutions, with the student exchange usually lasting ten weeks. However, the logistics and prohibitive cost excluded many from participation (Revell & Verhoeven, 2018).

The CDS has proved a great success at sustaining a transnational and transcultural community of practice around design between the different institutions. In this paper, we discuss the values and rationale for the project, both in terms of the structure and the thematic focus. Secondly, we describe the pedagogical and structural methods as well as the final output – the cookbook – through exploring specific recipes produced in the last two iterations. In conclusion, we describe the Common Design Studio itself as a recipe to demonstrate the key ingredients and encourage others to undertake similar global studios. We hope that this provides a transferrable model for future projects of a similar nature and rationale for further subject-driven, collaborative online projects that cross boundaries and time zones.

Why

Design scholar Arturo Escobar (2017) recently proposed the need for design to embrace "a praxis space generated by the interplay of an ethics of world making and a politics of social existence, and to bring a processual and relational ethics into design itself and into all we do" (p. 226). As an extension of a traditional exchange programme, the Common Design Studio as an intensive online experience addressed several goals. Firstly, it aimed to expand the benefits of cultural and institutional exchanges, especially at a time of increased awareness of the dangers of nationalism and anti-intellectualism across much of the Western hemisphere (Pater, 2020). Secondly, it addressed issues of sustainability both financially and environmentally, making it possible for staff and students to benefit from transnational and transcultural collaboration without the prohibitive costs of flying and the associated environmental impact. In one student's own words, "it was really good in the sense that it was a live brief and so we could collaborate with other people and have that experience working with people of different backgrounds, also in different places in the world" (Anonymous, Evaluating the Common Design Studio, 2022). And thirdly, it emphasised a "design as action" approach to online learning which over the last four iterations focused on specific themes, namely planetary health and the role of design. This became an important focus also in terms of scale and distribution of the project – the studio focused on global issues that impact at the local level.

The concept of the commons and commoning is key to the project. At a time of increasing uncertainty and climate urgency, when the role of design and its implications in the current context need to be carefully considered, working and acting collectively becomes even more important. Much of human-centred design "is founded on understandings of the human as a discrete, individual subject" (Forlano, 2017, p. 17), which often translates to instrumental design research projects that aim to solve localised and specific human-centred problems. In this context, the individual as consumer might have the power to choose, but not the power to resist or counter collectively (Forlano, 2017). Because of the complex socio-technical systems we are dealing with and the planetary challenges we face, this approach does not seem sufficient and our entanglements and "new relations to the natural world and to socio-technical systems are calling these previous understandings into question" (Forlano, 2017, p. 18).

Design education encourages creativity and imagination as core competencies in the designer's skill set. However, the glorification of imagination as a source of power, lashed to the destructive practices of industrial consumption, has made it a tool for exploitation. As the imagination activist Max Haiven (2014) states,

> The idea of creativity that emerges from the Enlightenment in Europe is an emblem to individualism, competition and egoism. In the neoliberal period, creativity has become big business, with the arts becoming ever more commodified and enclosed within corporate cultural empires. (p. 25)

Fostering imagination as a private or personal skill seems to disable the notion of the imaginary as a collective set of images and possibilities in which we envision our actions. It is in this context that a collective space in which most of these assumptions and ideas we take for granted can be altered. Haiven (2014) argues that "'imagination' is not a 'thing' that we, as individuals 'have.' It's a shared landscape or a common possibility that we share as communities" (p. 218). Transforming imagination from a private resource into a common space for action seems a pertinent project for our uncertain times.

In addition, the Common Design Studio itself models its practices and structure on the commons and commoning; it aims to be low cost, reproducible by anyone and open to all as a "cost-neutral model." As Nightingale (2011) notes when discussing design and the commons, "we need a conceptual framework that can better account for the emergent relationships between the human and nonhuman aspects of the commons" (p. 120). The CDS is an attempt to model such a framework and facilitate a space of common learning, experimentation and investigation into today's critical global questions.

With this in mind, the first intensive online collaborative studio took place in 2018, two years before the pandemic forced the issue of online working practices and online collaboration. The first two iterations were therefore novel in terms of online collaboration and prepared us well for the extraordinary conditions of the pandemic. The challenge for the Common Design Studio

> was to experiment with a model of online learning that actively enhanced the subject of design and the studio model from a subject perspective and provided added intellectual and creative value to academics and students instead of simply presenting an economic imperative. (Revell & Verhoeven, 2019, p. 407)

The model has taken into consideration the different time zones, institutional parameters around ideal times and integration into the curriculum, as well as synchronous and asynchronous working methods. To create a design studio atmosphere, the students were divided into smaller working groups, mixing students from the different institutions together. Meetings for briefings, presentations and lectures took place once a day for two hours on Zoom. In addition to these synchronous moments, we used a Discord server for asynchronous moments when the smaller groups worked remotely on the same project both together and over 24-hour time spans.

For each annual iteration of the Common Design Studio, we focus on collaborative working methods and group dynamics for the first few days. Especially in an online context with students who have never met face to face, we found that it is essential to concentrate initially on getting to know one another and building confidence in working with each other. Collaboration is identified as a key skill in a series of reports on the future of work (Störmer et al., 2014) and the CDS as a distributed studio makes this skill a focal point also.

Since 2021, in addition to working with and through design as action, we also purposefully decided to focus on themes that work at different scales, both planetary and local, and that can therefore be addressed in mixed design groups that work in a distributed way as well as a locally situated way. With this in mind, in 2021 we co-designed a brief on Ideas for Humanity: A Cookbook for Planetary Health and in 2022 we co-developed a brief on Radical Gardening in Urban Spaces: Designing For, With and Through our Environment.

These project briefs address non-trivial issues that connect staff and students in different parts of the world through a concern for planetary health and a desire for more than simple survival. Together, we explored documented risks to our interconnected ecologies; collectively, we wanted to offer more than preventative measures, instead looking to positive futures made possible through knowledge sharing and design as a means of action.

In the current and urgent context of the climate emergency, the role of design has come under renewed pressure to consider its responsibility in the making of the crisis. But rather than contributing to a form of eco-anxiety and resulting inactivity, we were keen to consider how design can start thinking and acting through and with multispecies entanglements. This follows Donna Haraway's (2016) journey from the Anthropocene to the Chtulucene to "make... for still possible pasts, presents and futures" and to move from ideas of surviving to thriving in the twenty-first century (Commission for the Human Future, 2020).

How

Planning

In the early stages of each iteration, planning included identifying additional institutional partners to work with. Next, we sought to discover an overlap between the partners' academic timetables in which to run the CDS, requiring time for dialogue and reflection.

A thematic focus was chosen, leading to a search for resources, readings and appropriate speakers who could address the students. These were mapped across the schedule along with academic staff availability to lead sessions and activities and provide prompts for the students.

At the beginning of each CDS iteration, students were organised into groups of six to eight, with representatives from each course of the partner institutions. In the iterations to date, the CDS student cohort has been between sixty and eighty individuals.

Timing

The CDS ran as an intensive experience over two weeks. Students would join a two-hour meeting every weekday for tasks, talks and discussion and engage in collaborative project exploration, planning and development. Students were also expected to contribute to their group projects asynchronously. The daily meetings established a cadence with urgency, and ideas, tasks and responses were reviewed daily.

Initial sessions endeavoured to create an environment of group cohesion, playfulness and creative confidence. It kicked off with an overview of the CDS and the brief, followed by staff and students introducing themselves using a rapid Pecha Kucha style presentation. There were a series of activities that highlighted the value of group collaboration, followed by rapid research on the theme as a group, leading to rapid brainstorming techniques. The initial group research briefing was framed to open up students' assumptions and expectations and used various exercises and prompts to encourage the groups towards an open-ended embodied investigation and non-instrumental ideation process. This allowed the groups to move towards identifying an area of focus for their proposal.

The following sessions required the groups to plan and prepare their proposal presentations, provide an early summary of their focus and continue work in progress with optional daily consultation. Meetings began with a brief conversation about the issues raised in consultation the previous day to help provide clarification and direction. The final session was a viewing of the group proposal videos with comments and feedback from students and staff.

Collaboration Platforms

We utilised a mixture of platforms to enable synchronous and asynchronous moments of working collaboratively. Zoom Meetings offered breakout rooms to manage participation in a timely manner at scale, allowing, at times, for dividing the cohort into four and providing rooms for the individual groups for collaborative tasks and development at other times.

The Miro platform was used as a collaborative whiteboard, collecting and organising resources and developing project assets and strategies. Miro boards were provided for groups as a persistent shared workspace that served to support exploration and development across disparate time zones for synchronous and asynchronous activities.

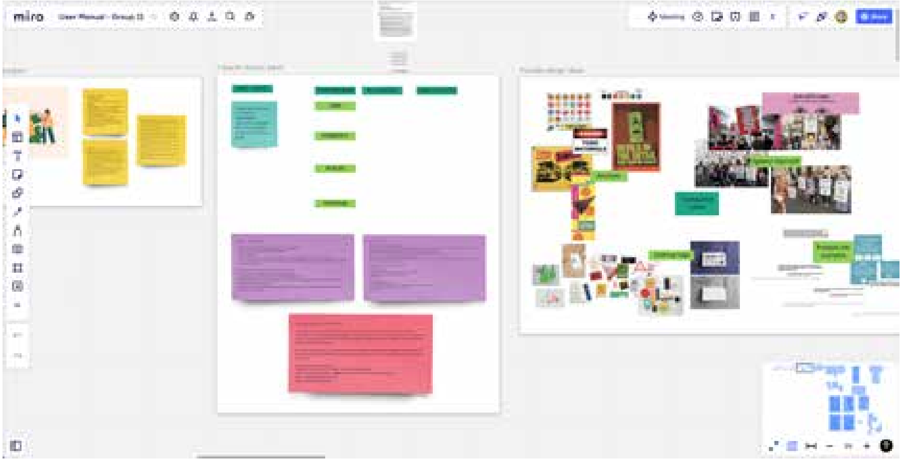

Figure 1. User manual – Group 11, 2021 – Miro board screenshot.

Discord was used to provide collective and group channels that had a threaded discussion model for collaborative engagement while also supporting text and video chat on a single server, enabling academic staff support and overview.

Case Studies

Here we discuss three examples of student recipes that exemplify some of the pedagogic goals and studio philosophy, as well as the tenacity and passion of our students.

Tag, You're It! – Activism, Intervention

This project is a call for accountability in the fashion industry. Students compared the movement to bring about social change in the awareness and use of single use plastics with a move to challenge the environmental, sustainable and ethical practices of the fashion industry. The titular "Tag" represents both clothing labels and social media hashtags.

The students stated "Tag, You're It" is a radical call to imagine a greener future where we work just as hard to protect the earth we inhabit. The project calls on consumers to initiate this monumental shift by first educating themselves and making more informed purchases, then creating a groundswell of pressure from the bottom up by going into retail stores and attaching to garments physical tags that feature personally curated messages speaking directly to fashion giants, urging them to take greater accountability for their actions and to pioneer the movement towards a more sustainable textile industry.

The project is a challenge for "people like us, awakening the everyday conscious activist," providing instructions for making tags to non-destructively attach information to garments in retail settings. The tags are in three shapes: triangles for sustainable material information, diamonds for a garment's carbon footprint and hexagonal shapes for labour issues. Accountability is pushed into the public forum by asking activists to post images of the tagged garments to social media, using hashtags to promote the movement and tag the manufacturer.

This group was thoroughly engaged with the exercises and provocations of the studio, collecting, sharing and documenting their development process using the whiteboard platform to effectively empower their collaboration.

The focus on informing people of issues in the fashion industry, providing a recipe for direct non-destructive action and publicising the issues through social media, is a comprehensive and potentially powerful proposal.

Figure 2. "Tag, You're It" – video screenshot.

FoodMiles – Local/Situation and Global/Distributed
The project "FoodMiles" reflects on differences in local areas and the opportunities and barriers specific to Australia, the UK and Spain. In their project, six students reconfigured existing recipes (of traditional food) within their individual local environments to offer local and seasonal options for grocery shopping and cooking. They addressed the issue of long-distance food transport, a feature of interconnected and globalised trade, from their situated perspectives in Barcelona, Melbourne and the UK. Each researched the commonly available seasonal produce and necessary groceries for their country or region and constructed flexible recipes with comparative food miles for using local versus imported ingredients. The group used the idea of cookbook recipes to introduce an educational component that helps empower people to make informed decisions. It is not uncommon for a traditional cookbook to be both a practical guide to meal construction as well as a representation of local culture and history. In this project, the group used their situated knowledge to share local food culture and draw attention to the contemporary nature of carbon-intensive food transport.

Pocket Gardens – Modifiable and Transferable
During the 2022 edition of the CDS, the students were challenged to address the urban landscape as a space for radical action. One group chose to address the lack of urban commons and green space through a recipe that encouraged creative acts of guerril-

la gardening. The “Pocket Gardens” recipe offered a provocation to create “pockets” by crocheting from scratch or cutting out pockets from unused garments. These would be filled with soil and plants that could flourish in the urban environment, and the “cook” would be encouraged to hang their pockets on city furniture such as bus stops, railings or signposts. The students’ investigation into their respective cities firstly uncovered a lot of enclosed, inaccessible or private green space. The impetus for them to create this recipe was driven by frustration and lack of ability to impact systemic issues such as urban planning or privatised green spaces. The recipe therefore was intended to mimic other transgressive urban activities such as graffiti and support those dispossessed of access to green space. The recipe itself was a good example of some simple, well-considered instructions that could be reproduced with ease and transposed onto any urban environment.

The three examples given here touch on the variety of group projects produced as part of the Common Design Studio – over the multiple iterations of the studio, there have been many more final presentations with wide-ranging focuses. In addition, although the students’ group project outcomes are a key outcome from the studio and give the CDS a public presence through exhibition and dissemination, they do not represent the totality of the experience nor fully communicate the educative benefits produced during the CDS experience. In some way, it is the experience of *being* in the studio that is the most important outcome. When students complete their degrees, they often find the CDS was a highlight of their education; meeting and working with a broad interdisciplinary group allows them to see themselves differently and gain insights into their own potential contributions as a practitioner on a global scale, beyond instrumental institutional contexts.

Outcomes and Pedagogical Reflection

The pedagogic outcomes for the students are primarily within the collaborative, international and interdisciplinary nature of the project. Working with creative practitioners and tutors from international design departments is intended to expand their view of design practice beyond narrow disciplinary boundaries, and rapid, remote and real-world scenarios were designed to reflect professional creative environments.

From 2021 onwards, the required deliverable for each group was a recipe that could be actioned (or “cooked”) by people in various locations and contexts. In the context of a design project, a recipe is a simple set of reproducible instructions to reach a specific goal, which in this case was related to the CDS theme. The recipes were then collected into a cookbook, which took the form of a website (commondesignstudio.net). This was created to contain, present and distribute the recipes, with each recipe consisting of a poster or “recipe card” giving the basic instructions and a video that demonstrates the use or reasoning for its creation. Each year, the completed recipes are shared online and have been exhibited as events of the Melbourne Design Week and the Barcelona Design Week (RMIT University, 2021).

The recipe and cookbook format were designed collaboratively by staff to address some practical issues related to online, project-based learning in previous iterations of the CDS. The staff tested the model of online distributed group projects in previous years with similar levels of cooperation between students but with substantially different outcome expectations. Previously, students were encouraged to respond to the brief with speculative concepts that could be performed or enacted in a video demonstration. However, designing artefacts and interactions and making high-fidelity prototypes across numerous remote locations was logistically challenging for students. We found that the desire to produce a functioning concept and a polished demonstration in a short timeframe often reduced the focus on how their designs would be used in their local environments.

Producing instructions in the form of a recipe was a useful contrast to previous iterations of the CDS. It is also different from traditional design deliverables and provides our students with various learning opportunities. Amongst them is the simple challenge that each recipe within the collective cookbook needs to be reproducible in numerous diverse contexts. This shift of perspective is intended to encourage designer-learners to think beyond the controllable interactions made possible through designed artefacts or experiences. It is often seen as the failure of design that an affordance or function is not intuited by its user; however, students are encouraged to embrace the ambiguity and possibility that the instructions hold. Also, in contrast to previous iterations that required demonstrable prototypes, asking students to produce instructions actively encourages a mindset of quick experimentation and iteration.

As design educators, we find that the process of designing and communicating recipes builds on many of the competencies that we consider vital to design education, such as the need to empathise with the specific groups who will "cook" a recipe. Each recipe needs to be designed for multiple locations, respond to local conditions or use local materials. Alongside the need for careful attention to individual circumstances was the careful consideration of the minutiae of recipe instructions. Before the recipe was created, the groups would collectively design "actions" that addressed the theme, which they would then test in their disparate locations. The actions would then need to be reverse-engineered into a set of discrete steps and communicated through text and image. Students are challenged to consider their outcomes being acted on in contexts they are not able to know and in ways they did not intend. This is, in fact, an exaggerated example of any design outcome, in which the perceived needs and desires of participants or users push against designer intentions. The allowable margin of ambiguity in a recipe is implicitly larger, and embraced as an opportunity when designing for use in diverse circumstances.

As mentioned, the CDS has addressed various sub-themes of planetary health. These types of complex problems are observable at a local (situated) level but often remain intangible and abstract at a global (distributed) level. The scale and complexity of the global systemic problems often leave students with an understandable feeling of powerlessness. To address this within our transnational collaboration, the students are asked to consider the thematic issues first by exploring manifestations in their respective environments and then sharing this local knowledge and experience. The cookbook format builds on this opportunity by encouraging individual and shared experiences to be addressed in a single recipe or set of actions. Therefore, an important requirement of each group's recipe is that it is designed to be "cooked" in more than one of the students' local conditions and is transferable to many others.

Conclusion

The recipe for the Common Design Studio is surprisingly simple, yet the conditions for its operation – its ingredients – are perhaps not so easily found in the contemporary tertiary education environment.

Partners

Firstly, one needs two or three, perhaps four, university-level programmes, cognate enough to communicate, with an orientation to project-based pedagogy and an openness to learning from others and engaging in collaborative group work remotely. In the case discussed here, the four collaborating programmes are quite diverse: firstly, a three-year bachelor's degree in Communication Design at RMIT in Melbourne, Australia. This programme extends from a traditional graphic design qualification in publication design, branding, packaging and illustration towards more contemporary understandings of expanded practice, incorporating newer practices such as service design, environmental graphics, strategic design, user-experience and interaction design. Secondly, another three-year undergraduate course in Interaction Design Arts offered by the London College of Communication, University of the Arts, London includes a programme which offers a multidisciplinary, practice-led, exploratory course examining the relationship between people and experiences through experimental technologies and processes. Thirdly, an undergraduate course offered by the London College of Communication, the BA (Hons) User Experience Design, is a practice-led and digitally focused course that explores the various dimensions of designing for user experience. Lastly, the BA in Design and MA in Ephemeral Architecture and Temporary Spaces programmes from ELISAVA, Barcelona focus on exploring the complexity of design through interactions between human beings and the built environment from a practical, ethical, social and technological approach. Thus, students and staff from different levels within university systems, undergraduate and postgraduate and different orientations and specialisations within the large field of design come together to create the Common Design Studio. The diversity of programmes may very well be an essential "ingredient" in that one of the key values and outcomes from the studio is the exchange and learning activated through diverse knowledge and practices – for staff and students.

Time

The studio has found that a two-week intensive "sprint" style studio provides an excellent space within which to establish trust, bring expertise, extend into the unknown and coalesce into final presentations. A fortnight can be found in a busy academic calendar, given flexibility and the willingness to compromise from all partners. While two weeks creates a demanding schedule for both students and staff, it is short enough to bring the zest of a sprint, while long enough to allow new relationships to form and authentic investigations to be undertaken. However, these two weeks are only the intensive studio itself; the lead time required is in the order of six months, incorporating six to ten one-hour team meetings as well as the associated research, planning, sourcing and thinking time to prepare to facilitate an authentic, engaging and extending experience.

Trust

The need for a high level of trust cannot be emphasised enough. Without trust – and a willingness to work together and risk the unknown – the studio does not exist. The Common Design Studio relies on an implicit spirit of innovation and generosity. The theme is carefully chosen and preparation for the studio is thorough, but the outcomes are unknown and need to remain so until the last day of the second week. The studio is open-ended and exploratory. At its best, all staff – as well as all students – are extended beyond their "'knowns" into unfamiliar ground, the studio itself being a collaborative site of multi-level inquiry, provocation and knowledge production. From a beginning design student to a published practitioner-researcher-academic, the studio provokes and extends. Exhibitions following studios offer some of this knowledge to the public realm but to a large extent, the experience of studio remains with those that took part and continues with them, beyond graduation, as their networks broaden through time and across the globe.

The Common Design Studio is a simple recipe, but it is not easy to achieve. All staff involved understand the extra effort required to successfully facilitate such an unusual offering. It goes above and beyond institutionally mandated rational formulas which calculate hours and staff and students and course fees (and which sometimes seem the core values of the educational businesses we operate within). Outcomes from the studio are experiential, social, educational and cultural, and necessarily remain unquantifiable. The studio's emphasis on authentic engagement with the unknown means student groups – despite facilitation and support – stand alone to succeed or fail; indeed, failure is sometimes the most productive, most educative outcome. Other, more prescriptive learning experiences can be designed to enable reliably high-quality outcomes, but these educational experiences generally have different aims: technical, skills-orientated and folio-building for known outcomes and known employments. Yet for design scholar Arturo Escobar (2017), "we are at a moment when many design schools are feeling the pressure to adapt to the mounting ecological and social challenges of today's world" (p. 153). The Common Design Studio attempts to meet these societal challenges through both its form and its theme, aiming to require authentic engagement with complexity in all its participants.

The next iteration for the Common Design Studio is, again, unknown; this ingredient is perhaps the most important one. What will the theme be? When will it run? Who will take part? What will be the outcome? We are unsure. What we do know is it requires *partners, time* and *trust* and a willingness to embrace the unknown. As with the best recipes, the whole is more than the sum of its parts, and the outcome hopefully surprises and delights all who partake. But you never know.

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A NOVEL APPROACH TO ESTIMATE DIETARY CARBON FOOTPRINT USING APPEARANCE-BASED ANALYSIS OF MEALS

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Abstract
Diet change is one successful climate change mitigation policy that people are curious about (Padgett et al., 2013; Mulrow et al., 2018). In this context, carbon calculators raise awareness of consumers' choice contributors to emissions. (Dreijerink et al., 2009; Barendregt et al., 2020). This research consisted of designing and implementing a prototype using the visual appearance of daily meals to estimate and track the user's carbon footprint.

To investigate how tracking and estimating a diet's carbon footprint affects the consumer's food choices, a diary study was conducted with 12 participants selected by their diet (vegan, vegetarian, and animal-based), aged 25-35 years. Participants were asked to record every single meal daily and calculate their meal's emissions by means of the "my emission calculator" and report it at the end of each day for one week. Analyzing the results of the diary study showed a reduction in CO2 emissions by 60% of participants over a week but this was not a steady or always-declining trend for all participants. Therefore, we conducted behavioral interviews to figure out if the reduction was due to carbon footprint data received by the calculator or not. During the behavioral interview, participants conveyed that by recognizing high carbon footprint dishes, they tried to reduce carbon footprint in other meals on other days. They also reported that although their information increased about the carbon footprint of every ingredient, it needed a lot of time and effort to enter all ingredients and calculate the emissions of their meal. The results of this study show the importance of designing a new system for tracking a diet's carbon footprint that is fast and user-friendly. This paper presents a hybrid method for estimating carbon footprints from users' daily diets, relying on appearance-based analysis of meals.

To discover the relationship between meal appearance and carbon footprint, 120 meal images whose carbon footprint was calculated based on their recipe were color-coded by two machine learning softwares – cssdrive and colorpalette. RGB colors extracted from the images were converted to 218 web colors with specific HEX color codes, and each color code was given a specific number for carbon footprint calculation. The eight dominant colors of each image were used as the basis for the calculation. Considering the type of diet (vegan, vegetarian, and animal-based) and type of meat (bovine, lamb and goat, pork, poultry, seafood), the comparative coefficient of greenhouse gasses was used to calculate the carbon footprint. The accuracy of this method was examined for 50 other dishes. The result showed that this method works for about 80% of dishes with mixed ingredients but does not work for single-color dishes. This visionary system paves the way for consumers to not only estimate their carbon footprint faster on a daily basis but also compare their daily emissions and try to decrease them over time.

Author Keywords
Carbon footprint; food diets; color-coding; carbon calculators; computer vision algorithm; data visualization.

Introduction

Few scientific papers study the potential contribution that lifestyle changes could make in tackling climate change (Koide et al., 2021). Eating habits for a sustainable lifestyle are a new but growing research field. Based on the research conducted by this study and results from Padgett et al. (2013), Mulrow et al. (2018), and Springmann et al. (2016), diet change is one successful climate change mitigation policy that people are curious about and can take action on. The studies about the impact of diet on one's carbon footprint address diets as a climate change mitigation strategy to reduce one's carbon footprint (Aston et al., 2012; Friel et al., 2009; Scarborough et al., 2012; Tilman & Clark, 2014).

One of the most recent approaches aimed at modifying eating habits is using carbon footprint calculators. "Carbon calculators" are seen as a powerful tool that allow individuals to map their lifestyle carbon emissions by providing data about lifestyle and living conditions (Anderson et al., 2020; Barendregt et al., 2020).

Carbon calculators have tried over time to take the information a step further than just the estimation of carbon footprint and applied strategies to promote lifestyle changes with smaller carbon footprints. Some examples are Wren, Bearing Points, Earth Hero, Deedster, Habits, and Eevie. In these calculators, calculations are based on questions about lifestyle and individual habits. All services apply data visualization to communicate with the users (Beranemark, 2021).

Although "carbon calculators" effectively raise awareness and increase knowledge about climate change, consumers find it difficult to use them because it takes a lot of time and effort to put every single ingredient into the calculator and then add the numbers to get the carbon footprint of just one meal. This is the main reason that consumers give up tracking and changing their diet. Another problem is that in these calculators, the carbon footprint is the climate change metric that people need to be looking at, but the numbers (i.e. a ton of carbon) are still a highly abstract concept that consumers find difficult to set a feeling toward to take action and modify their behavior. These problems show the importance of designing a fast and user-friendly system for tracking a diet's carbon footprint that visualizes abstract numbers in a playful way to motivate users to modify their food choices.

This paper aims to describe the methodological framework and design a hybrid algorithm for estimating and tracking the carbon footprint from users' daily diets by relying on the image recognition of meals. This algorithm's response to the above-mentioned problem lies in carbon footprint calculators: it allows users to calculate greenhouse gas (GHG) emissions of their meal in 30 seconds by taking a picture.

Besides providing end users with fast and correct estimates of their diet carbon footprints, this project has also applied findings from behavioral research in order to engage users beyond merely providing information and addresses the research question of "how to visualize carbon footprint to motivate dietary modification."

Methodology

Diary Study

To investigate how tracking and estimating a diet's carbon footprint affects the consumer's food choices, a diary study was conducted. This is a research method to collect qualitative data about user behaviors, activities, habits, and experiences over time (Courage et al., 2005).

The focus of this study is on diet among Swiss people because diet change is a potential target in high income countries like Switzerland. People in low-income countries lack diet diversity, and small amounts of meat and dairy can be an essential source of protein (Ernstoff et al., 2020). Moreover, the average Swiss diet is associated with 2.1 tons of $CO2e$ per person per year, while the Swiss federal government recommends 0.6 tons of $CO2e$/person/year.

Data was self-reported by 12 participants aging from 25-35 years with average, vegetarian, and vegan diets over one week. They were asked to keep taking photos of their daily meals and estimate the carbon footprint of their meals on a daily basis with a calculator called "myemissions" and report it at the end of each day. This calculator estimates users' dietary carbon footprint based on daily ingredient consumption.

Analyzing the result of the diary study showed a reduction in $CO2$ emissions by 60% of participants over a week. Reduction was 33% among participants with an average diet and 25% for those with a vegetarian diet, but this was not a steady or always-declining trend for all participants. The results also show that veganism is the diet with the lowest carbon footprint; it generated nearly one quarter less carbon footprint than the average and vegetarian diets. In contrast, average and vegetarian diets had fairly similar associated carbon footprints because the portion of meat intake was small and the amount of dairy, chocolate, and alcohol in the vegetarian diet compensated for the amount of meat consumed by other participants. The portion of high carbon ingredients plays an important role in the calculation. This result is also in contrast to the recent sociological research which introduced vegetarian and vegan diets as sustainable eating (Ernstoff et al., 2020). Most carbon footprint calculators are based on the question if the participants have vegan, vegetarian, or average diets. The result showed that this notion cannot be attributed to all people.

Semi-Structured Interview

To investigate the reason for reduction among participants with vegetarian and average diets, a semi-structured interview was conducted. The duration of the interview was 10 minutes. The result shows that using a carbon footprint calculator (myemissions) increased knowledge about sustainable food choices among participants so that they were curious to identify low carbon ingredients and reduce emissions day by day. However, 100% of participants reported that it is a long and tedious process to estimate the emission of ingredients for each meal. The calculation time varied from 12 to 17 minutes per meal.

75% of participants also conveyed that they had difficulty understanding how unsustainable their diet is by considering merely the size of the carbon footprint. This shows the numbers are so abstract that participants cannot build a relationship between the impact of food, carbon footprint, and climate change on specific diets. These results demonstrated the importance of designing a fast and user-friendly system for tracking dietary carbon footprints that visualize abstract numbers in a way that motivates people to modify their food choices.

Image Recognition Algorithm
Some studies have reported the effect of tracking eating habits by capturing meal images on behavioral change (Cordeiro et al., 2015). Others introduce taking photos for smartphone apps as a tool to promote healthy eating behaviors (Okumus & Bilgihan, 2014). Following this data, this study tried to use capturing meal images as a tool to track dietary carbon footprints. This section describes the design and structure of the image recognition algorithm and the theoretical factors considered in the carbon footprint calculation.

None of the carbon footprint calculators can give us accurate CO^2 emissions and the numbers provided by them are fair enough to make right decisions about the lifestyle (Berners-Lee, 2010). Considering this fact, at the next step of this study, it tried to find a relationship between color, type of food, and the carbon footprint of meals.

For this purpose, two machine learning softwares – cssdrive and colorpalette – were used to analyze and color code food images. Myemission was then used as a source for calculating CO^2 emissions for different dishes.

120 food images were color-coded. Eight dominant colors were extracted in every food image. Then, due to the wide variety of available colors in food images, each color represented a color spectrum and each color was given a specific amount of carbon footprint! The given numbers were examined in food images with the same dominant color by trial-and-error process.

To avoid complexity of colors, RGB colors were converted to 218 web colors with specific HEX color codes, and each color code was given a specific number for carbon footprint calculation. The eight dominant colors of each image were used as the basis for the calculation (see Figure 1).

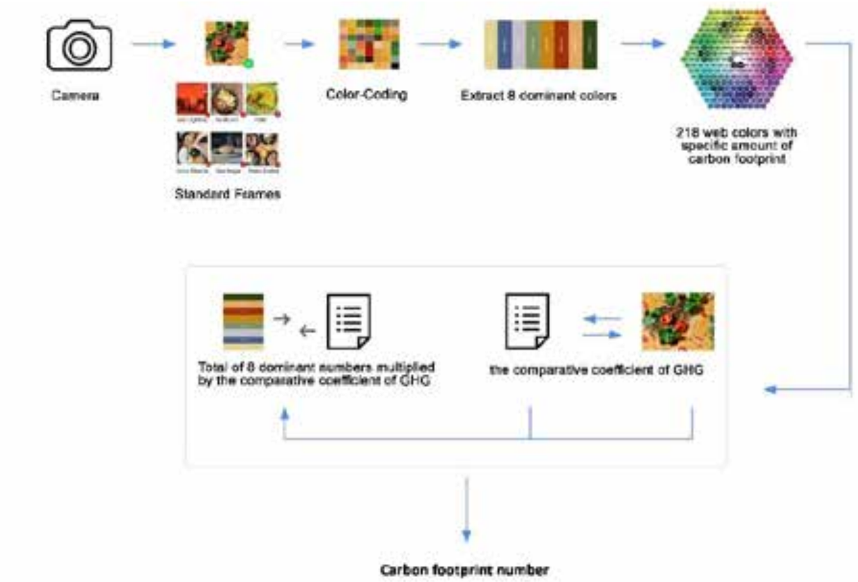

Figure 1. Calculation process based on appearance-based analysis of meals.

Considering the type of diet (vegan, vegetarian, and animal-based) and the comparative coefficient of GHG, a repetitive pattern was found which became the basis of calculations. So, the carbon footprint of each meal results from the total of eight dominant numbers multiplied by the comparative coefficient of GHG emissions (see Figure 2).

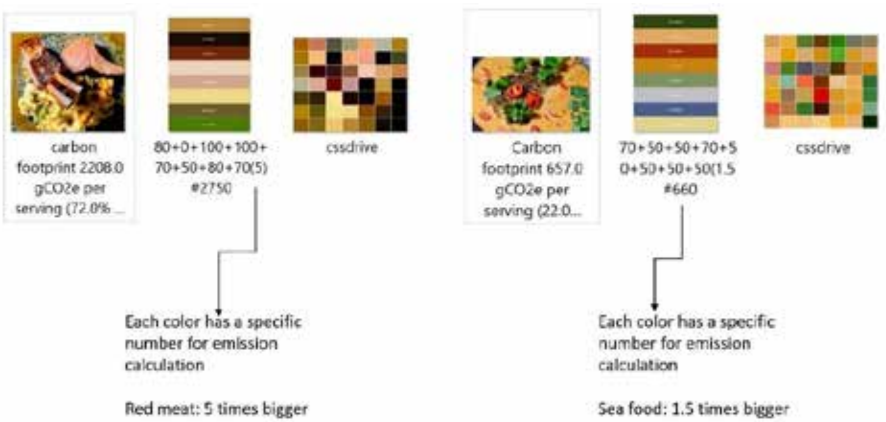

Figure 2. Estimation using a total of eight dominant numbers multiplied by the comparative coefficient of GHG.

The comparative coefficient of GHG created was based on two features:

- Classifying the coefficient of ingredients with high carbon footprints. The coefficient of ingredients produced during the process of calculating the carbon footprint is based on food colors and also the help of data from Scarborough et al. (2014). The data is based on GHG emissions for 94 food commodities, weighted for production in the UK, imports from the EU, and imports from outside the EU (see Table 1).
- Second, considering the portion of high-impact ingredients during calculation. As was proved during the diary study, the amount of high carbon ingredients like meat can change the result of calculation. So, the coefficient of GHG emissions changed due to the portion of high carbon ingredients.

Ingredients	coefficient of GHG
bovine meat	5.5
lamb	5
pork	2.5
seafood	1.5
poultry	2
egg	1.3
cheese	1.5
Other dairy	1.2
Papaya	1.5
Mango	1.3
blueberries	1.7
Asparagus	1.8
Tofu	1.7

Table 1. The comparative coefficient of GHG.

User Interface

This section describes the design and structure of the calculator. The calculator is structured in two sections: carbon footprint calculation and tracking emissions. As already mentioned, the calculation section estimates the carbon footprint based on an image recognition algorithm and two questions of eating pattern and portion of ingredients aimed at achieving the comparative coefficient of GHG emissions. The estimation takes 30 seconds. The amount of carbon footprint resulting from this calculation is the climate change metric that people need to be looking at (see Figure 3). But the numbers (for example, a ton of carbon) are still a highly abstract concept that people cannot set a feeling toward to take action and modify their behavior. Processing and transforming carbon footprint data into meaningful information increases its usefulness and subsequently deepens users' knowledge (Choi, 2012). Another goal of this study is to convert the amount of carbon footprint calculated by this algorithm into tangible and understandable concepts, resulting in an informed user and consequently, a more responsible citizen toward climate change.

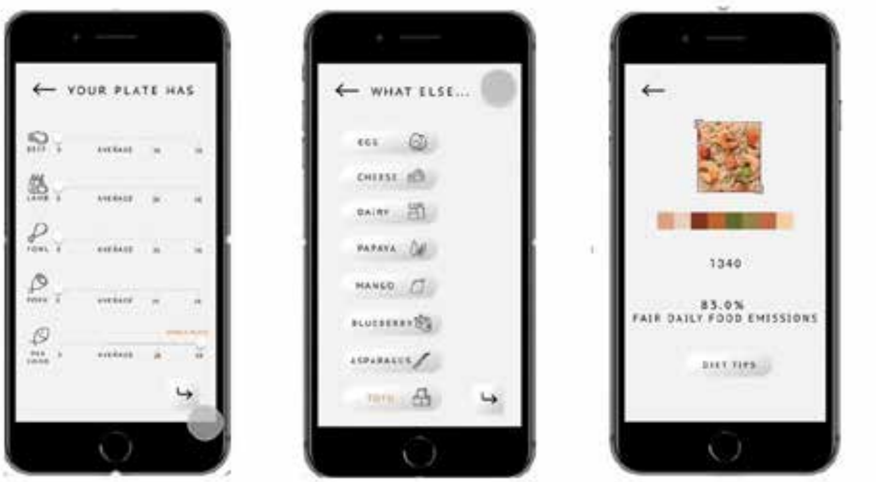

Figure 3. Questions of eating patterns and portion size of high carbon ingredients.

Visualize the Carbon Footprint to Motivate Dietary Modification

This section addresses the question of how to visualize the carbon footprint to motivate dietary modification. There are three phrases in this research question that should be taken into consideration: the decision-making process, data visualization, and behavioral change.

The goal is to use data visualization in the decision-making process as an accelerator for influencing behavioral change to become sustainable. Decision-making is a cognitive process that is classified into static and dynamic categories (Wang et al., 2004). Dietary decision-making is dynamic as it requires a series of decisions such as ingredients, preparation time, food preference, and financial status.

Looking at an overview of the dynamic decision model provided by Yingxu et al. in 2007, it can be seen that games are used to deal with the most complicated decision problems, which are dynamic and interactive. At the following stage, game-like elements can be used as a tool for carbon footprint visualization: “using game-like elements in non-game contexts is called gamification” (Lichtenberg et al., 2020).

Gamification as a Tool for Data Visualization

Gamification influences user behavior (Yang & Chen, 2017). Solutions to visualizing carbon footprints should be derived from gamification to lead to behavioral change. For this purpose, *behavioral change framework* was applied to show the role of gamification in the behavioral change process (see SUE Behavioral Design in the “Resources” section). Based on this framework, “under four conditions, people change their behavior, and their behavior changes to their habit” (Klöckner, 2013).

- The first condition in which a person changes their behavior is when she/he is "aware of the need" to take action.
- Under the second condition, the person needs to be "aware of the consequences" of a certain behavior.
- In the third condition, the person needs to "accept responsibility" for their actions.
- In the fourth condition, the person has to perceive themselves as "capable of helping."

Then, these four conditions were paired with "core drive of human motivation" in gamification to turn the abstract amount of carbon footprint – quantitative data – into qualitative information that motivates users to change their eating habits (see Figure 4).

Integrate Gamification into the Behavioral Change Framework
Ocatalysis framework is a gamification framework that introduces "8 Core Drives of Human Motivation" in gamification: meaning; accomplishment; empowerment; ownership; social influence; scarcity; unpredictability; and avoidance (Doherty et al. 2020).

According to this framework, any gamification process needs to specify a "set of human motivations" that efficiently guides the user experience (Toress et al., 2019). This is the only way to materialize the four aforementioned conditions that satisfy the process of behavioral change. All eight motivations and their techniques were studied and four motivations were chosen to pair with the four conditions of the behavioral framework: ownership, unpredictability, meaning, and accomplishment (Oliveira & Cruz, 2018). These four core drives pave the way to come up with a solution for how to visualize carbon footprint numbers that make users modify their eating habits. The behavioral framework was adopted due to gamification elements (see Figure 4).

Figure 4. Behavioral framework adopted to gamification elements.

The *awareness of need* parameter paired with the *ownership* motivation. In ownership, users take action because they feel like they own something. When users feel ownership, they want to meet the needs of what they own and make it better. Based on this definition, a *virtual plant* is introduced to the user. This virtual plant belongs to the user and is influenced by the user's diet.

Awareness of consequence paired with *unpredictability* motivation. This means that the virtual plant reflects positive or negative signs based on how high the carbon footprint number is. The effect of diet on this virtual pet is unpredictable; for example, if you have an unsustainable diet, your plant gets dry or shows other reflections. If you have a sustainable diet and the number is low, the virtual plant shows positive reflection. If users do not know what is going to happen during their next meal, their brain is engaged and they think about it, in this case, how bad the diet is as compared to the standard of the Swiss federal recommendation.

Accept responsibility paired with the *epic meaning* motivation comes into play when a story/narration gets involved in a way that makes users believe they are doing something greater than themselves. Suggesting low carbon food choices helps the progress of the virtual plant in the form of storytelling and challenges. *Capable of helping action* was paired with the *accomplishment* motivation. Accomplishment is the internal drive to make progress. The following food alternatives are visible so that the users can see the impact of their actions on the virtual plant.

Visualize Numbers of Carbon Footprint with a Virtual Plant

Ownership: Create a Virtual Avatar as a Plant

There are different ways of creating an avatar. In this project, two parameters were involved in the process of making a virtual plant:

- The user's preferences for plants and
- The user's eating habits.

In the first part of the visualization, users choose their favorite plant by choosing different features: pot, leaves, flowers, stem, and sepal. These features are given to users and they get their favorite plant based on their preference. The initial condition of the virtual plant is based on the user's current eating habits. The average Swiss diet (2 tons per person/per year) is taken as a criterion for the current condition of the user diet and so the virtual plant (Federal Office for the Environment, 2019).

Estimates of the closeness of the user's food emissions and the average diet are extracted from questions about eating patterns, e.g., vegan, vegetarian, omnivore/dairy consumption/type of drinks/etc. These questions help to sync the virtual plant to the user's current diet (see Figure 5).

Figure 5. Sync the virtual plant to the user's current diet.

Unpredictability: How Food Influences the Virtual Plant
After estimating user meals, the program records the carbon footprint number and reflects it through the virtual plant condition. Three significant metrics of plant growing – soil, moisture, and temperature – are synced into three main meals (breakfast/lunch/dinner). The program suggests plant reflection based on the aforementioned metrics on a daily basis (see Figure 6). The aim is to balance users' diets and reduce carbon footprint day by day. Comparison criteria are 5000 gr, the average amount of CO2 emission per day/per person among Swiss people (Federal Office for the Environment, 2019).

Epic Meaning: Accept Responsibility
The virtual plant reacts to the diet and then suggests food alternatives. Food choices offered by the program come from the color-coding algorithm and questions asked during the estimation (see Figure 3). Here, if the user replaces the shrimp with chicken and asparagus with spinach, she/he can reduce emissions. Initially, the algorithm suggests food alternatives with data derived from users. But it is expected that after one year, with access to big data from different food images and their carbon footprint, the algorithm will be able to predict emissions and ingredients and provide food choices without user intervention.

Accomplishment: Capable of Helping Action
The system records the dietary carbon footprint daily, weekly, and monthly. Based on this summary, following a sustainable diet over time influences the condition of the virtual plant for the better to show users are "capable of helping action[s]."

Discussion

In this paper, the results from the diary study and the semi-structured interview showed the potential role of carbon calculators in the estimation and reduction of participants' greenhouse gas emissions. However, the process of estimating and tracking carbon footprints was not a continuous process because calculators are so time-consuming and complex that participants were willing to stop using them after the diary study.

Furthermore, participants reported the incomprehensibility of carbon footprint numbers. Most carbon footprint calculators show users' emissions in the form of abstract numbers (a ton of carbon). None of them utilize a method that easily and visually maps out user-submitted behavior data, thus motivating individual carbon footprint reduction efforts. Following these findings, in this paper we specifically aimed to implement a hybrid method for estimating and tracking carbon footprints from users' daily diets by relying on the image recognition of meals and introducing a deeper understanding of the carbon footprint concept using the following research questions:

- How to implement a computer vision system to estimate users' dietary carbon footprint?
- How to visualize carbon footprint to motivate dietary modification?

In what follows, we discuss the answers to our research questions and present some limitations and opportunities for further research.

Our study showed that there is a meaningful relationship between the color of meals and their carbon footprint. This relationship can facilitate the carbon footprint calculation process. But to have a precise overview of greenhouse gas emissions, the calculation is not only based on the dominant colors of the meal but also on the comparative coefficient of GHG and eating patterns.

Considering these factors, we have presented a computer vision algorithm for tracking dietary carbon footprints. Users take photos of their meals and the carbon footprint of each meal results from the total of eight dominant numbers multiplied by the comparative coefficient of GHG. The level of accuracy of this system was examined for 50 dishes, and the result showed this estimation is as accurate as other calculators. The level of accuracy that is described by most calculators is not 100% accurate and it is good enough to make finely balanced decisions.

The novelty of this carbon calculator lies in the fact that it offers users the possibility to receive a precise and continuous overview of their greenhouse gas emissions through the image of their food. Nevertheless, the use of a computer vision algorithm can potentially lead to a faster estimation of users' GHG emissions (30 seconds), and also allows for continuous estimates.

In this system, data is constantly being collected to an increasing extent, and information visualization is essential to process this data (amount of carbon footprint) and make it understandable to users. The visualizations can be both static and interactive, but to understand complex data like carbon footprints and explore it more in-depth, the latter is preferable. So, in this study, data visualization was performed by using dynamic data visual representations to amplify cognition. To visualize dynamic data like the amount of carbon footprint, gamification was applied. The result of the calculation is not shown as numbers but as a virtual plant that is affected by the user's food choices. In other words, this virtual plant provides insights into the user's carbon footprint by communicating in a more intuitive way.

In this program, every user has a virtual plant that reflects their daily diet; if the user has an unsustainable diet, the plant gets dry or shows other reflections based on how unsustainable the food is. Then it offers alternative food options with smaller carbon footprints to fix the problem. This food suggestion does not ask the users to stop eating meat or avoid their favorite food, it suggests a balanced food alternative on a daily basis that motivates users to reduce their carbon footprint without depriving them of the food they enjoy.

This food suggestion system is based on the fact that all diets, including diets with restricted animal product consumption (vegan and vegetarian), still far exceed the limit of 0.6 tons of CO2 emissions per person, per year suggested by the federal office for the environment in Switzerland (Federal Office for the Environment, 2019). Only giving the notion of consuming less/zero meat is not helpful to mitigate CO2 emissions. This system offers food choices considering a sustainable and balanced diet. It helps consumers with a balanced diet take account of the environmental burden and know how food choices are presented to favor sustainable behavior.

Conclusion

Carbon calculators play an important role in engaging and involving citizen-consumers in the transition to a more sustainable society. The widespread use of calculators requires easy and practical steps of processing user information and converting this information into comprehensible data. Having an accessible process encourages users to learn more and take active measures to change their behavior.

Taking photos is an action that helps consumers keep track of what they eat. Based on this fact and considering the appearance of the meals, this paper describes how visual data like colors are paired with the comparative coefficient of GHG to provide a foundation for fast but reliable estimates of dietary carbon footprints. The idea of appearance-based analysis of meals suggests faster estimation of users’ GHG emissions (30 seconds), and also allows for continuous estimates.

The research phase of this study focused on behavioral science that shifts everyday choices towards more sustainable practices. This is a useful approach to make individual carbon emission output understandable and visualizes the effect of the dietary carbon footprint – and therefore climate change – on a virtual plant belonging to the users, ideally leading individuals to more responsible, environmentally beneficial behavior.

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Resources

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http://www.cssdrive.com/imagepalette/index.php
http://colorpalette.imageonline.co/
https://myemissions.green/

A SHIFT TO LIFE-CENTERED SYSTEMS THINKING: TEACHING MODULES TO DESIGN REGENERATIVE FUTURES

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Abstract
This paper critiques the use of design thinking (DT) to solve wicked problems (Rittel & Webber, 1973) and proposes life-centered systems thinking (LCST) as a better process to design for systemic positive impact. It presents a series of LCST modules that design educators can use to either start a prompt or act as a provocation to pause and pivot a project already in motion. This paper also details the strengths and weaknesses of each teaching module and how it was created, revised, and adapted based on student and instructor feedback in design courses at three different universities. The results are exciting and hold promise to increase designers' ability to design more climate and socially responsible outcomes.

Design is taught through a linear approach, with project prompts that historically focused on the intended visual outcome, leaving little room to investigate the root causes of an issue. Over the past two decades, DT has emerged from research done at Stanford University's Hasso Plattner Institute of Design to "...tackle society's most intractable problems" (McCarthy, 2022, p. 40). It adapted the design process (largely known only to design disciplines) into a formulaic, step-by-step, human-centered, solution-focused method that any profession can understand and implement to address simplistic to systemic problems.

However, as DT hopes to be more successful in solving systemic global issues, it still is a comparatively reductive toolkit that most often fails to meet the complex challenges at hand. It is unable to gaze beyond our anthropogenic perspective where "...the prevailing theories of design thinking in organizations remain entrenched in the making or *technē* paradigm. Ironically, this serves to maintain the status quo and stifle progress" (Lee, 2021, p. 497). Instead, a more holistic approach for adapting to our cultural shifts and growing climate crisis is to engage in LCST. LCST, as the authors see it, differentiates itself as a practice and mindset that is framework agnostic, discipline inclusive, nature-inspired, life-centered (not exclusively human-centered), and intersectional in its approach to problem framing. Like systems thinking (ST), it gives

> ... designers a powerful tool for circumnavigating the problems of the age. Focus on relationships over parts; recognize that systems exhibit self-organization and emergent behaviors; analyze the dynamic nature of systems to understand and influence the complex societal, technological, and economic ecosystem in which you and your organization operate. (Vassallo, 2017)

LCST is a fluid practice that does seek solutions but is problem focused.

It is also a mindset, a way of seeing the big picture and the details simultaneously by visualizing connections, causes and effects, and relationships between people, the planet, and their actions. In other words, LCST shows how everything is connected and that our natural systems depend on a dynamic non-equilibrium trying to achieve balance. Indigenous biologist Robin Wall Kimmerer (2015) builds upon this definition more poetically: "The breath of plants gives life to animals and the breath of animals gives life to plants. My breath is your breath, your breath is mine. It's the great poem of give and take, of reciprocity that animates the world" (p. 344).

Author Keywords
Life-centered; systems thinking; regenerative design; sustainable design; design education; design thinking.

Introduction
"Design schools now have the potential to play a second important role: that of agents of sustainable change: of critical and creative actors in the ongoing transition towards sustainability" – Ezio Manzini (2011, p. 11).

This paper analyzes the discourse around human-centered design thinking (DT) as a popular method of "problem-solving" and proposes a pivot toward life-centered systems thinking (LCST) as a process to design more ethical and just pathways of systemic change (Owens, 2019). It also includes an overview of the authors' ongoing pedagogical experimentation as case studies that attempt to find best practices and methods of integrating LCST into design education to build a better foundation from which designers can create more climate and socially responsible outcomes.

Historically, most design programs focus on skill and craft-based development that have a linear process in that they are aesthetically inclined, outcome-focused (Buchanan, 2001), and fail to embrace the fluid parameters between design disciplines (Meyer & Norman, 2020). In the view of Victor Papanek (2006), design schools "...teach too much design and not enough about the ecological, social, economic, and political environment in which design takes place" (p. 291). This is truer in undergraduate programs where students start to explore the kind of designer they want to become. Herein lies an opportunity to introduce young designers to the fourth order of design – design of environments and systems (Buchanan, 2001) – expanding their understanding of their potential as makers of the world and its accompanying responsibilities. This sentiment is echoed by Victor Margolin (2007) who states, "...faced with the growing complexity, designers have to think more profoundly about the future and their role in making it into the present" (p. 14).

Outside of design education, the place of design in socio-economic systems has shifted over the last decade, from being treated as a downstream step in business processes to a valuable competitive asset (Brown, 2020). Companies like frog design, IDEO, and McKinsey & Co. are betting on design to help innovate and transform business landscapes (frog design, 2017; Sheppard et al., 2021). This strategy resulted in the popularization of DT in business as a discipline "...that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (Brown, 2020). DT in this way democratized design (Gheerawo, 2018) and showed non-designers the value of designerly ways of knowing (Cross, 2001).

DT has since been developed by many individuals and organizations (Anderson, 2021) in a positive feedback loop of human-centered, solution-focused design within an innovation-hungry and profit-driven socio-economic system. DT has infiltrated the economic and educational landscape under a cloak of innovation, with multiple institutions claiming to be able to make designers out of businesspeople and innovators out of children. A quick search online will reveal a bouquet of learning options to choose from, run by reputable educational institutions like Harvard, Stanford, Cornell, and MIT, to purely online platforms like IDEO U, Coursera, edX, and Udemy. In the pursuit of implementing future-focused twenty-first century skills, DT has also found a place in primary and secondary schools across the globe in countries like Singapore (Commonwealth Secondary School, 2019), New Zealand (Swivel Careers; Te Kete Ipurangi), and India (Vincent, 2021).

For methodology and practice, DT has swapped out the deep and messy creative processes for a reductive one-size-fits-all method claiming instant innovation. "Real Design work is complex, chaotic and messy, Design Thinking is linear, simplistic and procedural" (Foster, 2022). Although this critique is shared by design theorists Kolko (2018), Vinsel (2017), Jen (99U, 2017), and Nussbaum (2011), DT made design more approachable and revealed its systemic potential (Nussbaum, 2011) to non-designers and designers tethered to the first and second orders of design (Buchanan, 2001). In this sense, DT has established a need for change, and opened a pathway to integrating systems thinking (ST) into the design practice – for which the authors of this article have much gratitude.

While important creative concepts are embedded in DT (Hokanson & Kenny, 2020), the authors critique the capacity of DT to solve crucial and urgent large-scale problems that are complex and inherently intersectional (Kaijser & Kronsell, 2013). Outside the boundaries of the business landscape and human experience, the DT framework fails to provide a way to deeply consider anything else because "design thinking is a solution-oriented endeavor, focused on neat, tidy endpoints" (Foster, 2022). It focuses on human metrics of success that are often limited to the economic and social well-being of a particular community (Brown, 2020), and falls short when a more holistic approach is needed that includes other interconnected beings and ecosystems (Owens, 2019).

In their more than 50 years of existence, HCD and DT failed to meet their claim to solve the world's most complex challenges. Considering the current state of our climate emergency – which calls for transformative change (Ripple et al., 2021) that crosses environmental, social, economic, and political boundaries – everyone, including designers, needs to play an active role in reshaping the future. This crisis requires a better systemic understanding of the world, divergent thinking, innovation, creativity, facilitation, humility, compassion, and tenacity in the face of uncertainty and rapid change. Designers and creatives nurture most of these capabilities through their education and practice, and we can leverage this to shift how we tackle complex problems.

The argument to invest in evolving DT methods of problem-solving is strong. Owens (2019) questions what it is to be "human" in HCD, stating,

> HCD that fails to take into consideration the ecological, socio-economical, and happiness costs of its production, distribution, and disposal is not truly human-centered. Design cannot be considered to truly have humans at its core if it ultimately further contributes to pollution, landfill mass, and exploitation of cheap labor.

Those at the helm of innovation and change would make more headway if they moved away from human-centered DT and developed practices that are more life-centered and systems-focused (Conway et al., 2017).

To cope with these increased demands being placed on design, many design academics have discussed the need for change in design education to develop skills that can engage with systemic challenges (Meyer & Norman, 2020). However, most designers in their formative years of design education are still unaware of design's systemic potential to solve wicked problems (Buchanan, 1992), and often never contemplate the same during their professional practice. Design consultants, collaborators, educators, and institutions need to start the slow but urgent task of building a ST practice in design.

Some claim that ST originates at the beginning of the 20th century, while others say it was just before World War II (Vikhornova, 2018). Systems thinking is one of many branches that stems from systems theory, the transdisciplinary study of interconnectedness and human-made or natural systems. Examples of branches and movements that evolved from it include living systems theory (Tracy, 1993), transition design (Irwin, 2015), and systems-oriented design (Sevaldson, 2013). Because interconnectedness is one of the core principles of systems work, it is vital to study systems and their practical application to solve large-scale complex problems (Sterman, 2002).

DT and LCST have some overlap in their theory and implementation. However, integrating LCST into design practice pushes the boundaries of HCD and grounds ST in concepts of intersectional environmentalism (Brown & Laird, 2022), regenerative design (Wahl, 2019), biomimicry (Fehler & Penick, 2019), and Indigenous knowledge (UNESCO, 2022). The below chart (Figure 1) compares facets of both, while acknowledging that it is a non-binary comparison.

Human-Centered Design Thinking	Life-Centered Systems Thinking
» Is a method and toolkit	» Is a practice and mindset
» Provides a structured framework	» Provides a fluid guide
» Seeks to simplify	» Embraces complexity
» Is used independently	» Is used integrating other disciplines
» Is focused on solution finding	» Is focused on problem framing/discovery
» Prioritizes certain humans	» Views all life as important
» Simplifies design for non-designers	» Enhances developed design practice
» Driven by socio-economics benefits	» Driven by intersectional environmentalism
» Upholds colonial structures	» Seeks to decolonize futures

Figure 1. Comparison of HCD and LCST.

Building LCST into design curricula can help enhance the innate problem-solving capabilities of designers while revealing our interdependencies. It can help designers better engage with large-scale complex issues and empower them to ethically engage with undiluted, real-world wicked problems and illuminate pathways of equitable action. The authors' ongoing experimentation to test this theory is discussed in the following sections of this paper.

Methodology

Project History

The idea to create LCST teaching modules for the designer emerged from the research of two of the authors – Benson and Fehler – in March of 2021. They presented their prior work in LCST as workshops at two different conferences. In both events, the authors' thesis was that LCST is the best way forward for humanity to design for the common good.

After both conferences, they collected feedback from workshop participants on their initial LCST toolkit and lectures. The general criticism was that their toolkit:

1. Was not holistic enough as it did not include enough global perspectives and input.
2 Needed to be separated into two audiences: the educator and practitioner.
3. Should be decolonized.

This feedback led Benson and Fehler to address the critique of their research. Responding to the first and third critique, they created a Systems Thinking Research Cluster that included a search for global scholars who could add additional perspectives, including that of Indigenous knowledge. The search ended in the addition of three new members. The first was one of the authors, Sequeira (based in India), and an Indigenous futurist (from Colombia). This search also included the addition of a graduate research assistant to include a student's voice that addresses the second critique of the prior systems thinking toolkit. The original toolkit presented at the two conferences as workshops was created for both design practitioners and educators. However, users found the toolkit to be mainly practitioner-focused and needed restructuring for use in the classroom. To aid in that process, an experienced student voice was necessary.

Research Framework

A project framework was co-created after multiple meetings and discussions amongst the research cluster (Appendix A). This framework helped determine that the LCST toolkit for design educators should take the form of a syllabus to match the intended audience's mode of working, with the aim of launching the pilot in a Fall 2021 classroom.

In the summer of 2021, the research cluster chose to explore the combination of Re-Nourish Systems Thinking (Benson & Perullo, 2019) and Visual Communication Design that Follows Nature's Laws (Fehler, 2020) for educators. This was transformed into a syllabus format that broke each section into lesson plans that included lectures, readings, exercises, and assignments that would guide both the design educator and student through learning ST and LCST. The initial syllabus was created as an eight-week course to be implemented at Benson's home institution.

The lessons learned from this first pilot using the revised LCST syllabus would be woven into an improved version to be taught in two different formats during the Spring of 2022 at Arizona State University (ASU) and University of Illinois at Urbana-Champaign (UIUC). At the end of each of these classes, student feedback was gathered to further revise the syllabus for broader dissemination into the design educator community. The final syllabus was designed for educators with limited knowledge of LCST, as that represents most global design educators, and designed to bring LCST practically and effectively into their classrooms with little effort.

Case Studies

Iteration One: UIUC

The LCST pilot syllabus was in an eight-week, two-credit graphic design course called *Design Inquiry,* taught in Fall 2021. The course was a vertical studio composed of juniors and seniors where learning occurs not just from the instructor but between grade levels. A typical *Design Inquiry* course has a maximum of twenty students, with the goal of an even split between juniors and seniors. In this section, the course in Fall 2021 had twenty students but an uneven share of juniors (sixteen) to seniors (four), and was taught online synchronously via Zoom twice a week in two-hour and forty-minute blocks.

Syllabus Structure for Iteration One

The Fall 2021 pilot LCST syllabus was created to match the eight-week timeline for this course. The overall goals for this pilot class were to test the effectiveness of the LCST syllabus based on students' retention of key concepts and their understanding of how to implement aspects of LCST in their process through end-of-course student evaluations and an online survey. The research cluster was also interested in learning how long design students ideally need to grasp these key LCST concepts and apply them pragmatically in the assigned projects. This information would be vital to test if the current syllabus worked well or needed to be adapted to aid student learning needs.

Assignments

The first two weeks were an introduction which included a lecture on key definitions and concepts, three mapping exercises, systems thinking readings and videos (with connected one-page writing reflections), and a discussion on eco-anxiety and how to cope and consequently thrive. The remaining six weeks were dedicated to creating a design intervention within the paper supply chain that could create a positive systemic impact on the triple bottom line – people, profit, and planet (Appendix B).

The first mapping exercise directed each student to sit in nature for ten minutes, pick natural artifact, and draw on paper how this object is connected to other elements within its system. The students were then placed in groups of four to combine their quick drawings into a larger connected system. The key takeaways Benson hoped the student designers would discover were that everything is connected; how to observe; and the definitions of a node, connection, and relationship within a system. These terms were further defined for them in a lecture and series of readings and videos assigned after the exercise.

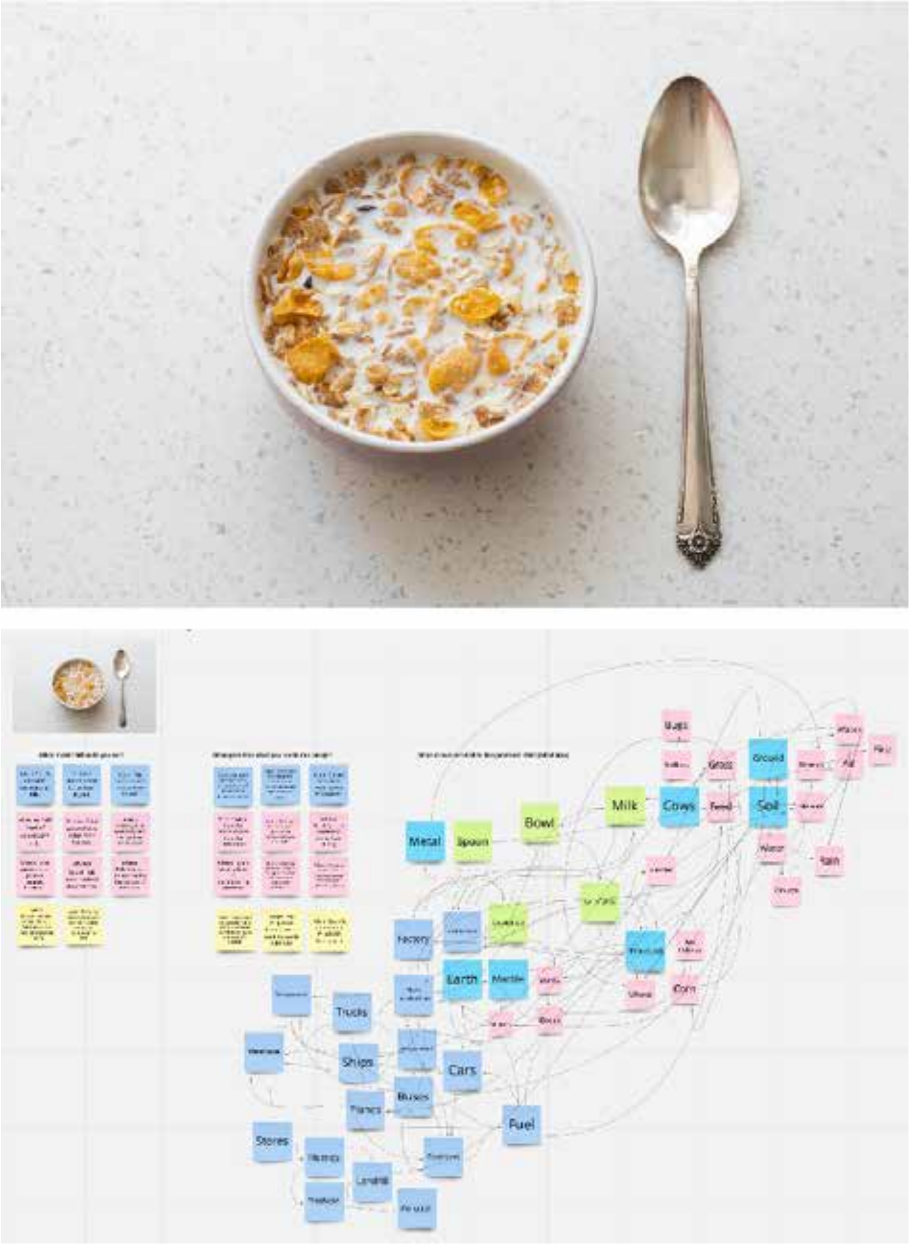

Figure 2. Image of a bowl of corn flakes used for the second mapping exercise in Systems Thinking syllabus iteration one (photo by enging akyurt on unsplash) and an example of a systems map created from mapping this image.

The second mapping exercise was in a small group format where students were given the image of a bowl of cereal in milk and a spoon sitting on a countertop (Figure 2). They were asked to spend a total of thirty minutes answering questions in three stages on a shared Miro board (Appendix C).

Students shared their answers within larger groups and combined their research and thoughts into a more holistic map in Miro. Each team was then asked to map the system of how a bowl of corn flakes made it to your home for breakfast (Figure 2) and to reflect on the process of how they came to that understanding for the following class period (Appendix C).

The goals for this second mapping exercise were to, again, help design students understand that everything is connected, realize that there are multiple elements, resources, and systems behind the simplest of things, and how the questions a person asks helps reveal hidden parts of systems.

The third and final mapping exercise led to the final six-week project. The students were randomly assigned to teams of four. Team members collaboratively worked online in Miro to map out how the paper industry works, who is involved, and what is affected along the way and at end-of-life for each element involved. They were asked to use different colors to identify connections, relationships, people, and impacts. Through this exercise, they would identify multiple leverage points within the complicated system to zoom into, re-map in more detail, and propose possible interventions. The student groups were also assigned to clean up this initial systems map into a designed poster for presentation and write a three to four paragraph reflection on the ST design process before beginning the solution-seeking phase of the project.

By the fifth week of this project, student teams presented three solutions to intervene in the paper manufacturing system. To evaluate and eventually choose a final path forward, Benson used the *Visual Communication Design that Follows Nature's Laws* worksheet (Fehler, 2020) as a guide for the teams to evaluate their potential solutions. This worksheet asks the designer a series of questions in three categories (functions and goals, transportation and manufacturing, and end-of-life design) about their project outcomes and awards more points for solutions that keep nature's systems top of mind. It also offers practical ideas to improve the idea if the scoring is low. This evaluation method was used by the students to choose the best path forward for the project, and amend any ideas that did not fully embrace life-centered design.

Reflective critique was utilized beyond the worksheet. Thought leaders in the discipline were invited to virtually attend both a work-in-process critique and a final critique to provide helpful comments to improve both the systems map and proposed solutions.

Class Outcomes

The final system maps created by the design teams were finessed and consolidated from the quick Miro board explorations into "well-designed" posters (Figure 3). In addition, the students were to create a zoomed-in map to show further details of connections, relationships, audiences, and impacts for their area of design intervention and, finally, a solution to the problem, determined by their research and mapping.

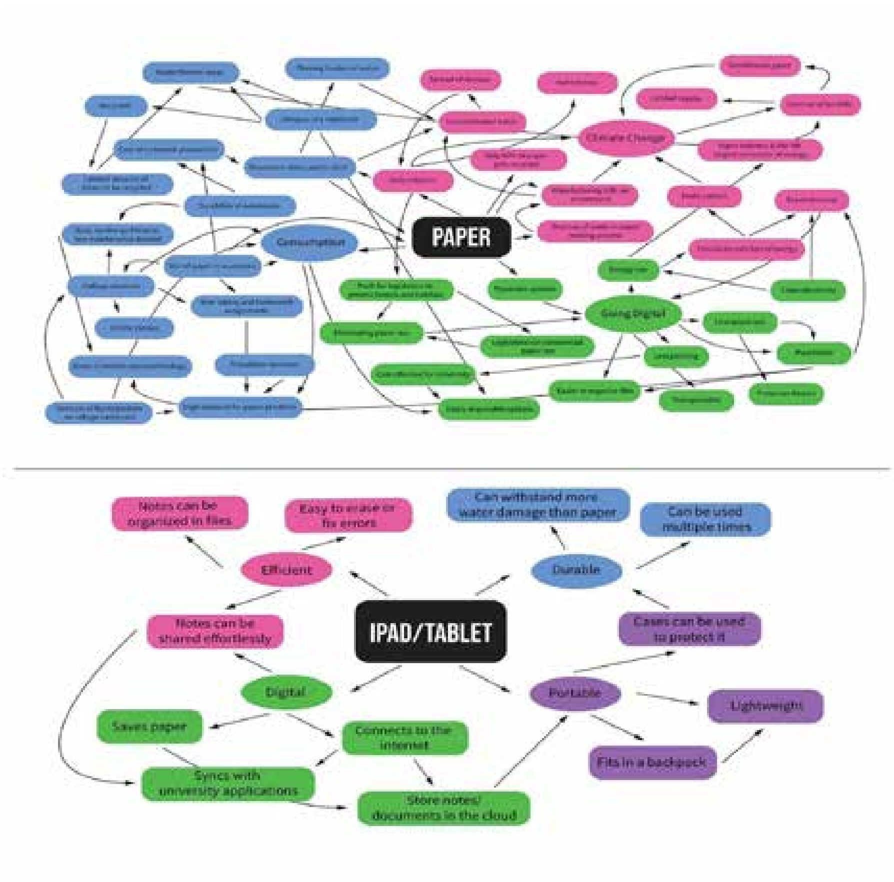

Figure 3. Example systems map and zoomed-in map from graphic design student team in Design Inquiry in Fall 2021.

The outcomes of these three main deliverables were largely underdeveloped by the students. The level of detail expected in the systems mapping was not realized, while solutions were mainly (66%) app-based. Students seemed to get stuck on using digital awareness solutions to tackle symptomatic issues the paper supply chain creates and avoided tackling more challenging root issues. This pitfall in their process likely existed due to the historical impacts of the linear-based, outcome-specific graphic design education still prevalent in the university curriculum, group-dynamic issues, and/or not investing enough time in the mapping portion of the assignment.

Lessons Learned from Iteration One

After the eight weeks, an online survey was disseminated to all students in the course asking them to evaluate how much they learned about LCST during the course and what could be improved upon in the next iteration. Of the twenty students, eleven filled out the survey. 72.7% of respondents felt they were now familiar with LCST principles, and 81.8%

felt they could use LCST to create innovative ideas as a designer in general. This was positive feedback in support of the organization of the syllabus. Furthermore, 45.5% of the students responded that using the *Visual Communication Design that Follows Nature's Laws* worksheet was helpful enough to use again in the future.

Qualitative data from the same online survey was collected from students on end-of-term evaluations, and from each member of the research cluster who attended the two critiques during the course. This data provided some valuable insights into improving the LCST syllabus in future iterations. It is important to note, however, that this class was only a graphic design course (not labeled as "LCST") and taught online synchronously during a difficult global pandemic. It is possible that any of those strains on the students could have altered the participation and outcomes adversely outside of any issues exclusively with the syllabus.

The qualitative data suggested that:

- More than two weeks were needed for LCST concepts and exercises.
- Providing finished LCST maps as examples would better guide the students through this new process.
- Visiting expert Zoom lectures was integral to a deeper understanding of the material; however, learning the material online was more challenging than in-person.
- Using a Miro board for mapping was less ideal than working on a whiteboard or large sheets of paper, face-to-face in a group.
- Breaking the syllabus into smaller modules on very niche topics could be used not only to start a project but as interventions to projects already underway. For instance, modules like Systems Mapping, Biomimicry, or Indigenous Knowledge could be included in existing design courses at any level, introducing parts of LCST quickly and effectively.

Iteration Two and Three: UIUC & ASU
Using the lessons learned from the eight-week pilot course in Fall 2021, the syllabus was rethought for Spring 2022. The new strategy was to use two sixteen week courses at two different universities and experiment with a longer mapping module that would kickstart a project in one course and help rethink an ongoing project in the other.

The course used to test the second iteration of the LCST syllabus at UIUC was *Sustainable Design Capstone.* It is a five-credit course for seniors in the Bachelor of Science of Sustainable Design (BSSD) degree that meets twice a week for three hours and forty minutes. The class was taught in person and had ten students who all transferred into the BSSD degree from different majors ranging from design-related degrees to the natural sciences. This meant that every student had a range of design competencies and skills. Before registering for the capstone, each student had passed a prerequisite where they developed a thesis proposal to be enacted in this course.

Syllabus Structure for Iteration Two: UIUC
Similar to the first iteration of the syllabus, the second included a lecture on key

definitions and concepts, three mapping exercises, systems thinking readings and videos (with connected one-page writing reflections), and a discussion on eco-anxiety and how to cope and consequently thrive. However, the syllabus was amended based on prior student feedback to include an exercise on causal loops (demonstrating the behavior of cause and effect of a system), finished systems mapping examples were provided to the students, and an extra three weeks were built into the module. Students came into the semester with a thesis project in mind, so the LCST module helped them rethink and better focus on more impactful solutions, using their maps as a guide.

Benson incorporated four visiting expert lecturers into the syllabus since students from the previous interaction found them helpful in understanding key concepts.

Class Outcomes from Iteration Two: UIUC

Figure 4. Image of a systems map on a whiteboard from a student design team in *Sustainable Design Capstone* in Spring 2022.

The outcomes from this LCST module were stronger than those seen in the course from Fall 2021. The students seemed to better grasp the reasoning behind LCST and why it was important to use in their design process. The BSSD students went into much greater detail on their maps and felt as if "they could go on forever" finding important connections and relationships in the system they were exploring.

The maps, as a result, were more detailed and impactful in helping the students think through and revise their initial thesis proposal (Figure 4). All the students refocused their thesis after the module finished. Typically, what began as a huge thesis transformed into one that was manageable, focused, and local, three parameters that can help the designer make a positive impact with their work.

Lessons Learned from Iteration Two: UIUC

The second version of the LCST syllabus expanded its introductory section from two to five weeks, and in-class feedback validated that this was a very effective decision. End of semester course reviews did not provide as robust of qualitative data as hoped, but these themes emerged from student conversations:

- During the initial mapping, worrying about color-coding different aspects of the system (people, connections, relationships, impacts) was overwhelming. Instead, it is best to add a second phase to the mapping exercise where those differentiations are noted.
- Using whiteboards in person is much easier and more effective to map a system than using an online tool like Miro.
- Teaching the students about causal loops was important to the overall success of their project outcome.
- Students who are already knowledgeable about the topic of sustainability are more invested in the concept of Life's Principles and the reasons to use LCST in their design process.
- When students are allowed to choose their project or theme, they are more invested in the entire process.
- The LCST module was an effective tool to intervene in existing design projects, allowing it to become more focused with greater systemic awareness and positive impact.

Iteration Three: ASU

This version of the LCST syllabus was taught by Fehler in Spring 2022. This sixteen-week course was called *Regenerative Graphic Design* and met for one hour and fifteen minutes twice a week in a hybrid model (one class in-person, one class asynchronous online). This was less face time than the other two course iterations at UIUC. The class had twenty-one students, mainly from the undergraduate Graphic Design program (fifteen). The remaining students were from marketing, architecture, digital culture, and biomimicry majors.

Syllabus Structure for Iteration Three: ASU

Since this class met for shorter blocks of time throughout the semester, the LCST module was only three weeks but had more asynchronous videos and readings embedded into the schedule. In this course, the LCST module was used by Fehler to instigate new ideas for the students' capstone projects, similar to iteration one by Benson.

Class Outcomes from Iteration Three: ASU

The comparison for this iteration is best made between it and the first case. Both were intended to start a new design project, with the major differences of an additional week and an exercise on causal loops. Nature journaling and mapping played an important role in the third and the first iteration. For the students, understanding of the key concepts of LCST was evident in the detailed systems maps, causal loops, and impactful and intelligent design solutions.

Feedback from the students enrolled in *Regenerative Graphic Design* came from qualitative data from written reflections assigned at the end of the semester. The essays demonstrated that the students saw how everything is connected, understood the basics of LCST, and were inspired by its capabilities to help designers approach complex problems by creating solutions that kept the planet top of mind.

Lessons Learned from Iteration Three: ASU
This version of the LCST syllabus expanded its introductory section from two to three weeks, allowing for more readings, videos, and discussions around the concepts. In-class feedback on this decision was very positive, providing additional support for the idea that increasing the time spent introducing LCST can have lasting benefits on knowledge retention. In addition, similar themes to the second case study emerged as lessons in the third iteration.

- Students who are already knowledgeable about the topic of sustainability are, in turn, more invested in the concept of life-centered design and the reasons to use LCST in their design process.
- Rotating students to iterate their maps helped to expand on their understanding of the system, providing richer maps.
- More frequent feedback loops for students on their causal loops also helped them gain more insight into how they can best be drawn and how they can inform design decisions.
- Using whiteboards in person is much easier and more effective to map a system than using an online tool like Miro.
- When students are allowed to choose their project or theme, they are more invested in the entire process.
- Teaching students about causal loops allowed students to understand relational impacts in a system, thus increasing the systemic quality of their project outcome.

Conclusions
The results of the three iterations of the LCST syllabi show its promise to help designers engage with large-scale complex issues and empower them with the tools and mindsets needed to ethically engage with undiluted wicked problems and illuminate pathways of equitable action. It is necessary, however, to disseminate another iteration for testing beyond the authors' institutions to the larger design education community for further feedback and refinement. This was the plan of the research cluster from its inception.

The following principles were derived from our learnings:

- An in-person group experience was the best method to learn and practice LCST in all three iterations of the syllabi.
- The mediums used to map and collaborate impacted both the intellectual process and creative output.
- Scaffolding each activity with clear examples and instructions helps novice systems designers enter complexity with more confidence and care.

- Voices from different disciplines help fill knowledge gaps and increase design confidence.
- A solid understanding of non-linear relations in systems by creating causal loops is key to unpacking cause and effects in systems.
- Ongoing reflections and critique individually, between peers, and from outsiders, help illuminate different perspectives and realities embedded in the system.

What would be ideal for students is the addition of more digestible ST courses in a design curriculum without a large solutions component built into the course. This would allow a more focused effort into the concepts and methods within LCST, leaving later courses to apply this process to design interventions. A curriculum overhaul is time-consuming and steeped in bureaucracy, making this conclusion an ideal but unlikely scenario soon.

This creates questions to address in future research for quicker and broader implementation of LCST in design education. Can the syllabus be reinvented into focused modules as an effective 90-minute workshop for higher-level design students? Or can the material be delivered asynchronously weeks before a class begins to prime learning for the exercises to be done in class synchronously? Fehler attempted both in a workshop in Spring 2022 for upper-level design students at the California College of Arts who needed intervention in their current sustainable design project. Feedback from this experiment was positive, leading the authors to believe quicker workshops can be done in the right situations.

Overall, teaching LCST is a challenge even for a design educator experienced in and passionate about the topic. The practice and mindsets of LCST help evolve the current tools and methods of linear HCD that students and educators already have. It also challenges students to break conventions and boundaries, embrace complexity over simplicity, accept the possible absence of a designed resolution, and be reflective about how their work impacts all life. All this requires a personal and internally driven will to put in the labor needed for systems change.

LCST or any ST-oriented practice requires an investment of additional time and energy to question how designers can better understand and actively participate in the world. However, despite the challenges, LCST is vital for designers to compassionately comprehend our interconnected world. It is a catalyst to unfold the possibilities of new ideas, missed opportunities, and the path to design more climate and socially responsible outcomes. With more experience in LCST processes, designers can avoid shallow innovations typical of DT (as seen in the first syllabus iteration where 66% of the class proposed mobile applications) which are reductive technocentric solutions to systemic problems. Design should not be reductive, formulaic, and only profit-driven but rather non-linear, contextual, and ethically transformative. LCST is a crucial practice and mindset that enables novice and experienced designers to understand the complexity and connections within a set of problems and empowers them to leverage their unique skills to design just, ethical solutions that can improve all life on earth.

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Appendices

Appendix A

Project Framework for the Systems Thinking Research Cluster:

1. Decide on group dynamics, organization, and deadlines.
2 Discuss the baseline structure on which to build an educator toolkit.
3. Create an educator toolkit to test either in a classroom or professional studio.
4. Test the effectiveness of the educator toolkit through student feedback.
5. Revise the toolkit.
6. Re-test the effectiveness of the toolkit through student feedback.
7. Revise and design the toolkit for educator use.
8. Disseminate to design educators.

Appendix B

The first iteration of the syllabus followed the Re-nourish Systems Thinking Toolkit structure and was organized as such:

Week 1: Regenerating Our Practice – Introductions, Definitions, and Exercises
Week 2: Setting Goals and Mapping Exercises
Week 3: Map Out the Problem
Week 4: Brainstorm Ideas
Week 5: Evaluate Ideas and Design
Week 6: Present Prototypes and Refine
Week 7: Refine Ideas
Week 8: Present Final Ideas

Appendix C

These were the first set of reflection questions asked during the corn flakes system exercise, where the students had 30 minutes to answer:

1. What is this? What do you see?
2. What goes into what you see in this image?
3. What all was needed to design/create this?

These were the second set of reflection questions asked after the corn flakes system exercise:

1. What was easy and what was hard about this exercise?
2. How can we visualize connected elements to better understand their relationships?
3. Where/when do we stop making connections?
4. In your opinion, how would knowing how things are connected impact your work as a designer?

ADAPTIVE DESIGN EDUCATION STRATEGIES FOR EQUITABLE ACCESS

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Abstract
This professional paper reflexively narrates specific adaptive design education strategies deployed in a design studies course at a large public research university in the United States. *Design & Identity in Everyday Life* is a high-enrollment, hybrid-format humanities course introducing first-year non-majors to design. Multiple rapidly shifting contexts impacted the need for pedagogical adaptation during the first two semesters the course was offered. These included the seismic impact of Black Lives Matter, the global COVID-19 pandemic, the escalating consequences of climate change, and the structural inequity driving the relative impact of these factors across diverse communities. In this case study, three design educators address how their positionality impacts their quest to co-design – with each other and with students – a design education experience that is adaptive and equitable during crisis. The narrators are: (1) a Queer-identifying student, then in their first semester of graduate school; (2) an Iranian student, then an experienced teacher's assistant in the final year of her MFA program; and (3) an invisibly disabled female assistant professor with significant design teaching experience. This case study deploys a dialogic narrative approach to unpacking the course design framework, one that blends emancipatory research and co-design methodologies with more traditional pedagogical models as required by course-specific university guidelines.

Author Keywords
Access; co-design; equity; pedagogy; positionality.

Context
The college course *Design & Identity in Everyday Life* asks students to consider how design works as a tool for shaping, understanding, and communicating identity – "the fact of being who or what a person is" – in everyday life. Designed environments, objects, and interfaces allow us to shape the parameters of how we see ourselves and others, organize how we navigate public spaces and digital environments, impact the way we understand everything from political alignments to brand preferences, and position us within local communities and global commodities marketplaces. The course argues that since specific places, times, and cultures influence how humans conceptualize and operationalize design, knowledge of these contexts allows us to recognize our own position(s) as

particular rather than universal. Using a global range of artifacts as case studies, participants interrogate issues related to the form, function, and philosophy of everyday designs to become more informed, empowered makers and users of design.

This course is a high-enrollment, hybrid course at a large public research institution in a politically conservative state in the United States. Filling a general education humanities requirement for first-year students, the three-credit course is open to any major and has no prerequisites. In Spring 2021, 75 online students enrolled. Students met for one synchronous instructional hour on Zoom; three sections of 25 students met at three different times. The remainder of the interaction was asynchronous. This modality was a direct result of COVID-19, not a feature of the course as initially proposed the year before. In Fall 2021, the course enrolled 155 students in six sections. Though the university had returned to face-to-face instruction and many students chose this modality, there was an optional Zoom section at each of the three synchronous class times. Each week, students could choose to attend their assigned face-to-face classroom or the simultaneous Zoom class. Synchronous interaction centered collaborative design thinking and/or making activities in both environments. Asynchronous course material each week included reading, viewing, and listening assignments; a content-based quiz; and a short, image-based, critical writing assignment.

The course has multiple student learning outcomes in the humanities broadly and design studies explicitly. Put simply, students expand their understanding of how humans make and use design, constructing a mental model of design which can support global, inclusive, participatory identities. Students notice and analyze how design plays a role in constructing intersectional individual identities, particularly their own. The intersectional lenses most prominently included in assigned content are class, race, ethnicity, nationality, gender, (dis)ability, and political and religious affiliation. Students also identify and evaluate how issues connected to form, function, and philosophy play a role in the design process as it shapes collective socio-cultural and political identities. Students demonstrate these emergent capacities through critical writing and applied design activities.

Students focus on contextualizing their own positionality in the course, but this narrative paper centers the positionality of the facilitating design educators. Educators' positionality impacts how – and even if – adaptive strategies are considered, introduced, and sustained within classroom communities. For example, studies examining how educators transitioned to emergency remote teaching during COVID-19 offer quantitative insight regarding how educators' positionality impacts their pedagogical strategies (Karakaya, 2021; Peimani & Kamalipour, 2021). Likewise, studies demonstrate the inequitable impact of students' and teachers' race on instructional outcomes, particularly, but not only, when course content engages issues of race (Weir, 2016; Kohli & Pizarro, 2022). Thus, we find it probable that our positionalities as instructors impact course design strategies and adaptive pedagogical responses during crisis.

While change poses challenges, "it also provides opportunities to critically consider new strategies and re-evaluate how pedagogies might" evolve (Henriksen et al., 2020, p. 206). As spring semester 2021 began, our shared spaces were undergoing significant change in response to multiple crises. George Floyd, then the most immediately recognizable Black victim of police violence in the U.S., had been murdered on May 25, 2020; Derek

Chauvin's trial would begin March 2021. The global COVID-19 pandemic was entering its second year, and vaccines were not yet widely available. As coast-adjacent residents, we knew that 2020 had been the most active hurricane season in recorded history; 2021 would become the third most active. On January 6, during the first week of our institution's semester, supporters of then-President Trump staged an insurrection in Washington, D.C., attempting to overturn the results of the 2020 presidential election. By fall of 2021, though President Biden had assumed office and sped up vaccine distribution, none of these complex problems were resolved. Multiple ongoing crises, then, impacted both semesters of *Design & Identity*. Our pedagogical goals, beyond meeting the course's student learning objectives, centered on the facilitation of an equitable and positive design learning environment for all students, regardless of differences in individual circumstances and needs; we strove for an ethic of care (Persky, 2021; Hutchison, 2021).

Methodological Framework

As designers, we – like teacher educators Baran and AlZoubi (2020) – turned to "human-centered design to address [students'] immediate needs, engage them in empathetic and human-oriented activities, and build a supportive online learning community." Like emancipatory researchers Hutton and Heath (2020), we sought ways to "minimise the binaries between knowledge and action" within our particular zones of praxis (p. 2698). Following narrative researchers O'Grady et al. (2018), we are now sharing our experiences in a public-facing research context because "narrative methods enable silenced knowledge to be articulated" (p. 153). Sometimes called "critical autoethnographic narrative" (Yazan, 2018), reflexive first-person accounts hold the potential to "deconstruct the dominant discourses" within a discipline or field, shifting pedagogical praxis. As educators with individual identities – spanning Queer, disabled, Black, Indigenous, and people of color (BIPOC), feminist, and language-diverse communities – we find that multiple aspects of our own identities frequently undergo silencing in academic contexts. We suggest that first steps toward adaptive, equitable design pedagogies might include making room to hear multiple, complex, and sometimes conflicting accounts of previously un- or under-examined educational contexts.

Emancipatory research models prioritize collaborative, reflexive, intersectional action centered on community priorities; focus on interactions between people and their environments; contribute to a strong evidence base; and are evaluated by participants (McColl et al., 2013, p. 71-75). *Design & Identity* engages many of these principles. The course asks students to collaborate among themselves and with teachers, turn a critical gaze toward their own beliefs and actions, and situate their analysis of design within a hyper-local classroom community and the broader communities to which they belong. All assigned content and collaborative activities take an intersectional approach, focusing explicitly on how people – with their intersectional identities – interact with designed environments at many scales. Throughout the course, participants offer continual feedback through a variety of mechanisms, including an explicit process of beta testing the course experience. Within emancipatory research, desired outcomes tend to promote four broad tenants: agency, dialog, inclusion, and rationality – the latter contextualized as freedom to interrogate and evaluate information, environments, and/or systems through dialogs "facilitating creative expression, truth exposure, the surfacing of diverse perspectives, democratization, and sincere inputs" (Young et al., 2021, p. 6364). *Design & Identity* facilitates students' agency through assignment choice, fosters open dialog in every course interaction, includes all voices (which do not harm others), and surfaces diverse perspectives. Most importantly, the course centers "the process of individuals sharing their insights and learning from others' insights," which the Learning Collaborative (McColl et al., 2013, p. 2) offers as the very definition of emancipation.

Narrating Our Critically Reflexive Praxis

Narrator 1: Brooke Hull (she/they)

Adapting to New Mental Models of Design Alongside Students

When I began teaching *Design & Identity in Everyday Life*, I had just received my BFA in Graphic Design and was beginning my first semester working toward my MFA. I pursued an MFA so I could teach, but also because I yearned for more from design. My BFA followed an American Modernist reading of the Bauhaus model, and some instructors discouraged classroom engagement with socio-political issues. I knew design could be more than technical skills, I just didn't know how to get there.

Within my first few weeks of graduate school, I was exposed to the inequities present within design and the crisis that has come from teaching design from a white, male perspective. I uncovered how my positionality relates to design and acknowledged the importance of recognizing and centering voices from socially created "margins" (hooks, 2000; Escobar, 2017). Teaching *Design & Identity* furthered these lessons as I learned alongside my students. Reflecting on working with the over 155 students in the course has allowed me to unpack how my positionality and identity as an educator both affected and was affected by my students through our dialogic interactions, primarily through their critical writing.

My favorite example of a student's positionality informing my own came from a student who wrote about the use of pins to subtly represent, or code, Queer identity in our shared space. As a Queer person myself, I was surprised and excited to learn this code existed in our space. Later in the course, we designed pins with students, and I now wear my students' designs on my bag, both to participate in this queer code and to actively remember the joy of learning from my students (Figure 1).

Figure 1. The author's backpack and a detail of 3 pins designed by students.

Teaching this course underscored for me the importance of recognizing and actively listening to different voices and identities in our work as designers and educators, something that has become key to my own design work and research. Discussing socio-political issues is inherently a wicked problem, so adapting to and valuing discomfort is key (Buchanan, 1992). Actively listening to our students and creating reciprocal, dialogic spaces allowed this course to sit in that discomfort and recognize our students' ways of doing and being. Through these dialogic spaces, we can co-create new knowledges and encourage learning from those who are often decentered in pedagogical spaces. This allows for shifts in positionality, our own and our students', toward more pluriversal, multivocal ways of doing and being – in, and beyond, the classroom.

Narrator 2: Samira ShiriDevich (she/her)
Adapting Design Practice Models to Design Studies Teaching Models
I came to the U.S. as an experienced agency-based graphic designer and entrepreneur from a vertical design world. I designed *for* my clients *from* my studio, and I imagined what users needed. There was always a boss/client who accepted or rejected my designs, ultimately defining good design. Education and work in Iran trained me to keep the same approach in my teaching, where I was the boss/teacher and my students designed for imaginary clients and good grades.

I came to the U.S. to study in a program focused on design for equity, hoping to find my own freedom and use design to help others regain theirs. It was not an easy transition from Iranian collective culture to American culture. The biggest challenge was adapting to a new approach to design, one cognizant of my context and positionality. My design research framed how I approached *Design & Identity*. By the time the class began, I'd completed projects on Iran's design history, a visual essay semiotically analyzing global freedom posters, and a reciprocal map-based system to make accessible guidance, resources, and information about pursuing freedom.

Soon after, I collaborated with Project YouthBuild (PYB) with two peers, students from Argentina and Jordan. PYB is a degree completion and jobs training program for students who have been forced out of high school. Our goal was to co-design a social media campaign for PYB to increase their visibility. We used a horizontal human-centered approach emphasizing community-engaged design with people as they contributed their own expertise. In every project, I centered trust, collaboration, storytelling, and sharing.

In Spring 2021, as a teaching assistant in *Design & Identity*, I graded students' weekly blogs and participated in weekly class sessions. I met students briefly on Zoom but by reading their blogs, I learned about their lives. They were a diverse group with different majors, nationalities, beliefs, and religions (Figure 2). In Fall 2021, as an instructor, I was responsible for teaching three face-to-face sections, a very different experience. I worked with students who were Arab, Jewish, atheist, non-binary, first-generation college students, and second-generation immigrants. My positionality led me to prioritize making a safe space for all the students to share their thoughts and experiences in everyday life. I did this by sharing my stories and vulnerabilities with them. Each week's photo blogging posts also allowed me to encourage students to share more of their experiences. One non-binary individual was interested in Queer topics, so I encouraged them to share more about their profound passion in our class.

Figure 2. Students used open-access avatar generators to create self-portraits representative of their diversity.

Teaching *Design & Identity* had some uncomfortable moments for me. As a woman from the Middle East, I read many stereotypes about our lives in my students' blogs. Some of them were offensive. In these cases, my approach was to share resources, like my experiences living in those countries, and historical perspectives, such as my grandma's stories. Teaching showed me how different we are and how these differences can help us grow – if we facilitate a space where people feel safe to share. It is interesting how many different voices exist in one place, and encouraging these voices to be heard can create new sources of knowledge and ideas. Teaching *Design & Identity* showed me how we could use design to discover those sources and help everyday people use them to communicate and make change.

Narrator 3: Dori Griffin (she/her)
Leveraging Personal Adaptations to Facilitate Adaptive Structural Change
I'm a teacher with invisible disabilities, which I never felt empowered to articulate publicly as a student or junior faculty member. Rather, like many people with disabilities, I devised my own informal, invisible accommodations. Like about 3.5% of the adult population in

the U.S., I'm immunocompromised, and my immune disorder comes (as do most) with multiple secondary diagnoses. COVID-19 offered me a stark personal choice between the dangers of silence and speaking. Many of my prior adaptive pedagogical decisions in pursuit of equity were comparatively easy, such as abandoning high-stakes classroom testing because it's racially inequitable or accommodating students whose disabilities haven't been "approved" by the university's Americans with Disabilities Act (ADA) office. Choosing to speak publicly within the academy as a person with disabilities wasn't easy at all, but as I observed many peers' refusal to adapt their pedagogies and policies to COVID-19, it felt necessary (Figure 3). Intentionally, and with a focus on pursuing equity, I have leveraged my positionality to make *Design & Identity* adaptive. Here, I'll offer three concrete examples.

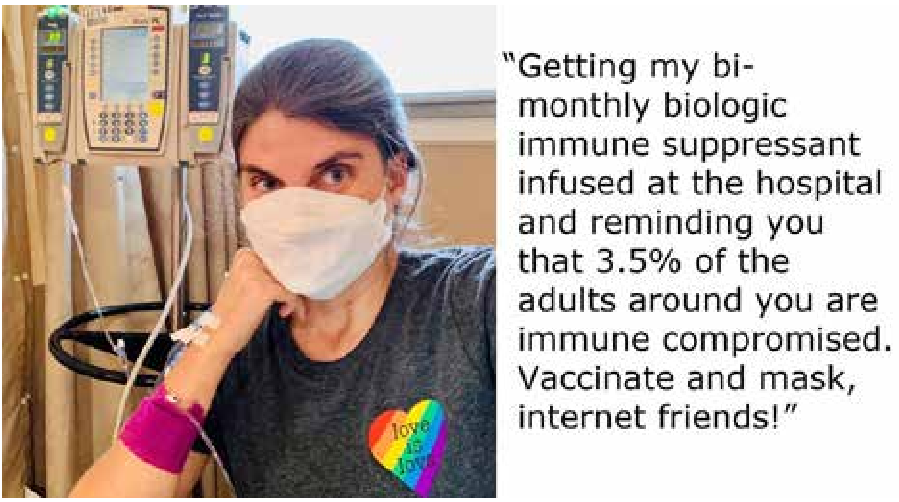

Figure 3. The author shared her disability status on public-facing social media, including @dr_dori on Instagram.

Firstly, as a university instructor, I couldn't choose between holding classes face-to-face or on Zoom – only cancer patients undergoing chemotherapy and solid organ transplant patients qualified for COVID-related ADA instructional accommodation at our institution. When we returned to in-person learning, *Design & Identity* students chose between face-to-face and Zoom attendance individually, weekly, and at their own discretion. The university didn't support the mechanisms our teaching team deployed to make this happen, turning equitable student access into an option for instructors and leaving the burden of significant additional work with us.

Secondly, because access to technology varies significantly across class, which is in turn often inequitably race-based, our Zoom attendees weren't required to use their video and could participate entirely through chat. As lockdown began in 2020, I poured every spare moment into learning research-based best practices for online instruction and never required students' on-camera participation. Early on, this decision was reinforced by the participatory, successful student who "stepped away for a moment" during class because one of their four younger siblings needed help accessing online school using their family's shared low-quality internet connection; this student never used audio or video, and I only knew why because of information they shared on their course evaluation. Yet I can't recall an instance where official university guidance acknowledged technology access inequities or how instructors might adapt their online pedagogy for increased equity. Multimodal instruction (simultaneously face-to-face, audio/video, audio-only, and chat-only to accommodate different kinds of access needs and physical/cognitive abilities) is difficult to facilitate. Again, our teaching team developed and implemented this approach without structural support, but it was very successful for meeting students' needs.

Finally, personal experience with both physiological and psychological diagnoses informed how our course policies support adaptation during crisis. BIPOC students continue to face the dual pandemics of COVID-19 and systemic racism. Additionally, in a high-enrollment class, our students enter the classroom as a neurodiverse population: Autism spectrum, major depression, anxiety, and post-traumatic stress disorder tend to be the most shared diagnoses. Meanwhile, physical disabilities range from temporary or chronic mobility issues to chronic diseases like Type I Diabetes or rheumatoid arthritis. Two simple adaptations have proven very useful for all students. First, we never require documentation for excused absences when students notify us ahead of class time. At first this seemed a risky policy, but students have been respectful of it. Second, though we avoid high-stakes in-class tests, students do take frequent, low-stakes, open-book quizzes on their own time. We don't use monitoring software and students can take each quiz twice, retaining their highest score. We allow students to opt out of quiz questions covering material with which they were unable to engage due to trauma.

Design inherently deals with difficult thematic content; as graphic designer Antoinette Carroll (2020) puts it, "Like all systems, systems of oppression, inequality, and inequity are by design. Therefore, they can be redesigned." While this offers significant hope – we can intentionally design toward equity! – it also means that students impacted by inequity may be further harmed if forced to engage with all course content regardless of their current circumstances and capacities in the face of ongoing systemic crises. Therefore, each week's assignment list notes content, especially in cases where titles may not provide sufficient clues; we don't use "trigger warnings" as the data suggests this language isn't helpful (Grayson, 2021; Kyrölä, 2019; Robillard, 2020). Each quiz includes a yes/no question notifying us if students opted out of specific content, on which they aren't graded. They leave corresponding quiz questions blank to indicate which content they've avoided. Again, they needn't offer proof, and they've been very respectful of the policy. Almost universally, they also choose to engage difficult content, though many students leave notes that they deeply appreciate the choice to opt out should they see a need.

Outcomes

It is an ongoing challenge to reframe our mental models of design and to face our disciplinary complicity with the creation and maintenance of inequitable systems. Now, using adaptive pedagogical practices to push back against systemic inequity – even in the very limited ways we have narrated here – remains a personal choice, largely unsupported by academic infrastructure. We hope that making explicit and contextualizing a few of our micro-adaptations might contribute to two goals. One, we seek to expose diverse and sincere viewpoints (Young et al., 2021). Two, we seek to engage not just "critique and envisioning" (Murray & Ozanne, 2009, p. 836) but "critical participation" (Hutton & Heath, 2020) as our discipline redesigns itself toward systemic equity.

This paper is not intended to offer best practices or a transferable model. The praxis we describe here relies on our interpretation of research regarding data-driven, emergent best practices connected to online learning, race in the United States, COVID-19, and trauma-informed pedagogy. It emphasizes our positionalities and how these impacted our praxis, making explicit the specific contexts in which we operated and how those informed our pedagogical adaptations during rapidly changing, and often crises-level, circumstances. We have embraced narrative and emancipatory research models in support of two goals: "narrative inquiry has the potential to inform policy because it is attentive to lives first" (Gavida & Adu, 2022, p. 4) and, during multiple crises, we sought policy which would be supportive of students' lives. As designer Leslie-Ann Noel (2016) puts it, emancipatory research offers us the chance to design our praxis "cognizant of [our] privilege [so as] to allow the perspective and 'voice' of the 'other' to emerge on an even standing as their own" (p. 467-468). Likewise, *Design & Identity* seeks to facilitate equitable dialogue among multiple perspectives. We plan to continue working toward both goals in future iterations of the course.

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ADAPTIVE RESUMES IN DISRUPTED FUTURES

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Abstract

As the impacts of the climate crisis continue to unfold, more and more workers will become displaced (International Labour Organization). While the bulk of disruption will be felt by the working poor in the third world, every part of the economy will eventually be impacted. Within the United States, millions of people will face dramatic changes to the environment because of rising temperatures, widespread fires, flooding, and more. In response, there will be an increased need for workers at all levels to migrate or switch employment sectors. As a design researcher, I am specifically interested in how design artifacts play a role in worker cross-sector mobility. There is one crucial artifact that plays a facilitating role within this dynamic: the resume. The resume is a seemingly innocuous player in the job-seeking process. However, when viewed as a narrative artifact, it becomes obvious that the resume has untapped potential. As workers seek to enter new and unfamiliar domains, they will need better tools to help them construct relatable narratives about their unique blend of experiences and skills. Over the last two years, my team has been examining the space of worker adaptability through the development of a solution called *Real CV*. This project seeks to help workers articulate their strengths and translate domain-specific abilities and experiences into narratives that can be understood by a wider audience. Put another way, I seek to update the format of the resume to help workers become more adaptable to their evolving surroundings. This paper will identify weaknesses with the CV through a critical intersectional lens (Booysen, 2018) and will detail the use of a constructive design methodology (Bardzell et al., 2015; Dorst, 2013) to examine an updated resume system. In the end, a concept for a Real CV application is presented which showcases the necessary criteria for a job in a more inclusive and adaptable resume format.

Author Keywords

Resume; constructive design; user interface design; migration; climate crisis.

Background

As the climate crisis unfolds, our work lives will increasingly be marked by disruption. The primary drivers behind this disruption are unprecedented levels of displacement or migration and changes in labor demand. In terms of climate-driven migration, an estimated 143 million people will be forced to migrate by 2050 (Podesta, 2019, p. 8). This is on top of the millions that have already been forced to move because of extreme weather, floods, fires, and rising water. The most extreme disruptions will be felt by very poor areas like Latin America, sub-Saharan Africa, and Southeast Asia. There are very real concerns for these populations as the future is likely to bring food and home insecurity, discrimination in foreign countries, poor health, and even death to many. While the plight of these populations may be the gravest, climate change will not discriminate in its effects on human life.

Workers within every sector and economic class will have their lives disrupted in some way. Middle- and upper-class workers in countries like the United States will be forced to abandon careers or move between sectors with little to no warning. It is difficult for workers to transition between sectors, especially during times of societal change (Kinder & Lenhart, 2019). While there are many factors that contribute to this difficulty – including the fast pace of technological development and limited access to training opportunities – there is an important factor that is especially relevant to design: communication. Workers who are forced to move between sectors have the undue burden of convincing employers that they are worthy of employment. The resume or curriculum vitae (CV) usually does the heavy lifting in this dynamic as workers attempt to communicate their relevant skills. However, as this study will unpack, it fails as a useful communication artifact when it tries to communicate cross-sector transitions. Before we get too in-depth about the resume's failure, it is important to understand the scope of the coming workforce disruption within the United States. The two primary drivers behind this disruption are internal migration driven by extreme weather and a shift in demand within the labor market. A third factor, the acceptance of transferable skills from unconventional domains, can play an important role in worker mobility.

Climate-Based Migration

Recent studies on the potential impacts of climate change on the U.S. provide a useful case study to examine how everyone – not just the third-world poor – will be impacted. In 2020, ProPublica conducted an analysis of how each of the major factors of climate change – heat, fires, extreme weather, sea levels, and crop yields – will impact each region in the U.S. (Shaw et al., 2020). Their findings showed that major effects will play out in most areas of the U.S. and will likely cause people to migrate within the country. There are many reasons why Americans might move: extreme heat in the southwest, fires in California, poor crop yields in the south, and rising water on the eastern seaboard, Great Lakes area, and Mississippi River Delta. On a smaller scale, extreme weather has the potential to disrupt localized communities anywhere in the country. Consider Greenville, California that was destroyed by the Dixie wildfire (Anguiano, 2022), or Midland, Michigan that was flooded by dam which broke after record rainfall (Earth Resources Observation and Science Center, 2020), or Fair Bluff, North Carolina that was hit by two hurricanes within two years (Graff, 2019). Lustgarten projects that 162 million Americans will experience a decline in the quality of their environment, with 93 million experiencing severe changes by 2070 (Lustgarten, 2020).

While the changes within the U.S. are not catastrophic for most regions, they are significant enough that large numbers of people will no longer be happy with the climate or environment of their region. It is realistic to think that a sizable number of people will grow tired of endless days of over 100F° temperatures (Livingston, 2020) or wildfire anxiety (Lahr, 2020) and seek to move to other regions. The northern part of the country is the most obvious destination as warmer weather will make the region even more livable and could lead to economic booms (Shaw et al., 2020). Specific predictions around migration are incredibly complex but conservative estimates predict that a sizable number of

Americans (32-45 million or >10% of the total population) will migrate within the country as a direct result of the climate crisis (Fan et al., 2018).

Labor Market Demand
Running counter to regional migration, we will also see climate-driven workplace disruption brought on by industrial shifts. As the effects of climate become more dire and we (hopefully) move into low-carbon economies, scholars note that many existing jobs will either change, emerge, or disappear (Brown, 2015). Of course, most of this disruption will fall on the energy sector as we move to renewable energy production. Workers will move out of the oil fields and into the wind farms. In fact, careers in wind and solar energy are projected to increase by 46-58% over the next 10 years – some of the highest growth in any sector (Peach, 2021). Green jobs require a different skill set than their non-green counterparts. Studies show that they generally require more education, training, and abstract thinking skills (Consoli et al., 2016). However, energy is not the only sector that will change. Some career changes will initiate out of necessity as our society scrambles to mitigate the effects of the climate crisis. To this end, it is estimated that we will see a growth in social services as a result of climate disasters, infrastructure planning and development, environmental research and planning, and more (McCleary, 2020). This is just a small sampling of the changes to labor markets in response to an evolving climate. Many workers will need to switch careers or evolve within their sector to remain viable.

Unconventional Transferable Skills
Regardless of the driver behind a career change – whether it be migration, sector evolution, or societal need – the demands of the U.S. labor market will undergo dramatic changes in the coming decades. Workers will need help as they seek jobs in new sectors or regional markets. Research into how workers transition between jobs reveals that the process is difficult because "Hiring managers typically demand that workers demonstrate the exact skills and work experience 'required' to do the jobs for which they're applying" (Weise, 2020). As workers are forced to move into unfamiliar territory or take on green jobs that did not previously exist, it will become increasingly hard to match previous and required skills or experiences. In many situations, it will be impossible to provide a one-to-one skill match from strictly work experiences. However, that does not mean that workers do not have those skills. There will be a need for workers to be able to identify relevant skills from other areas of their life.

Feminist scholars have thought about this dilemma for many years as the same dynamic exists for femme workers, especially working mothers, who try to enter patriarchal careers. Lotte Bailyn (2006) and others have argued that our experiences at home have a direct impact on our work and that the relationship between our home and work lives should be much more fluid. In reflecting on your own life, it is easy to see how experiences at home have led to new skills that transfer into the workplace. For parents, the Covid pandemic surfaced many of these new skills. Think of all the new skills that were acquired as parents had to become homeschool teachers (perseverance, crisis management, empathy, etc.). We gain transferable skills in many other avenues of life too: in personal relationships, as a member of communities, and even in moments of pain (harassment, victimhood, loss, etc.). In displaced employment settings, workers will greatly benefit from being able to connect transferable skills from their "life" contexts to the requirements for employment.

Research Goals

As workers struggle to enter new sectors and communicate their experiential and unconventional value, they are forced to use an old tool: the resume. However, in thinking about how the resume fits into this context, two big problems arise. One is that resumes follow a rigid format. This is mostly because experiences are situated chronologically through the lens of position and work activity. This format pushes the narrative about work experience to be industry-specific and tends to ignore underlying, transferable skills. For example, an oil drill operator may list "Operate pumps or compressors" as a direct work experience. While this is technically correct, this description provides a limited understanding of worker ability. Someone outside the oil industry is not likely to know all the skills that are necessary to complete this task, which could include attention to detail, critical thinking, operations monitoring, coordination, judgment, reading comprehension, quality control analysis, troubleshooting, manual dexterity, and more (O*NET, 2022). This list of skills can be applicable to many other jobs in many other sectors, but the resume limits this worker's ability to make those connections. This format also requires skills to be directly connected to work experiences. Relevant skills that were acquired at home or through other "life" experiences do not have a place in existing resume formats.

The other failing of resumes as we use them today is that workers are often unaware of the skills that employers require. This is especially true for workers transitioning between sectors. However, Weise et al. have also found that the "required" skills of the same job can differ regionally (Weise et al., 2019). This means that even within the same job, a worker in Florida may require a fundamentally different skill set than one in Michigan. This reality is not obvious for most workers, making their post-migration job search even harder.

Through the above research, we can build the following logical structure to lead to a hypothesis for this study:

1. Climate disruption is forcing workers to transition to new and unfamiliar fields.
2. Employers want to see a direct connection between required skills and applicant experiences on the resume.
3. Workers do not know what skills are necessary for these new fields.
4. Required job skills can vary by region.
5. Workers have useful, relevant skills that are acquired in their home/personal life.
6. Workers have a rigid concept of a resume and may not have the ability to abstract experiences into skills and vice versa.

Through this inductive logic, the core problem becomes one of communication via the resume. Workers who are displaced or are transitioning between sectors need help advocating for themselves in unfamiliar spaces. This is where design comes into play. A constructive design approach can help conceptualize a new tool that can systematize the creation of a new kind of resume. In turn, the prototype can act as a catalyst to advance discussion about the future of work and the need for a more progressive understanding of "experience." In the sections below, I will discuss the constructive design methodology and describe the resultant prototype. In the end, I will reflect on the prototype and discuss the usefulness of constructive design in this type of problem space.

Methodology

This project is an ideal candidate for a constructive design inquiry, which emphasizes creative production as the central means of knowledge production. When working in ill-defined contexts (like climate-disrupted futures), designers can utilize constructive design and its unique form of abductive logic to generate prototypes that reveal understanding that is otherwise unattainable. Bardzell et al. (2015) describe constructive design as a "thing-making practice whose objects can offer a critique of the present and reveal alternative futures, while remaining grounded in empirical science, behavioral theory, contemporary technological possibility, and socio-cultural practices" (2094).

However, there are many ways to go about "thing-making" – or prototyping – and specific methods can result in different conclusions. Wensveen and Matthews (2014) provide a helpful framework in which to think about how and why prototypes get integrated into research. This project is speculative in nature and is responding to a general set of principles that were derived from observation and secondary research. The problem space is situated within a context – the work transition experience – but does not involve specific users in its development process. To that end, using Wensveen and Matthews (2014) as a guide, I will employ prototypes as a "research archetype." Rather than act as a tool to directly gather data, the prototype will serve as a physical embodiment of the understood concepts which integrate "specific examples to demonstrate [its] potential and justify that they constitute a contribution" (Wensveen & Matthews, 2014, 268). In this way, the prototype acts a sort of "design exemplar" which itself acts as a form of knowledge encapsulation (Bardzell et al., 2015) that can contribute to the broader discourse of "work in disrupted futures."

To provide structure to the prototyping process, we look to Dorst's (2013) "Academic Design." As a framework, academic design enables designers to operate in exploratory spaces, where problems are loosely understood and solutions are difficult, by relying on "design abduction" to create a central, operational model (Dorst, 2013, p. 6). This central model is constructed through a combination of traditional design activities (divergent exploration) and research into the problem domain (steps 1 and 2 in Figure 1). Through that process, a conceptual frame is identified to provide workable direction within the constellation of possible directions. This process enables designers to propose new solution directions that are grounded in both contextual understanding and in conversation with existing literature. With a model in hand, the designer can then enact an iterative process of design and reflection which results in prototypes and reports back to the relevant fields (steps 3 and 4 in Figure 1). In the end, the prototypes that are developed through the process – and thoughtful reflection on them – have the potential to formulate a variety of content for dissemination: new design knowledge, potential innovation or commercialization opportunities, and an opportunity to speculate about possible futures and their implications (steps 5, 6, and 7 in Figure 1). I will now discuss the creation of the prototype, beginning with the development of a frame.

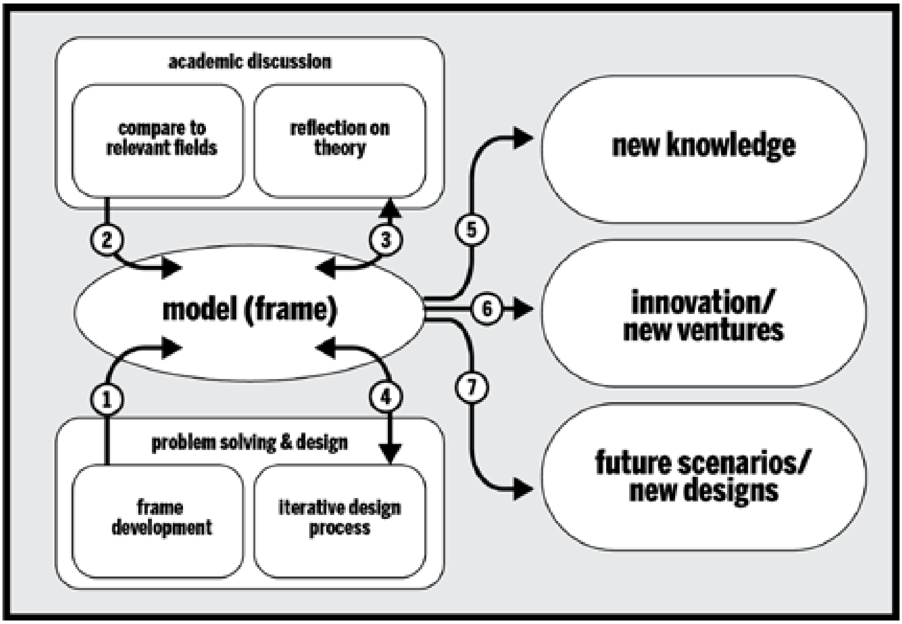

Figure 1. Dorst's academic design framework.

Frame Development

Following the academic design process, it is important to first develop a frame or "model of understanding" for a potential solution. The frame for this research was developed in a rather circuitous way. Since the beginning of the Covid-19 pandemic, I have been working with a research team that is investigating the academic CV. More specifically, this work is inquiring into how the academic CV perpetuates many of the negative aspects of academia, namely neoliberal competition (Besley & Peters, 2006; Cannizzo, 2018; Maisuria, 2020), and systemic racial and gender inequalities (Colby & Fowler, 2020; DeCuir-Gunby & Gunby, 2016; Muñoz & Villanueva, 2022; O'Meara et al., 2017; Toutkoushian & Bellas, 1999; Williams June, 2022) and is leading to high rates of burnout and turnover among academics. This research uncovered two insights that have led directly to this new inquiry. First, we uncovered that the rigid structure of the CV, shaped by recent trends in quantification of academic assessment, does not adequately portray faculty effort. The CV hides the "invisible" labor (service commitments, student concerns, etc.) that many women and underrepresented minorities endure, putting them at a disadvantage against their privileged colleagues. The other key insight came as we inquired into the difficulties of leaving academia for private industry. Because it focuses on academic work product and not skills, the CV is not built to help faculty transition out of academia. Instead, faculty must translate their academic work into industrial skill sets for a resume. So, we started operating on these two basic ideas: the format of the CV is not sacrosanct and should be revised to better serve its role; and the resume acts as a translator, connecting past experiences with expected skills.

This idea of a resume-as-translator became our operating frame. Through it, we designed several prototypes that serve academics (Wheeler, 2020) but realized that the core principles of our inquiry could be usefully applied to other sectors. There are several settings where workers could benefit from this kind of translator, including future workers who are displaced because of climate. However, the "disrupted worker" context is unique from the academic context in several ways. To better understand these differences and examine how a design would need to operate in this setting, I began the process of constructive prototyping, which I will describe below.

Prototyping Process

In thinking about the prototype, there are two distinct components that needed to be developed as part of the "translator" concept. The first part is the raw translation of experiences into requisite skills. The second part is the communication of those raw skills into the new relevant work contexts. With this in mind, the prototyping process required a pairing of system mapping with a contemporary user interface/user experience (UI/UX) practice. System mapping would allow a better understanding of what was required to complete the input-translation-export process necessary to complete both components of the design. Then, with that system-level understanding, a user interface prototype could be developed to better understand the specific details of how the interaction would work.

"Real CV" System

The system map displayed in Figure 2 proposes a new way for core elements of the solution to work together. The central component that powers the concept is a "translational artificial intelligence (AI) engine" ("Translator AI" in Figure 2). The promise of the Translator AI is that it can generate a resume that matches the user's skills, regardless of the contexts in which the skills were developed, to the required skills of a position. Through the user interface ("Real CV UI"), a user uploads past experiences or accomplishments from their work history. In this way, the Real CV UI acts as a container where users can capture any potential information that might go into a resume but does not require them to filter their input in any way. It also allows the user to capture non-work experiences that they may encounter in their home or personal life. This feature will eventually allow users to connect life experiences to their resultant, useful workplace skills. All past experiences get translated into skills, which are saved in a central "Personal Skill Library."

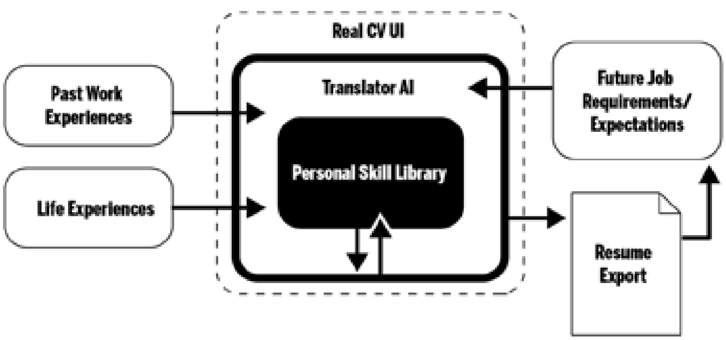

Figure 2. Real CV information process.

Once a user has identified a position they would like to secure, they load it into the UI, where the translator reverse engineers the required skills. Behind the scenes, the AI will compare the written job description to generally known trends about the position or field and integrate any unique regional skills that may be required. Once it has identified what the position requires, the AI will reference the Personal Skill Library to match the necessary skills. For example, if the position requires the skill of "critical thinking," the system will simply identify that the skill has been acquired somewhere in the past. It does not matter where it was acquired (a previous job, at home, etc.), rather just that it *was* acquired somewhere. Once the maximum number of skills have been matched, the user can export a formatted resume that communicates their ability to perform in the position, regardless of their past work experiences.

Real CV User Interface

To get a more nuanced understanding of how this proposed system would operate, a UI prototype was developed using Adobe XD software. The prototype was developed pragmatically and utilizes contemporary best practices around usability (Nielsen, 2020) and user experience (Yablonski, 2020). The intention behind this approach was to be as realistic as possible to best understand how the interface would need to operate to accomplish the goals of the system plan.

Figure 3 depicts the primary dashboard of the Real CV UI. On the dashboard, users upload individual experiences or accomplishments from past work or life experiences. With the exception of "life" experiences which are positioned first, work experiences are organized chronologically by position to mirror a traditional resume. The dashboard essentially acts as a container for all of the user's past experiences. It is just a holding zone that will get utilized later. The dashboard also collects more general information about the user's abilities and history, including educational background, languages, and technical skills. Users need to be explicit about these details because the information is relevant to employers but cannot be captured through the translation process. Later, I will discuss how this information gets included in the new resume but is de-emphasized to better highlight core skills.

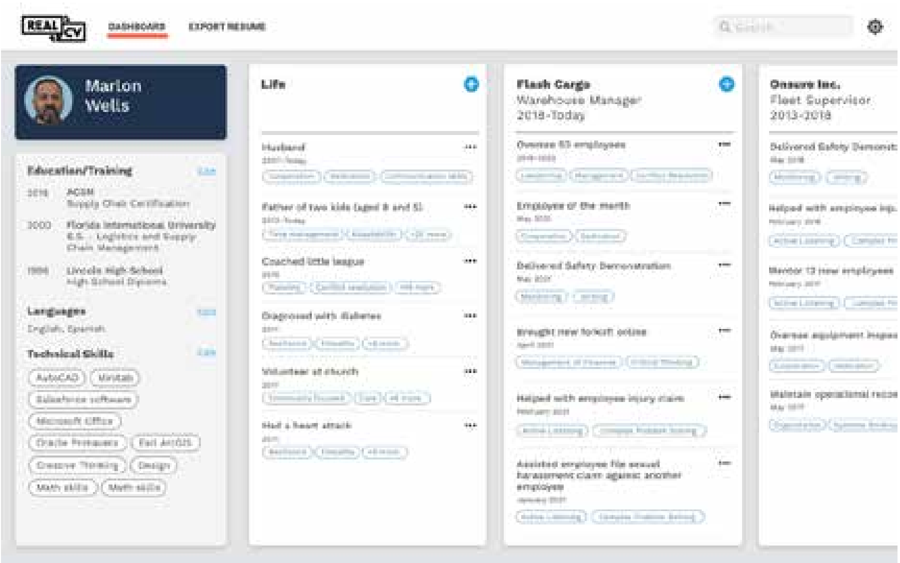

Figure 3. Real CV primary dashboard.

When the user is ready to add a new experience to their dashboard, they simply click the "+" sign associated with each top-level category (the life category or under a specific position). Figure 4 depicts the initial step of adding these experiences. In the form field, the user is prompted to "Search for experiences or accomplishments," where they can just start typing in the experience they have in mind. Alternatively, they can browse suggested experiences that the system has identified for them. These experiences are identified from what Real CV has learned from other users in similar work environments. It is also optimized to suggest experiences that demonstrate a range of underlying skills. To work best, Real CV needs to have a detailed summary of work experiences and these suggestions aid that by helping users recall experiences that they would have otherwise forgotten or overlooked.

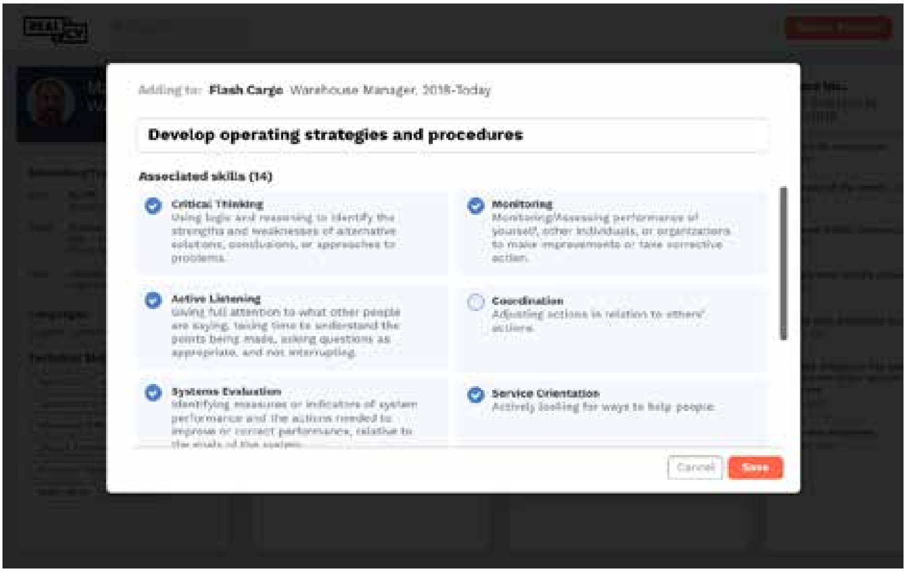

Figure 4. Real CV dialog to add past experiences.

Once the user enters or selects an experience, the Translator AI converts it to its underlying skills and displays that information for them. In Figure 5, you can see how the UI provides a detailed breakdown of all the skills that the AI believes are part of the experience. The user then has the ability to refine which skills remain tagged to the experience by checking or unchecking the skill. Once the user clicks "Save," the experience is logged and all of the associated skills are saved to their Personal Skill Library. The user can repeat this process until they have captured all their relevant experiences.

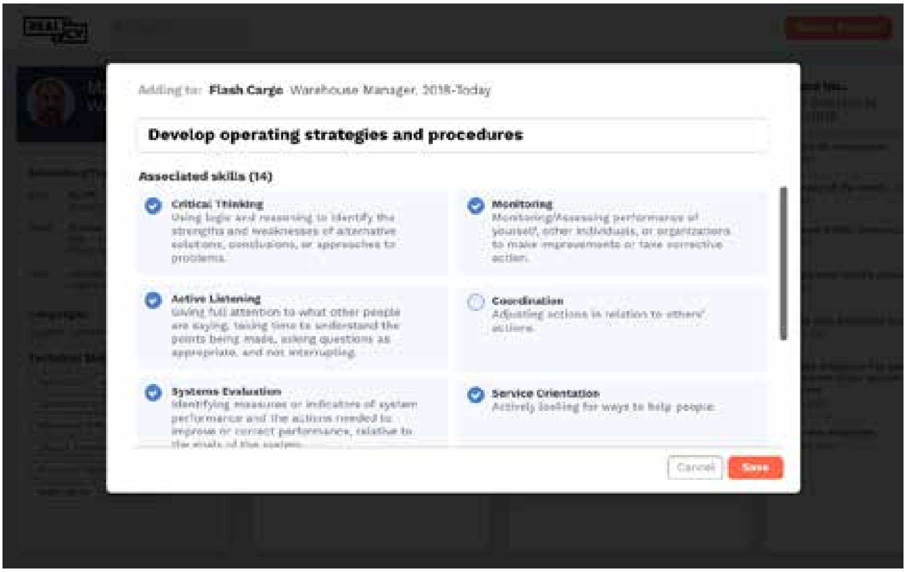

Figure 5. Real CV past experience dialog showing skill translation.

When the user is ready to export a resume, they switch to the "Export Resume" tab at the top of the UI (Figure 6). In this area of the UI, the user can prepare their resume for a specific job application. They must first identify which job they are applying for by selecting either a generic job title or by searching for a specific listing on the web (this is seen in the panel on the left side of the UI). In Figure 6, the user has found a specific job listing. Once found, the Translator AI interprets what skills are necessary and cross-references them with regional skill differences. It then searches the Personal Skill Library to match the user's skills to those required by the position. The user can review which skills the AI has identified and see the related experiences for each skill; individual experiences can be unselected if they choose to leave them off the resume. The UI also indicates when a skill is necessary but not found in the library, as seen via the "Monitoring" skill in Figure 6.

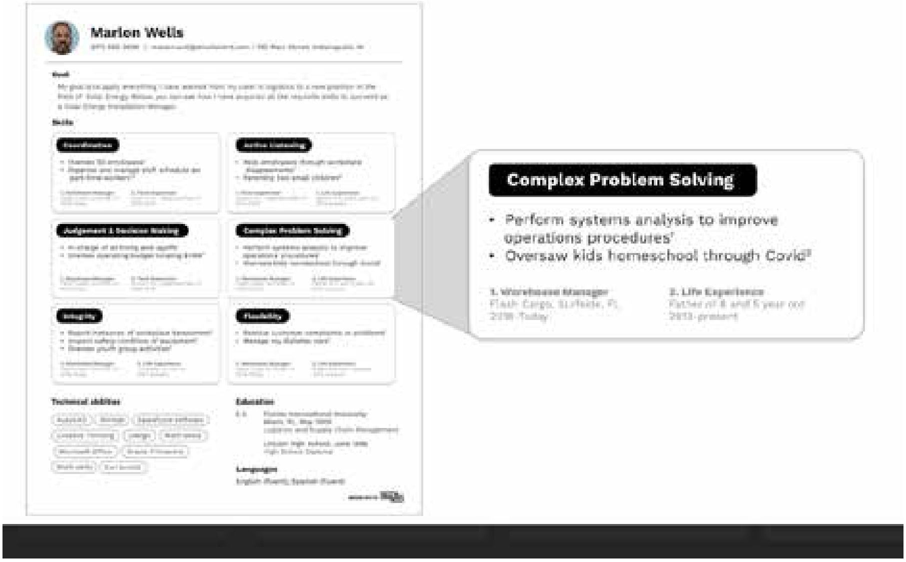

Figure 6. Real CV "Export Resume" screen.

Once the user is satisfied with their skill/experience selections, they can export their unique resume to be included as part of their application. Figure 7 depicts an example of a resume export. The resume does include traditional information that would be expected on a resume: name, contact info, education, and technical abilities. However, within the core of the resume, the narrative is organized by required skills rather than job title, as would be traditional. Each skill is highlighted and supported by descriptions of the related experience. In Figure 7, the flexibility of the system is demonstrated as "Complex Problem Solving" is supported by both work-related experiences and life experiences (parent-hood). Formatting the resume this way reinforces that the worker has the right skills for the job and deemphasizes specific job titles or other information that could be viewed as disqualifying. Each resume export is intended to be used only once, for the specific job application. The biggest benefit of using Real CV rather than making a resume by hand is that the resume can adapt to each unique job listing. The system enables an infinite number of skill combinations that can be adjusted to best advocate for the user.

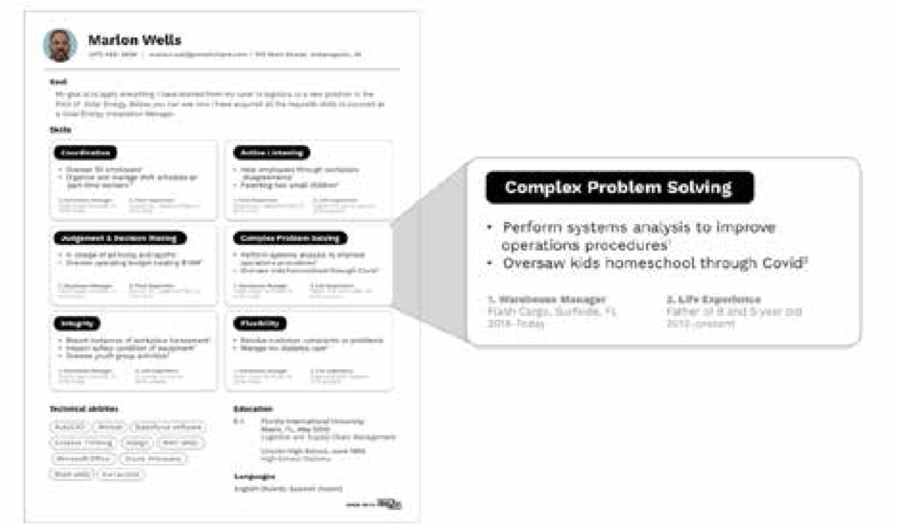

Figure 6. Real CV resume export.

Discussion

Following Dorst's (2013) academic design structure, the creation of the above prototype should lead to new understanding on several fronts: new knowledge, innovation, and future scenario identification. In the sections below, I will outline the developments within each category.

New Knowledge

As previously mentioned, according to Bardzell et al. (2015), constructive prototypes are a form of embodied knowledge. They are expressions of design abduction which uniquely combines known and intuited information about a future problem space. To that end, the Real CV prototype is now able to enter the discourse about work in climate-disrupted futures. It makes several specific contributions to the discussion. First, it calls into question the usefulness of the traditional resume in these futures and demonstrates that there are other possible solutions. Second, it suggests that worker value be measured in skills rather than experiences. Finally, it reiterates the relevance of home or life experiences in the context of the workplace. The Real CV prototype can hopefully inspire further creative development around how to tell stories about the usefulness of non-work experiences within work contexts. As the discourse around the future of work continues to grow, Real CV can act as an design exemplar to foster discussion and debate.

Innovation

Real CV provides a path for innovation via its centralized Translator AI. Artificial intelligence is not a novel concept within the area of work and labor. In fact, an entire industry of workforce development has been built around the use of artificial intelligence to identify weaknesses in worker skill sets (Weise, 2020). Tools like Sky Hive (2022), FutureFit AI (2022), and Emsi (2022) allow users to leverage AI to understand their current skills and compare them against the expectation of their industry or employer. However, instead of advocating for individual workers, these are enterprise-level solutions that focus on helping employers optimize their workforce. The Real CV Translator and UI provides an example of how an AI can tap into "big data" to optimize it to help individuals. The prototype also presents a path that helps counteract bias in hiring processes. For a variety of reasons, hiring AIs are notoriously biased (Dastin, 2018). The reality of the contemporary hiring process is that an algorithm will review a resume before a human will. The AI that is reviewing the full pool of candidates is often looking for keywords that meet the basic criteria of the job (Parikh & Forbes Human Resources Council, 2021). Because Real CV generates the resume for the user, it can theoretically optimize the language it uses to mirror requirements of the hiring software AI filters. While we are focused on generating resumes with the Translator AI, there could be many additional applications for its core functionality of converting abstract experiences into concrete skills.

Future Scenarios

Because this project was based in a speculative future scenario, it is difficult to speculate further. However, this work does contribute to the broader discussion around future climate disruption in the United States. While this project was focused on the work component of that future, there are many other topics that still need to be discussed. In the future described in this project, nearly every aspect of life will be altered in some way. This prototype helps other researchers of the future visualize a small component of that future with more nuance. In the more immediate future, we know that workers already need tools to help them find work and transition between sectors. This research also references workforce displacement research that was conducted after the 2008 Great Recession and the 2020 Covid-19 Pandemic. Many of the findings from those moments of disruption were applicable to our speculative future. As a society, we are likely to face more moments of turmoil that will disrupt work. In being designed for such a distant future, Real CV should be able to inform more immediate crises along the way.

Conclusion

It is safe to assume that work is going to be interrupted in a climate-disrupted future. Workers who are forced to move regions or into new lines of work need to communicate their skills to potential employers. As they exist today, resumes are not equipped to satisfy workers' communication needs. Through an exploratory, constructive process, the prototype for Real CV was developed as a design exemplar that addresses the weakness of the resume. The central feature of the prototype became the Translator AI, which converts work experiences into skills. In turn, Real CV uses that skill library to connect acquired skills to the required skills of a position. By matching skills in this way, Real CV empowers individual workers to advocate for themselves in unfamiliar sectors and more easily transition to their climate-disrupted life. Moving forward, my team is focused on developing the translational AI to begin testing its viability in real scenarios. In the end, this project contributes to the growing body of literature around the use of constructive design research. Designers have always had trouble turning design activity into academic knowledge. This project sought to provide a case study on how to use prototyping as an archetype of research activity and then convert that prototype into knowledge via Dorst's (2013) academic design framework.

The future is fraught with peril. Designers should have a major voice in counteracting that peril. The Real CV case study provides a roadmap for other designers to use to develop pragmatic, speculative solutions to the very real problems we face together.

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CLIMATIC ADAPTABILITY IN THE FORM OF PILE DWELLINGS IN THE PALACES OF THE WESTERN HAN DYNASTY

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Abstract

In Chinese history, a fundamental change in architecture occurred during the Western Han Dynasty (206 B.C.E.-9 C.E.), when the palace of the principality replaced the patriarchal system as a symbol of power and was also the highest architectural technological achievement of the time. As the archaeological excavation reports reveal, these palaces, located in different climate zones and distinguished by climate-adapted strategies, were built with similar layouts, materials, and techniques but were seen as an overreach that caused chaotic hierarchies in later dynasties. As such, they offer us a unique, fleeting opportunity to compare these palaces from the point of view of understanding the climatic adaptability of our ancestors. This study compares and analyzes the adaptability of four palace buildings of pile-type architecture (a structure built above the ground on a bamboo post frame) under the same system in different regions with different climates, as referenced by the capital city of Chang'an in the Han Dynasty.

This study found that the pile-type building form broke the inherent cognition since the distribution range was not limited to the south and, with the further development of archaeological excavations, there were also application cases of pile-type architecture in the north. The ancient builders' process of climate adaptation produced different manifestations of architecture for different climate zones; the purer pile-type forms, with overhead ground as the main feature, presented closer to the south, and the north was altered according to the climate to achieve the diversified use of the pile type. By summarizing the architectural wisdom of the ancestors according to local conditions, analyzing of the adaptability principle of the pile-type building form to the climate, and learning more about the possibility of combining the pile-type building with other energy-saving methods, the building designer can create a modern application of the traditional pile-type building. This type of building creates a low-cost, efficient, passive way to save energy to achieve climate response, so that the pile-type building becomes a more equal climate-adapted building form in contemporary times.

Author Keywords
Western Han Dynasty; palace; climatic adaptability; pile-type building; passive energy saving.

Introduction

Buildings have been constructed as environment-adaptive shelters from the weather since the very beginning of human history. Nevertheless, the development of technology seems to have somehow driven indoor comfort apart from adapting to the outdoor climate. According to a new United Nations report (GlobalABC, 2020), CO2 emissions from the operation of buildings in 2019 increased to 9.95 GtCO2 and hit their highest-ever level, accounting for 38% of all energy-related CO2 emissions and moving the sector further away from fulfilling its huge potential to slow climate change and contribute significantly to the goals of the Paris Agreement.

The current pandemic recovery provides an opportunity to reflect on how the roads parted and push building renovation and performance standards for newly constructed buildings by learning from our ancestors, despite heritage buildings being mostly discussed in terms of architectural or historical significance.

In the current case study, specific ancient palaces in China were chosen for three major reasons. First, heritage palaces were built in the most climate adaptive way to guarantee the greatest possible comfort for kings and emperors. Second, they could represent the highest level of ancient building technology. Third, palaces are normally well conserved and documented, providing the most complete information for climate adaptation studies.

In Chinese architectural history, the conventional views of the origin of Chinese houses as pile dwellings in the south and cave dwellings in the north have been gradually dismantled with the progress of archaeological excavations. After the prosperity of pile-type buildings, they gradually declined due to raw materials, politics, and other reasons, but their simple construction, low cost, and wide range of environmental adaptability may become a model for modern architecture to learn from, and its research can have modern applications. In this paper, we use the pile dwelling palaces as examples to analyze the different structures and layouts in different climate zones and summarize the lessons learned from heritage architecture.

We used depth mapping to analyze four palaces with a standard form in the same period of the Western Han Dynasty *(*206 B.C.E.-9 C.E.*)*, similar to the Weiyang Palace in Chang'an of the central empire. By comparing and analyzing different architectural forms and the characteristics of pile-type buildings in four climate zones, we can arrive at energy-efficient design as climatically adaptable inspirations for buildings today.

Literature Review

Application of Climate Adaptability of Traditional Architecture in Modern Architecture

Due to the lack of modern construction technologies at the time, the adaptation technology of the historical building environment is mainly "passive design," reflected in ventilation, heat preservation, and heat insulation, and uses different design strategies in terms of materials, structure, and layout.

In terms of ventilation, the Indian architect Charles Coria's "Tube House," which draws on traditional Indian Mughal architecture and Venturi ventilation principles (C. Li, 2019), and Renzo Piano's use of computer-aided design techniques in the Tjibaou Cultural Centre, are both examples of modern architecture applying traditional building ventilation principles to achieve effective energy-saving improvements (L. Li, 2004).

When it comes to materials, many developed countries are revisiting the ancient building material of "raw earth," and villas built from it are becoming a back-to-nature pursuit that is being promoted to developing countries in Africa (M. Wang, 2006). In terms of construction, drawing on the characteristics of the double-tiled roofs of the traditional Minnan ancient houses in China, Ken Yang developed the idea of a double roof designed with integral louvers for shading, while the air interlayer in the middle increases the thermal resistance of the roof, making it well insulated and quick to dissipate heat (L. Zhang, 2015). In terms of layout, Hosseini et al. (2020) studied the factors affecting the performance of coherent façades from the perspective of climatic conditions, using a comparative study between traditional and modern façades in the city of Mashhad to improve the efficiency of the façade of contemporary houses in Mashhad and thus reduce energy consumption.

Distribution and Changes of Pile-Type Buildings in China

Judging from archaeological sites and ancient documents, the distribution of Chinese pile-type buildings in history is much more extensive than the current situation, and it is recorded that even the Su Shen tribe in northeastern China lived in "nests in summer and caves in winter" (Shi, 2013; Tang, 2000).

Although the distribution of pile-type architectural sites is concentrated in the Yangtze River Basin, it involves several Neolithic cultural areas spanning China's east, west, south, and north. Among the many Han Dynasty Ming artifacts and Han portrait bricks are pile-type buildings which reached their peak in the Han Dynasty and gradually declined after the Han Dynasty. Since then, the pile-type building has continued to develop in the forested, ethnic minority southwest area as a widely used architectural form in ancient palaces and houses. Pile-type construction is simple, the cost is low, and the energy-savings and wide applicability are a more equal form of climate adaptation. Therefore, this paper takes the Han Dynasty palace as an example for comparative analysis. Paying attention to the energy-efficient pile-type design elements in historical buildings and making necessary improvements and updates in combination with modern technology could inspire energy-saving building design.

Data

In this study, we have selected four vassal palaces built on the Chang'an palace model as examples for an in-depth case study: case A, the Weiyang Palace in Chang'an (now Xi'an), the first capital of the Han Dynasty; case B, the Chengcun Kingdom Palace of Mount Wuyi, UNESCO Mixed World Heritage (ref. 911bis) in Fujian Province; case C, the Nanyue King's Palace in Panyu (now Guangzhou); and case D, the Goguryeo King's Palace, UNESCO World Heritage (ref. 1135) in the Wandu Mountain City, Jilin Province, and Case D, located in Siberia, Russia (Fig. 1). Taking these four palaces as representatives, the adaptation of the buildings to their climate zones was studied, in line with the technical feasibility. At the same time, the universality of the study was further enhanced by the addition of houses and other buildings in the same climate zones at different times.

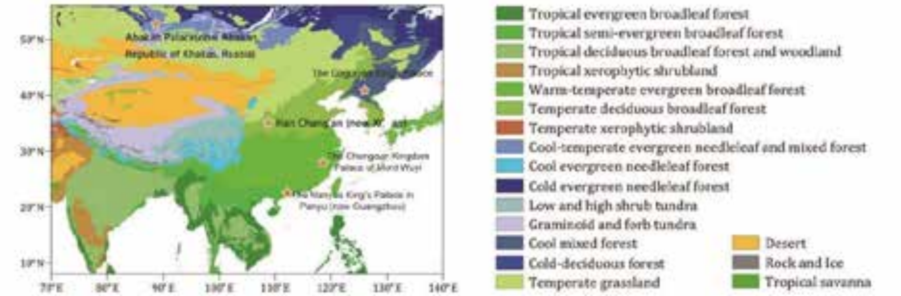

Figure 1. The climate zones of the case palaces on the East Asia biome map (Zheng et al., 2014).

In order to obtain the reference of the ancient pile-type architectural form to the adaptation to modern climate, we used the horizontal comparison method to compare the palaces of different pile-type forms. Two comparison prerequisites were therefore necessary. Firstly, to ensure comparability between palaces, we used a convex map of space syntax to compare the layouts of the four palace courts as well as the palace building groups, quantifying the consistency of their global integration to make sure the chosen cases were comparable (Figure 2). Secondly, for the climate data in the four locations, to ensure the comparability and application of ancient and modern buildings affected by climatic factors and due to the lack of quantitative paleoclimatic records, we used reconstructed data. This data was drawn from the climatic amplitude method (Fauquette et al., 1998) in reference to the biome map of East Asia (Figure 1), modified from the terrestrial ecoregions determined from the stratum of plant pollen (Olson et al., 2001) instead of using China's current Building Climate Demarcation Standard (GB 50178-93). Comparing the obtained climate zone distribution map with the current building climate division, we found that there is little difference between the two, so we also queried some modern climate data as a supplement. Modern climate data were derived from the China Meteorological Data Network and the World Weather Information Service Network, which analyze the climate of the four palaces in China and the climate of Abakan in Russia (results are shown in Figure 3).

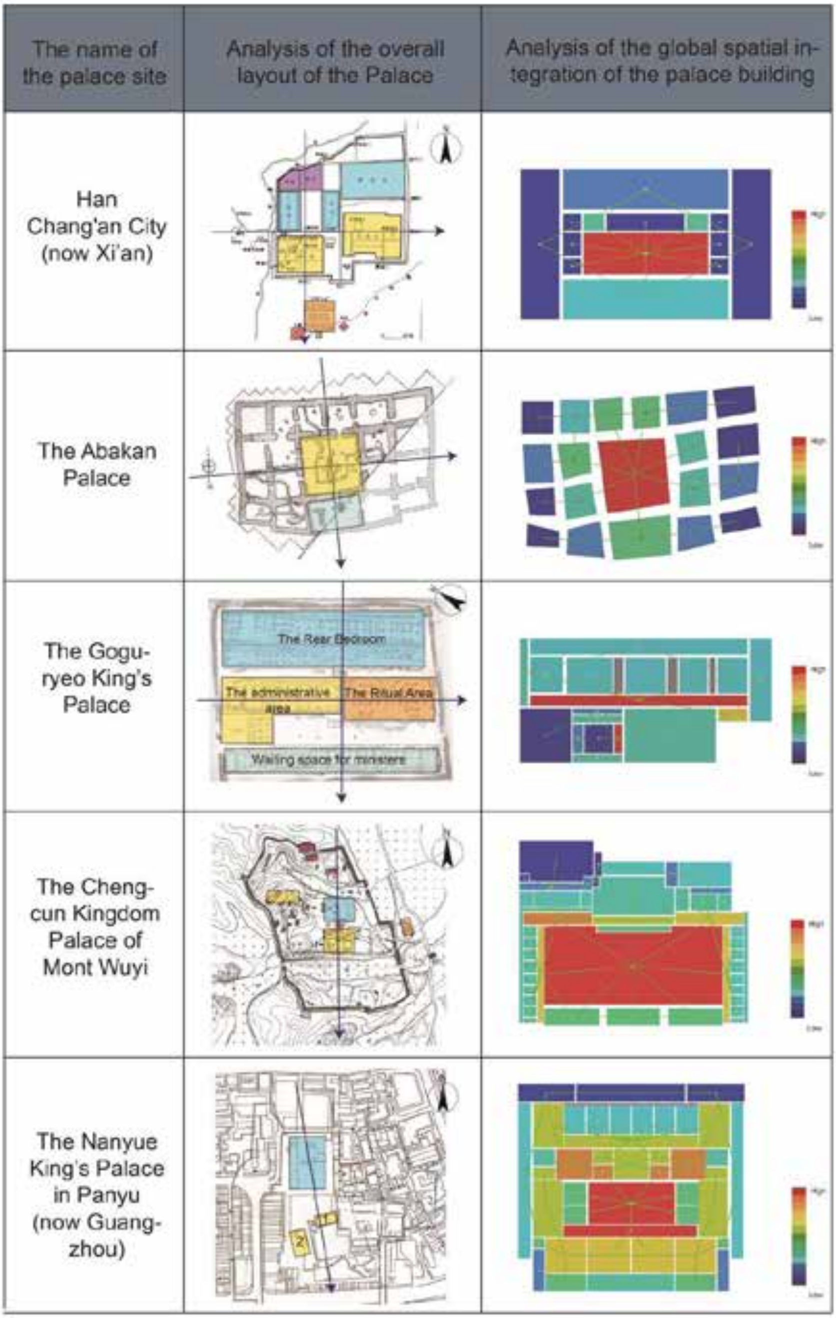

Figure 2. Four Western Han palaces chosen for this study.

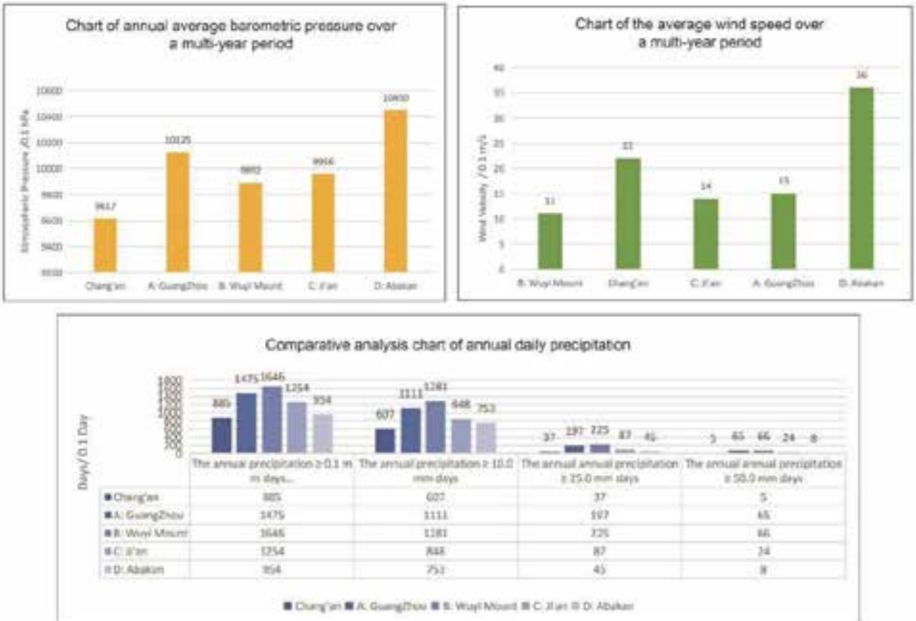

Figure 3. Climate data analysis of five palace areas.

Horizontal and Vertical Comparative Analysis of the Use of Pile-Type Building by Palaces and Surrounding Residential Areas in Different Climatic Zones

Ancient texts record that building moisture protection is mainly handled in two ways: high platforms and pile type. The Qin and Han Dynasties (221 B.C.E.-220 C.E.) became the golden period of high-platform palace architecture in China, based on the advantages of ventilation, moisture-proofing, flood control, and convenient lighting of high-platform buildings themselves, as well as the interaction of other technical and political factors (Lu, 2020). We can see that during the Western Han Dynasty, Chang'an Weiyang Palace adopted a rammed earth platform which could not only withstand the tide and was waterproof but also slowly became a symbol of the level of the palace. After the Eastern Han Dynasty (25-220 C.E.), due to the development of structural technology, the palace could achieve a towering main structure and no longer needed a high platform to reflect its majesty; further, the pile-type architectural form was weakened by the lack of wood in the Central Plains. The pile-type building form was not eliminated because it could not adapt to the climate but for other objective reasons. However, in the palace architecture of the Western Han Dynasty, the combination of high rammed earth platforms and pile-type building is fully reflected and the evolution and transformation between the high platform and pile-type building under the domination of different climates are explored through the classification of palaces in four different climate zones (N. Li, 2020). The study of the practices, principles, and energy-saving effects of traditional technical measures can make the traditional technology effectively applied, and explore the enlightenment of the highest ancient construction process to modern climate adaptation.

Tropical Semi-Evergreen Broadleaf Forest

The Lingnan climate has typical humid and hot climate characteristics; the average annual relative humidity is about 80%, and the humid heat time is long compared with other subtropical regions, making the humid and hot climate characteristics more prominent. To adapt to this climate and avoid wild beasts and insects, the Indigenous people adopted the nesting pile-type building, forming the cultural characteristics of the Indigenous architecture (Mai, 2016).

Later, with the armed conquest of the region by the central government, the Indigenous peoples of the region gradually merged with the Han people and slowly changed from the completely open architectural form of the pile-type building with the main wooden structure to the traditional Lingnan building based on brick and wood structures to address the climate problems of Lingnan. At this time, the climate adaptation strategy changed from "complete openness" to "outer closure and internal opening." The highest form of expression of this period is the Nanyue King's Palace, and a study of the palace architecture helps us understand this part of the cultural characteristics.

The archaeological excavation report (Z. Li, 2008) shows that the excavated area of the South Vietnamese palace site contains the remains of three rows of parallel timber structures running essentially east to west, each row being laid in large squared timbers with sleepers beneath. It is assumed that the columns in the northern part of the site, which has been excavated, also correspond to the revealed column positions in the form of a pile-type structure with low brackets, forming the layout of a hall. The silt found in the palace area proves that the foundations were muddy and that the so-called "sleepers" under the square timbers were laying the base for the muddy foundations (Yang, 2001; Zeng, 2002). It is the two rows closer, the column of two square wood strip foundation and a connected shorter square wood (pillow), so that the two joined to form an uneven sinking resistance of the foundation as a whole, to achieve heat dissipation and dehumidification for the wet areas. The ceramic house, as a construction vessel (also known as a medieval vessel) that shows the living conditions and architectural concepts of the ancient ancestors buried in Han dynasty tombs, also reflects this form of pile dwelling. The low walls around the bottom of the house (Chen, 2014) allowed people to keep livestock at the bottom, an improvement on the previous method of piling at the bottom, increasing the space available for the house and making the structure more reasonable, while the emergence of brick and tile also made up for the safety problems of wooden structures that were prone to fire.

This authentic Lingnan style of architecture spread widely and has been in use for a long time. Traces of it can still be seen in some rural areas of southern China – the houses of the Yao people in Guangdong often have miscellaneous items underneath and people living above. The Li people on Hainan Island (Zhong, 2019) have houses which resemble a boat in outline and are spaced out like a cabin, with the whole house off the ground and supported by wooden poles with livestock below and people above, living, sleeping, cooking and eating in the same room. The bamboo houses of the Dai tribe people in Yunnan (Liu, 2010) are also pile-type buildings, and researchers have pointed out that the recent rise of the Riding House in Guangzhou (Huang, 2006) can also be seen as a more recent variation of the pile-type house.

Warm-Temperate Evergreen Broadleaf Forest
Liu Jian's *Book of Great An* mentions that the earliest house inhabited by the Minyue people was a kind of pile-type building, and there are a large number of pile-type buildings preserved here. Fujian, as the starting point of the Maritime Silk Road and Zheng He's voyage to the West, has frequently communicated with the outside world by sea since ancient times. Between Fujian and the Austronesian language areas, there have been waves of cross-sea migration or economic and trade exchanges and other activities in history. Many archaeological discoveries reveal that, due to interactions between Fujian and the Austronesian language area from ancient times to the pre-Qin period (to 221 B.C.E.), immigrants spread the pile-type architectural style, essentially bridging the two places (Liang, 2021) and leading to wide dissemination of pile-type architecture.

Low pile-type architectural forms have also been found in the Gaohuping palace ruins area of Han City, Chong'an, Fujian. The climate of northern Fujian needs moisture-proof structures, and compared to the Nanyue region, the Minyue region has hot summers and cold winters. Pottery pipes arranged parallel and loops were also found in the northeast of the palace, and research speculated that the pottery pipes seemed to be related to heating. Archaeology has found that a low column is placed every one meter or so between the entire row of load-bearing columns of the palace, which is used for laying wooden planks on the upper floor (Lin, 1985). The raised floor originated from pile-type buildings and is the main form of living in hot and humid areas. Based on the central Central Plains approach, the floor is paved with baked earth mounds for fire and moisture protection. The palace of the Minyue King, based on the Han palace system, was adjusted according to the climate. The high-platform had a sub-step in front of it, but the main step was not made into overhead flooring to prevent moisture and ventilate. A version of the low wall was built on the front and the inside was adapted to an elevated floor; from the front, it was completely rammed earth main step (Yang, 2001). In short, its bottom platform is a pile-type building with raised floors and surrounded by rammed earth walls.

For comparison of the climatic adaptability of solid flooring, overhead flooring, and fully open ventilated flooring, experimental studies (D. Wang, 2008) of raised flooring and solid flooring in the rainy season found that the raised floor can significantly reduce the air humidity in the room. Compared with the bottom floor in direct contact with outdoor air, the thermal insulation performance of the raised floor can be improved in situations with unfavorable ventilation. Thermal experiments on raised floors in winter and summer have shown that the thermal performance of raised floors is superior to that of facades and fully open raised floors in this climate zone. Not only can the thermal environment of the room be improved when the air conditioner is not used for heating, but also the heat load of the room air conditioner can be greatly reduced. Therefore, in the Minyue region, although the building is constructed on a platform and has a pile-type structure under the platform, its upper layer and even the roof and other modeling structure styles are no different from similar buildings in the Central Plains. The evolved pile-type palace adopts the form of a rammed earth wall enclosure and middle elevated floor to combine southern moisture insulation, summer cooling, and winter insulation. It reflects that thousands of years ago, in addition to retaining its original reasonable characteristics, the Yue people also absorbed the more advanced architectural structures of other ethnic groups to adapt to the local climate.

Cool Mixed Forest

Traditionally, the pile-type building is considered a southern building; while the general perception is that the north stores grain in the cellar and the south stores it in the pile-type building "Jing" (K. Zhang, 2021), the pile-type granary is also found on the Goguryeo murals in northeast China. Goguryeo was one of the ancient ethnic minorities in northeast China in existence for 705 years; the palace site as a whole is relatively well preserved, and its architectural remains are more known in the architectural circles as a "history of stone architecture." Goguryeo is located in the mountains and plains, so fishing, hunting, and animal husbandry were the main modes of production and lifestyle; because of the life near water and the long cold winter, the place combines summer fishing and winter hunting lifestyles, producing the combination of pile-type building and semi-crypt building. With the introduction of Han culture, farming culture gradually emerged as the main mode of production. The upper nobles did not produce, provided by the commoners at the bottom, so the palace and the noble houses had large granaries, while the commoners were mainly small warehouses.

In the Tomb Mural of Ji'an Masangou (Geng, 1982), there are two floating clouds on the ridge to symbolize the height of the warehouse and the amount of grain storage. Underneath the roof of the barn are four ochre columns which are crossed laterally with planks to form a fence, with two shields in the middle and six ochre pillars at the bottom which are lifted off the ground to prevent the grain from retaining moisture and mildew. Studies speculate that the storage space of the palace was similar to that of the Minyue King's City, and there is a small pillar between the load-bearing columns. Not only that, but large pile-type buildings have been found in the Central Plains of Northern China, Henan Erlitou Ruins (2070-1600 B.C.E.), Zhengzhou Shang City (1600-1046 B.C.E.), and Yanshi Shang City Palace Ruins (1600-1046 B.C.E.). These overhead pile-type buildings are simpler to build than the cellar, the cost is lower, they offer ventilation and are moisture-proof, and the bottom area of the pile-type building can also be used as tool storage. This breaks the inherent understanding that pile-type architecture only exists in the south and expands the application area of pile-type architecture.

The adjacent Korean Peninsula, due to similarly long and cold winters, has formed characteristic Korean houses over thousands of years of architectural evolution due to its distinctive maritime characteristics. Compared with the Minyue region, the winter in this climate zone is colder and longer and the pottery pipe heating no longer suffices, leading to Korean houses evolving into a characteristic full layer ondol over the generations. The ondol structural form can be seen as a combination of pile-type and high platform, with the bottom floor overhead to isolate moisture but enclosed and combined with high chimneys to form an underfloor heating space. Compared with the northeast region of China, the Korean ondol overhead height is small and the heat transfer range is wide. Ondol makes full use of radiation, conduction, and convection to achieve efficient use of resources.

Cool-Temperate Evergreen Needleleaf and Mixed Forest

In 1940, the ruins of a Han-style palace were discovered eight kilometers from Abakannan, the capital of the Hakas Autonomous Republic in present-day Southern Siberia, Russia. From 1941 to 1946, Russian archaeological teams excavated the site and found a central hall and wing-room which were restored into a roof-like building with four-sided sloped eaves, known as the "northernmost Han palace." There is an overhead layer under the main hall and house, and heating channels inside made of stone, twisting and turning rings which lead into the main hall and more than half of the houses to form central heating, so as to ensure higher indoor temperatures and adapt to the local cold climate.

A summary of ancient building forms can provide examples and references for climate-resilient design of future buildings (Figure 4). In modern prefabricated buildings, the synergy between raised floor and dry floor heating separates the pipelines and is an integrated ground that is installed in combination onsite, consisting of an adjustable support structure and surface layer. By adjusting the supporting foot to bring the ground to a uniform height then installing the force plate on it and laying the ground finish material, the overhead cavity can be laid with drainage, heating, electrical, and other pipeline equipment. The ground overhead layer ensures the flow of air under the floor and offers better thermal insulation performance.

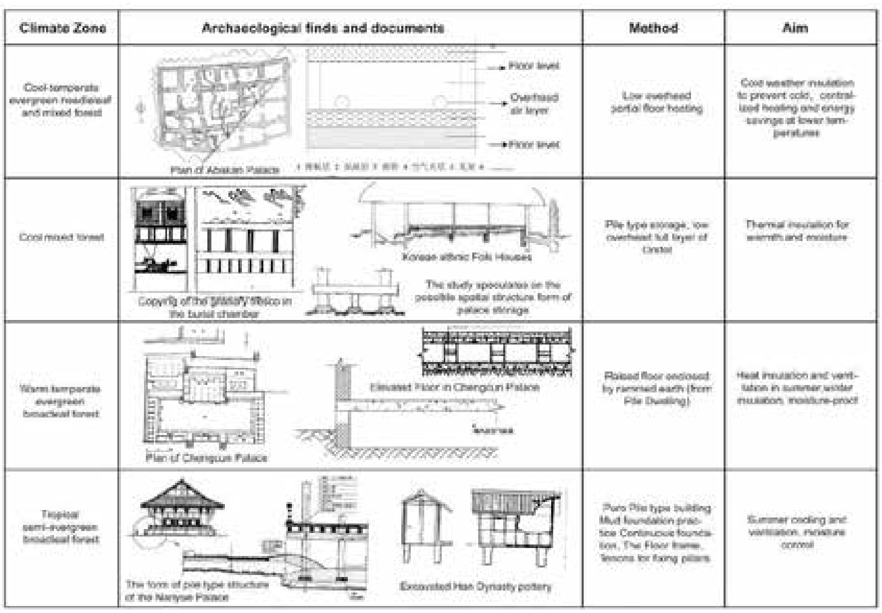

Figure 4. Comparative analysis of pile-type buildings for four regions.

Findings

The study found that pile-type buildings are beyond the previous understanding, not only distributed in the south but with moisture-proof ventilation. In the study of the pile-type architecture of the four palaces and their areas, we have found that the pile-type building manifests differently in different climate zones; the further south one goes, the pile-type building forms presented more purely due to the stronger demand for ventilation (Figure 5). In the tropical semi-evergreen broadleaf forest zone where the Nanyue King's Palace is located, pile-type buildings used the completely open form of overhead on the ground floor to achieve ventilation and allow for heat dissipation and dehumidification. The warm-temperate evergreen broadleaf forest zone where the Chengcun Kingdom Palace is located needs to take into account dehumidification and cooling and certain winter insulation requirements, mandating the enclosed overhead floor pile-type building. The architecture in the cool mixed forest zone where the Goguryeo King's Palace is located takes into account both moisture protection and thermal insulation needs as seen in the overhead full layer ondol form of the Korean ethnic groups. The cool-temperate evergreen needle-leaf and mixed forest zone where the Abakan Palace is located combined the overhead form with underfloor heating to enhance convective overhead floor radiant heating, demonstrating the need for stronger protection from the cold.

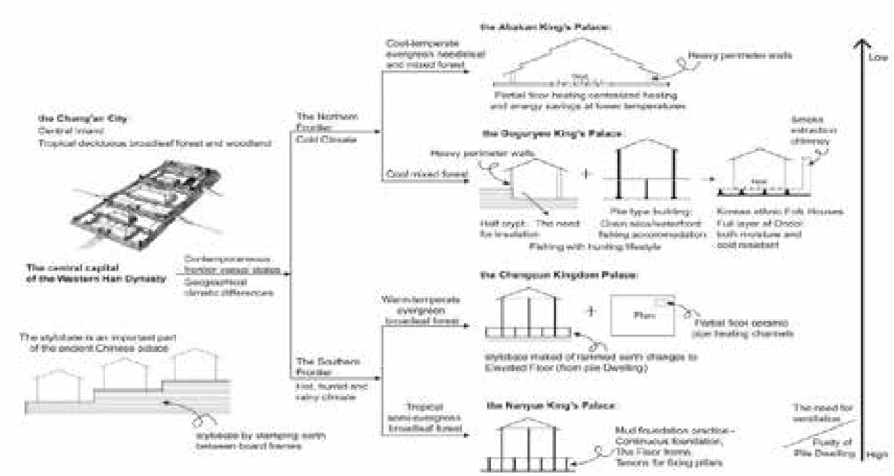

Figure 5. Climatic influences on the changing form of pile-type architecture in the palaces in frontier vassal states.

Discussion

Several of the palaces in this study include world cultural heritage, and the research is very significant. In ancient times, passive energy conservation was mainly used and the palace, as the most skilled building in the history of Chinese civilization, was studied to help us inspire modern buildings in terms of energy conservation. In addition to the palace, the pile-type building was widely distributed in ancient local houses since it is simple in structure, low in cost, and can be constructed using local materials, so it can become a more equal form of climate adaptation.

However, the superstructure of the palaces has been damaged to a certain extent by war and dynastic renewal, the archaeological excavation is not yet complete, the materials used in the pile-type building are organic so their durability is poor, and the proof data that can be obtained is not complete enough and can only be studied with the help of data documents, image retention, and excavated tools. In this regard, we still need to investigate in-depth. In addition, for the modern application of pile-type buildings, the large-scale use of wood has a large environmental impact and is not feasible. Therefore, in learning traditional technologies, it is necessary to enhance the strengths, abandon the shortcomings, and choose the most reasonable ways of using them.

Conclusion

With the development of modern conceptual awareness and structural techniques, we dug into the spatial forms of traditional architecture that have developed from the pile-type building, which were richer than we expected. Amongst other things, pile architecture in the Lingnan region has developed into a cavalcade style which has many benefits in terms of climate adaptation and its regulation as it develops further into taller buildings, as Le Corbusier did: the ground floor was raised so that the ground could be used, the buildings led to roof gardens, and the underground railway ran underneath. The result is a model of a city with maximum access to daylight and ventilation, which is also very useful for urban integration, visual permeability, and climate adaptation.

In-depth studies into traditional techniques like pile architecture could be rewarding when thinking about the inherent logical connections, the composition of its elements, and its variables, and then applying them flexibly to the practice of architectural design, which we believe will be very inspiring for the adaptation of modern architectural design to the climate.

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CO-CREATING VISUAL DIALOGS FOR CRISES AND EMERGENCIES: CLIMATE SCENARIOS AS OPPORTUNITIES

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Abstract
Today we live with the impacts of natural events causing complex transitions such as crises and emergencies – among them social, climate, and health – with large impacts on the experience and development of communities. Such a massive change brings an urgent need to adapt the scope and practices of design. Considering such challenges as opportunities, this paper presents two main focuses: on one hand, the importance of sharing and delivering simple visual information tools to optimize communication and interaction in critical contexts; a collaborative information kit for managing Covid-19 is one example. However, some local interpretations and practices affect the performance and involvement of effective communication for critical scenarios, constituting permanent challenges. On the other hand, emergent scenarios constitute complex transitions that stimulate new approaches to managing crises and emergencies. Here, participatory workshops that evolved from face-to-face to online platforms evidence practical ways to adapt. The cases presented here extensively utilize the Guemil Icons for Emergencies, a project developed by a team from UC School of Design, Chile (Diseño UC) and the National Research Centre for Integrated Disaster Management (CIGIDEN). Through the cases, this paper shows how exploring open tools – such as visual tools – and co-creating instances for dialog – such as participatory design – constitute approaches to the role of an adaptation defined by design, perceptions of experience provided by discovering what communities think and know. Therefore, new ways to communicate need innovative approaches to adapt to upcoming crises and emergencies. As the conclusion emphasizes, climate crises bring new opportunities and an open design approach facilitates collaboration, promoting resilient cultures; design for adaptation constitutes a starting topic.

Author Keywords
Visual; dialogs; crises; climate; adaptation; experience.

Introduction
Today, we live with the impacts of natural events causing complex transitions such as climate emergencies. In line with the topic of design adaptation, this paper explores the possibilities of developing projects that, starting from information needs, aim to contribute to dealing by design, generating the chance to co-create visual dialogs for crises and emergencies. Integrated into this complexity, design becomes a multidimensional key

resource, facilitating community communication in risk and emergency contexts. Principles of communication, information, and participatory design are explained as a part of this process. Two real study cases will be developed as examples:

- Case 1: Visual tool development involving open-access projects that integrate visual design, creative performance, and collaboration.
- Case 2: Participatory design to manage crises and emergencies that expands and integrates collaborative design into other disciplinary spheres.

Both cases complement each other in illustrating how such disruptive experiences might be adaptive by design and how they can contribute to creating new ways of approaching the management of crises and emergencies, enhancing participation. Examples demonstrate how visual information for crises and emergencies integrates visual communication and collaboration, revealing potential. Critical scenarios, such as the Covid-19 pandemic around the world, constitute opportunities for developing innovative approaches that articulate change. As this paper will present and discuss, design offers an opportunity to confront such challenges and create a culture of adaptation and resilience. Future scenarios such as the climate will bring new challenges; such final thoughts are explored in the conclusion.

Context: Crises and Emergencies

Crises and emergencies are considered a combination of local and global topics with implications for ways of living that modify design and communication, forcing us to think and act around new possibilities. Nowadays, approaches centered on risk reduction, such as those by the United Nations Office for Disaster Risk Reduction (UNDRR) (2015, 2017), constitute a paradigm in transformation: from dealing with disaster effects to a focus on preparation and prevention where approaches to communication and collaborative processes become fundamental, i.e. designing for moments such as before, during, and after a critical event (Twigg, 2015). This is defined by UNDRR (2015) as disaster risk reduction (DRR). Figure 1 illustrates a conceptual framework, with risk experience and information demands as a continuum of communication (Ramírez, 2020).

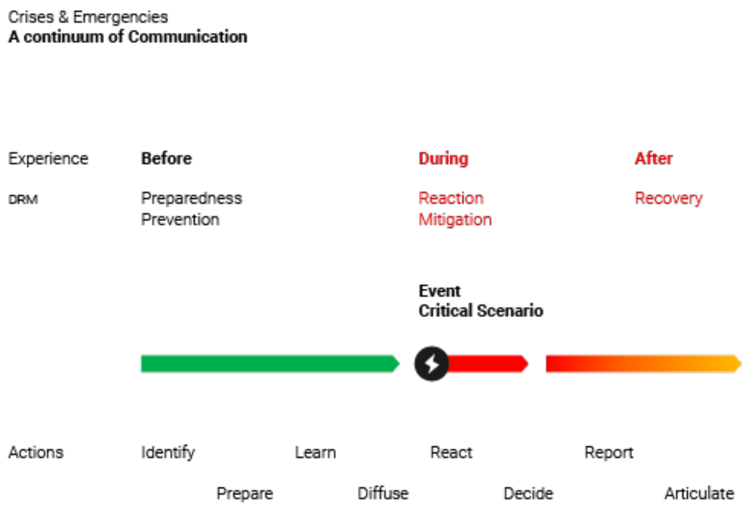

Figure 1. Conceptual framework. A continuum of communication: experience, disaster risk reduction, and actions considered in different moments (source: Ramírez, 2020).

The context of developing such activities allows for approaching design as a changing paradigm: from dealing with disasters and their consequences to the application of disaster risk reduction policies and strategies to manage risks. As observed from the experience of individuals and communities, DRR defines concrete actions, prioritized in multidimensional frameworks such as the *Sendai Framework for Disaster Risk Reduction 2015-2030* (UNDRR, 2015). Disaster risk reduction is aimed at preventing new disasters and reducing existing disaster risks. Considering the *Sendai Framework*'s priorities, such as "increase preparedness for disaster, in order to respond with effectivity and efficiency to facilitate recovery, rehabilitation and rebuild," the framework promotes the use of information tools – among them visual language-based applications – to effectively communicate critical messages, contributing to bypassing access, cultural, or language barriers (UNDRR, 2015). Such context poses essential questions and challenges for design, bringing new opportunities for developing innovative approaches that articulate experiences of adaptation, among them those for communicating the experience of crisis and emergency.

Critical scenarios emerge as activators of information and communication needs. Thus, actions – such as preparing for, reacting to, and recovery from – become articulators for designing information for crises and emergencies. However, to transform such experiences requires interactions with information to become visible, understandable, and simple to transfer into actions. It is fundamental not only to give shape to these concepts but also to provide users with the ability to understand visual languages and apply messages.

Designing for Adaptation

Design today is a reflection of contemporary challenges faced by humanity, articulated by solutions such as communication of causes, impacts, and procedures. Based on creativity and social responsibility, designers detect needs and find solutions to facilitate everyday interactions, contributing to adapting and transforming scenarios. In all circumstances, visual information is a central part of everyday experiences. Precedents in graphic information design include visual campaigns that are educational/instructional, with the most well-known solutions including signage, infographics, or digital apps. However, such supports also have limitations, among them access, literacy, and technology. When designing for adapting to critical experiences, actions such as identifying, preparing, mitigating, and recovering become fundamental.

Information design has been defined as the art and science of preparing information to be usable by human beings with efficiency and effectiveness (Horn, 1999). As a multi-discipline, information design emerges as a response to people's need to "understand and use" everyday information, contributing to "mak[ing] the complex easier to understand and to use" (Barrat & Walker, 2005). Ideally, a designed message allows people to visualize, understand, and facilitate their decisions. Throughout their methods and developments (among them visual), diverse communication supports are developed, aspiring to be distinguishable, understandable, and applicable in multiple contexts.

In everyday contexts, interacting with information can be understood as a sequence developed in three steps: visualizing, understanding, and applying information which contributes to visualizing, seeing, comprehending, and applying visual contents that are clear, opportune, and transferable to actions (Allard et al., 2014). However such a sequence is also projectable to those needs generated by crises and emergencies, designing information is going beyond visualization to action in a permanent adaptation. Thus, designed information can impact transforming experiences in moments before, during, and after an emergency or critical event (Ramírez, 2018, 2020).

Designing information creates opportunities to prepare for potentially critical scenarios involving the climate or hazards, facilitating seeing, understanding, and applying the information for effective management of risks. In other words, optimally designed information requires advancement beyond the development of nice visuals or public relation messages: to adapt the messages to the experiences of communities at risk, it is necessary to explore and develop new ways to stimulate engagement and co-creation, focusing on meanings.

Adaptation might be considered a challenge for projects in design. Graphic elements with common interpretation can contribute to constructing meanings, then transform a visual language into action, promoting the identification of risks, preparedness, and adaptation, among other factors. However, a critical factor is that information is usually informed by local interpretations or meanings – cataloging the associations that a person can make from a particular representation such as a symbol is an example of this (cf. Ramírez, 2018, 2021).

Visual Communication as a Dialog Activator

Design today needs to facilitate everyday experiences, contributing to new possibilities and transforming realities. Design is key to recognizing and understanding problems, needs, and eventual demands, from observing to proposing creatively to transform; as Sanders (2002) states, "Discovering what people think and know provides us with their

perceptions of experience."
Considering the *Sendai Framework* priorities – such as "understand the risk of disaster" – as activations, dialogs that apply visual components to facilitate the access and discussion of scenarios add information that is relevant and meaningful, giving participants a chance to create their own interpretations (UNDRR, 2015). In this context, an emergency becomes an activator of needs, among them those of communication and information. A focus on adaptation might be an exploration of possibilities for the communication of such scenarios, empowering communities to co-create their own approaches, transforming the whole experience.

However, variables such as access barriers, disinformation, and local interpretations constitute permanent challenges for effective communication. Through simple tools and engaging creative methods such as participatory activities, these are opportunities to discuss and create meaningful interpretations in local, regional, and global contexts. For example, for discrete units of meanings such as symbols or icons, theoretically, their ubiquitous use supposes they might be interpreted in an unequivocal way intended to be universal (Boersema & Adams, 2017). However, as Mejía and Zender (2013) state, in practice, this is a controversial variable, especially in critical contexts where the message delivered is highly meaningful. To test indicators such as meaning and representational preferences, different initiatives such as user tests allow us to collect and measure interpretations. Information about performance such as precision in interpretation is then analyzed to indicate their performance, following methods based on the work of Brugger (1999), ISO (2011), and Frascara (2015). Tests reveal if each representation is associated with the expected meanings, or if there should be other factors to consider such as the cultural background, language, previous experiences, or familiarity with the represented concepts (see www.guemil.info).

Thus, from discrete solutions to the implementation of design systems' reshaping of visual communication supports, experiences facilitate nurturing dialogs from scenarios, identifying hazards, or discussing disaster risks. It is crucial to involve different participants and communities to define performance, approaching what Sanders (2002) calls "design for experiencing." Such articulation by design is a permanent call to explore innovative, open collaboration processes where design is a way of thinking-doing, a node to facilitate the exploration of new scenarios.

How does the projectual approach create adaptations? The following developments will show opportunities to explore design processes and tools, and how co-creating visual dialogs is a way to adapt and re-design the experience of an emergency by enhancing participation. Approaches to disaster risk reduction through education as reviewed in Cabello et al. (2021) evidence the opportunities to approach these emergent and critical scenarios in multiple ways, empowering collaboration and creating new ways to adapt. Two study cases are showcased in this paper; these are supplemented with examples and discussion.

Case 1. Visual Tools for Emergencies
This is a design development to create a response for stating a common language that uses icons and texts, generating information pieces that explore adaptive participation in crisis scenarios by deploying visual information in simultaneous formats. Such different

pieces are open-access and available to use both in print and digital forms. Visual design, testing, and activities are being developed, adding participative co-creation. Examples of applications include:

- **Guemil Infokits Covid-19:** Observing critical scenarios and their information needs, opportunities arise to develop new tools and involve communities. One visual language activator for communicating in emergencies is Guemil Infokit, a set of pictorial instructions for Covid-19 management. These are visual information multiplatform pieces (print and digital) that facilitate access for managing Covid-19 through simple instructional messages. Considering cultural inclusion, texts are translated by collaborators locally and around the world, so far to 15 local languages, including Quechua, Hindi, Mapudungún, Náhuatl, Kreyòl, Guaraní, and Rapa Nui, among others. Figure 2 shows this system, composed of twelve boards.

Figure 2. Guemil Infokits is a set of visual tools to manage Covid-19 risks that integrates instructional messages and texts translated collaboratively tino 15+ languages.

As a simple design system, Infokits exemplifies how systemic thinking contributes to implementing simple information solutions. Besides being easy to implement in digital and physical media, these can activate multicultural dialogs, resulting in meaningful communication devices for communities.

- **Guemil Activators:** This is an experimental set of visual pieces, where activation is driven by instructional design principles: how-tos and dos and don'ts for a specific situation (i.e. tsunami evacuation or heat wave). Activators are designed to combine both pictographic and textual information to be deployed as synoptical sequences (a sign or printed piece) and as discrete images for digital supports (scrolling or animations). Figure 3 shows examples of such graphic tools being co-developed by designers and validated by researchers and communities of practice (i.e. CIGIDEN).

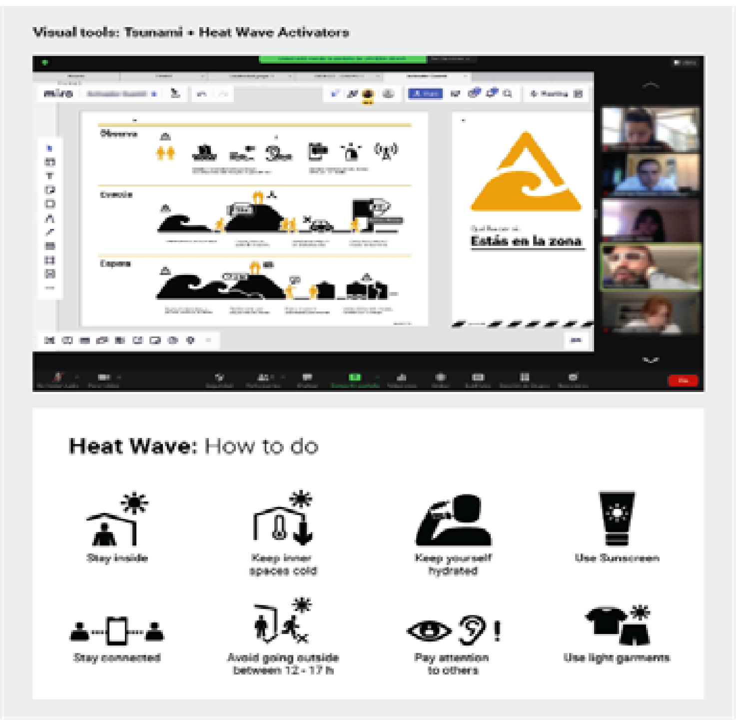

Figure 3. The graphic tools called Activators are designed to visually help users manage a critical scenario such as a tsunami evacuation or what to do in a heat wave.

A symbol set such as Activators and its information products constitute evidence of the potential role of visual language in critical scenarios. Graphic components are validated by experts and tested by users as a way to collect interpretations and measure if graphic language is effective in creating comprehensible and usable communication. As a result, Design + Performance acts to obtain an articulator resource for the communication of risks and emergencies (cf. Ramírez, 2021).

Such a collaboration between design and validation generates a body of knowledge as content for research and development (different tools and kits can be viewed at www.guemil.info). The set also constitutes a design system that allows further participatory design initiatives, such as creative workshops, to activate dialog. Initially designed as face-to-face meetings, they were implemented as hands-on workshops, evolving to remote modes that adapted to pandemic challenges, expanding their limits. This participatory process is explained in the following section.

Case 2. Participatory Design: Adaptation with Users

Participatory design can be defined as a projectual approach where processes (i.e. involvement) are more important than outcomes. As Sanders (2002) indicates, this is "a shift in attitude from designing *for* users to one of designing *with* users." In participatory experiences, the participant becomes a critical component and designers become facilitators of the process. An outcome is usually a dialog, activated by the creative task (challenge), where the process (collective ideation) is equally as important as the result (prototypes). Co-ideation of disaster preparedness strategies with participatory activities have been described by authors such as van Manen et al. (2015). This case is mainly composed of six workshops adapted to the Covid-19 emergency (2020-2021), working with community groups from schools, research centers, and public organizations. These were organized with local organizations and academic institutions in Chile and Peru, giving shape to new ways to adapt and create transformative dialogs, from face-to-face activities to remote on-screen interactions and outcomes. An example of such a practical instance is:

- **Workshop "Visual Information for Emergencies":** As an instance first created to explore the application of Guemil Icons in educational situations, this workshop consisted of a creative activity based on an open design process and co-creative design principles, such as ideation and rapid prototyping. "Visual information design for emergencies" was a practical, hands-on workshop where participants started by discussing their own experiences in an emergency, generating dialog. Then, through templates and processes such as ideation and compositions using paper prototyping, they developed solutions in a limited timeframe (usually 60 minutes), displaying visual information in discrete signs or sequences.

Workshop outcomes are sequences of visual instructional or signage information, combining text, icons, and colors to identify hazards, manage risks, and transform the scenario originally defined. Both internal dialogs and external presentations enrich the participatory experience. For the implementation, diverse tools and digital platforms were explored, i.e. Miro, Unity, and Github, among others. All workshop resources are available from the Github repository (www.github.com/Guemil). Figure 4 illustrates the results from such experiences.

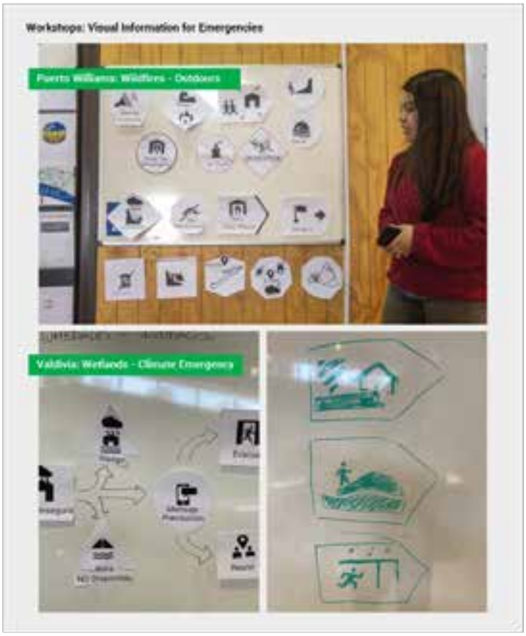

Figure 4. Participatory workshops applying rapid-prototyping. Puerto Williams Chile, 2020: the last in-person workshop before the pandemic, topics referred to outdoors and wildfires in Patagonia. Then, in late 2022 in Valdivia, Chile, topics referred to local climate emergencies such as floods and wetlands.

- **Disaster Imagination Game (DIG):** A creative, hands-on method for disaster drills conducted in community-based workshops, DIG was originally developed in Japan and described in Huamán et al. (2019). This creative game uses a cartographic representation as a base for participants to work on a given challenge – a disaster scenario. They define how to deal with different situations, establishing roles and activities to solve the scenario through collaboration. Returning from online to face-to-face activities, we adapted DIG principles to explore ways to connect when working with communities. Figure 5 illustrates the DIG application, with a map of a local school being used to work on a tsunami evacuation challenge with the community in Cartagena, Chile.
- **CreaGuemil:** A web application that facilitates creative working with remote participants, CreaGuemil was designed as a game interface based on the Unity game engine. It is a digital adaptation of the “visual information for emergencies” workshop, designed to facilitate their online implementation during the Covid-19 crisis. It was supported by the Chilean National Arts Funds, Design Research, FONDART 2019. Figure 5 shows the results of participatory sessions during 2020 and 2021, applying DIG in massive online sessions using CreaGuemil with nearly 120 participants.

Figure 5. Participatory workshop in Cartagena, Chile using the DIG technique, identifying risks and hazards for a local school community in collaboration with CIGIDEN. An outcome from the remote workshops conducted using the web app CreaGuemil (2020, 2021).

Discussion

As shown, designing for the experience of crises and emergencies brings opportunities for new creative visions that become meaningful for individuals and communities. The cases highlighted illustrate how design requires continuously evolving for adaptation: from symbol sets to an exploration of multi-platform solutions to stimulating creative dialogs involving sharing how communities approach their own critical experiences.

Regarding specific tools and methods for approaching critical scenarios, different design-led approaches allow the designer to make, reflect, and involve communities in co-creating new ways to dialog. Such a development of instruments and platforms enhances their implementation, showing how to deploy new possibilities for facilitating the adaptation of communication through simple design systems and opening the scope to scenarios on global and local scales. Exploring needs and meanings and combining applied methods and tools, visions, ideas, and local adaptations to manage risks reduces vulnerability and fosters resilience. Most activities are customizable and can be integrated with others already available, making it possible to combine specific tools, procedures, and practical principles. Such cases demonstrate how it becomes possible to explore innovative ways of creating conversation and networks through the adaptation of collaborative platforms.

It is fundamental to continue promoting open access to information, collecting interpretations, and involving interactions from those who participate, in parallel with refining creative processes. Drawing on a permanent adaptation, new roles for design become possible (i.e. designers as facilitators in participatory processes). However, beyond each of the solutions and systems presented, there are practical aspects to manage, and some questions to address through the implementation of different supports and dynamics as ways to manage critical scenarios for projectual disciplines. Going beyond the cases presented above, additional opportunities for collaborative development connecting topics in design and emergencies are:

- The "Integral Plan of School Safety" (Plan, Integral de Seguridad Escolar (PISE) Chile) (2018). This is a public policy, oriented to integral safety through prevention, mitigation, and preparedness, considering challenges such as climate adaptation as a part of their integral approach. Topics such as drought or heavy rains evidence how exploring topics such as emergencies and combining education policies allow for collaboration between multiple actors. As an example, the participatory online workshops conducted during the Covid-19 crisis were presented in a Chilean National Conference for Public Education in December 2020.
- The Design for Emergencies workgroup from UC Chile School of Design. This multidisciplinary group involves design teaching applied to research and development, covering topics in crises, emergencies, or preparedness as opportunities to explore, prototype, develop, and test solutions by applying products, services, information, and user experiences. Collaborating with scientific research centers such as CIGIDEN and public organizations such as the National Agency for Emergency (ONEMI), their projects and results give shape to their research and development line in Design for Resilience, published on the website www.d4rs.info (2020).
- The *Workshop Guidebook Design for Emergency Management* is a practical guidebook edited by a multidisciplinary team at the Design Network for Emergency Management (www.DNEM.org , 2019). It is intended for designers, emergency managers, and other interested parties and provides an easily accessible overview of visual language, iconography, cognition, rapid prototyping, evaluation, and ethics in emergencies. The guidebook is available in both print and digital formats and includes activities such as design workshops for emergency management.

Such opportunities demonstrate the importance of promoting interdisciplinary collaboration and embracing a permanent adaptation. Empowering communities with simple and accessible platforms for participation and preparedness, such projects combine tools for interaction, validation, and a permanent transformation of the experience in order to adapt to incoming scenarios, since "discovering what people think and know provides us with their perceptions of experience" (Sanders, 2002). Such topics constitute reflections to conclude this paper.

Final Reflections: Opportunities for Adaptation

Approached from a design perspective, the cases presented here show how crises and emergencies constitute challenging topics to create participative and creative dialogs to deal with adaptation. In recent times, limitations such as those from the Covid-19 global crisis have constituted opportunities to explore and develop new ways to create visual information supports, expanding their reach as a tool for adaptation to upcoming scenarios such as multicultural exchanges.

Transforming experiences is a permanent opportunity for collaboration and creating cultures of resilience: as the cases demonstrate, designers consider such perceptions a new way to explore joint solutions and co-develop possible futures with new ways to adapt through dialog, imagination, and interpretation. Collaborative design possibilities stimulate discussion of tools and activities such as open platforms and participatory instances. Following the presented cases, opportunities for adaptation appear by applying visual languages, education, and information:

- **Visuals as a Common Language**
  It is important to focus on common challenges that are permanently open to inclusion as a topic for workshops and conversations. Participants provide their perceptions of experience on local and global scales, sharing a visual language for adaptation (i.e. open-access). Visual tools allow us to contextualize, dialog, and apply, promoting a collective consciousness about critical experiences. By generating and verifying common languages, it is possible to co-create possible futures, contributing to mitigating the effects of events that turn into disasters. Facilitating open access to information is key to confronting coming challenges.
- **Educate for Adaptation**
  Another opportunity to amplify the action field of design is to create collaborative networks that face adaptation at local and global levels; education is a key asset to construct such adaptation as a permanent task. Multicultural variables are also key to facilitating access to visual tools, instruments, and methods that allow us to visualize hazards or eventual crises, understand scenarios, and activate preparedness – for example, those derived from displacements or pandemics. Moreover, design based on creative collaboration constitutes opportunities for visualizing local knowledge; a long-lasting impact is oriented to educate for resilience.
- **Information for Preparing**
  A third opportunity is to design information systematically, integrating multiple supports and applications from those needs that are promoted by communities towards the facilitation to generate their own instruments and methods. Information systems can facilitate preparedness and adaptation to incoming scenarios. Evolving from discrete solutions such as symbol sets to design systems, new applications are being explored for visual communication created with communities. The cases presented here go beyond the graphical exercise of developing supports or

campaigning towards deploying creative possibilities, activating communities, and facilitating measurable and meaningful dialogs. Sharing design principles allows us to observe the reach of information by involvement, permanently inviting us to participate in interpreting meanings for risk, hazards, or disasters. All contribute to preparing, adapting, and transforming the experience.

Climate Scenarios: The Next Adaptation

As mentioned before, critical scenarios become opportunities for participation. Aiming to amplify the field of action, identifying common challenges as a matter of concern is key. Such scenarios demand new roles, approaching both practical and collaborative levels. Climate challenges are an urgent topic to manage with design. The projects shown provide the opportunity to explore both creative and social approaches, balancing reflection and doing. Risks, crises, and emergencies will continue bringing challenges and changing behaviors, systems, and environments for design makers and practitioners. Such transformations bring massive challenges that constitute opportunities to explore and develop innovations for permanent adaptation. In a rapidly changing context, climate impacts need open-access design approaches: such solutions materialize in information products and creative dialogs, contributing to reducing the perception of vulnerability, helping to identify potential risks, and aiding in transforming the experience.

Specifically, visual communicators must question and adapt, from the creation of messages containing meaningful contents to the representation of global identities while also considering singularities in a process that involves communities and creates ways of adaptation. How do we activate adaptation by design? In our experience, information designed with active participants can enhance preparedness, contribute to decision making, and create adaptive ways to face incoming scenarios.

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COLLABORATING TO BUILD RESILIENT COMMUNITIES: CREATING A MODEL FOR SUSTAINABLE COMMUNITY SPATIAL RENEWAL

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Abstract
This paper examines the positive impact of collaboration between government, designers, and community residents on the resilience and sustainability of communities through current design practice. The design practice is an urban renewal event initiated by the government based on China's urban development shift from incremental expansion to sustainable stock resource exploitation. It has been successfully held for four years. The fourth edition (this project) of the event is a micro perspective of the community space, with a real focus on the needs of community residents.

The project aims to help urban communities gain better sustainability, comfort, and accessibility to public space through low-intervention strategies on stock land resources so that local governments, residents, and designers can be connected through a process of social participation. This paper advocates the active impact of design initiatives for community public spaces in response to urban development and social change. It analyzes how to design interventions for public spaces that can improve the adaptability of older communities in the modern urban development process. Through the idea of integrated resilient cities, design empowerment connects government-initiated design activities to the community, creating a new model for micro-renewal of sustainable community public spaces (Ahmad & Talib, 2015).

The project site is one of Shanghai's communities, which contains the earliest workers' village in Shanghai, built in the 1950s. There is a low level of spatial participation throughout the community due to housing conditions, outdated infrastructure, a lack of quality public spaces, and many leftover spaces that are not well utilized. Therefore, the project develops solutions through small and incremental steps. In curated exhibitions, urban furniture (artistic sitting furniture, telephone booth art gallery, child-friendly activity facilities, public art) are placed as exhibits in some of the leftover spaces in the community's public space. In this way, the public space of the entire community becomes a "public exhibition hall" and a "community living room," and the design strategy maximizes solving the leftover space in the community to meet the daily interaction needs of the community residents. Some co-creation activities will be held with community residents during the exhibition to facilitate effective civic empowerment through social participation and engagement. Ultimately, the design study creates a new model of "exhibition for building" community renewal and considers the future direction of community resilience and sustainability. At the same time, the exploration of this model provides new ideas for adaptive design in older communities, contributing to social innovation and providing well-being for community residents.

Author Keywords
Resilient communities; public space; sustainable urban renewal; adaptive design; "exhibition for building."

Introduction

Since 2013, the Chinese government has gradually implemented a sustainable development strategy, and China's urban development has entered a new stage of action with the stock of spatial resources (Wang & He, 2015). In Shanghai, due to economic and other reasons, many old communities in the urban area are long-established. The accelerated urbanization process has led to the decay of these old neighborhoods, which are not well adapted to the development of the times, thus creating a series of social problems. The Shanghai government has launched a top-down urban public activity since 2015 to enhance the resilience of older neighborhoods and restore urban adaptability. This activity is a crucial practice around the interaction between public art and the spatial environment at this stage in China and an essential exploration of the current urban renewal process.

The activity has now been successfully held for four years. The first three editions had a more macroscopic perspective, focusing on the transformation of urban industrial sites on a large scale. The fourth edition microscopes the view into the community space, with the theme "15-Minute Community Living Circle – People's City," and studies the needs of community residents.

The project site is located in a community with a strong sense of life, a high percentage of elderly and children, and a traditional old workers' new village. Since more than 70% of the existing community are old houses built in the 1950s and 1980s, the area inside the homes is about 40-60 square meters, with less space available for indoor activities, and the residents have a high frequency of use and demand for public space. In the fieldwork process, many cases were found in which the changing times and the changing needs of residents led to a decrease in the utilization rate of some spaces, a weakening of space functions, and a large amount of leftover space. Faced with the growing needs of the urban population, the public facilities and public space environment of communities urgently need renewal.

In the above context, how can designers use their practical expertise to empower design to restore adaptive capacity in older communities? Design requires a new, more proactive approach to economic and social change. Design must shift from passive to active (Lou, 2010).

Therefore, in the context of government-led projects, the designer coordinates all stakeholders in a collaborative co-creation and brings into play the initiative of the site users (residents) in the community building process. Combining the top-down approach of the government and the bottom-up approach of the community, they jointly promote the adaptive development of old communities towards a new model of spatial and social resilience (Thorpe & Manzini, 2018).

Resilient Design Enhances Adaptability in Older Communities

Theories Related to Resilient Cities

Resilient cities were originally applied to disaster preparedness, particularly for response and recovery from unexpected emergencies. In recent years, the concept has received renewed and widespread attention due to the outbreak of the Covid-19 pandemic. Resilience is the ability of a social-ecological system to absorb or withstand perturbations and other stressors, keeping the system within the same framework and essentially maintaining its structure and function. It describes the degree to which a system can self-organize, learn, and adapt (Holling et al., 2002). Urban communities are facing adaptive issues such as environmental, economic, and social well-being, proposing the use of restoration, acupuncture, and other methods to make communities healthier and more dynamic (Pearson et al., 2014).

Social resilience is operationalized as the ability of social systems to maintain functionality while promoting social trust, reciprocity, collaboration, and characteristics among networks of different sizes (Putnam, 2015). Social resilience has three main dimensions: the ability to cope, the ability to adapt, and the ability to change (Keck & Sakdapolrak, 2013).

Impact of "Resilience" on the Adaptability of Older Communities in Modern Cities

Older communities are not better adapted to the rapidly developing urban environment due to their long construction time. Therefore, it often leads to physical space problems and internal social cohesion problems in communities, producing lower spatial functional and social system resilience (Ni & Cattaneo, 2019). Consequently, the design team used adaptive intervention strategies to create spatially, systematically, and socially oriented resilient communities. We coordinate government, community residents, and designers to explore the spatial potential of older communities, restore their self-adaptation to modern cities, and promote more sustainable urban development (Webb et al., 2018).

How Do We Collaborate to Build Resilient Communities?

Stakeholder Collaboration

In this project, three different important groups of participants were involved in co-creation (Figure 1):

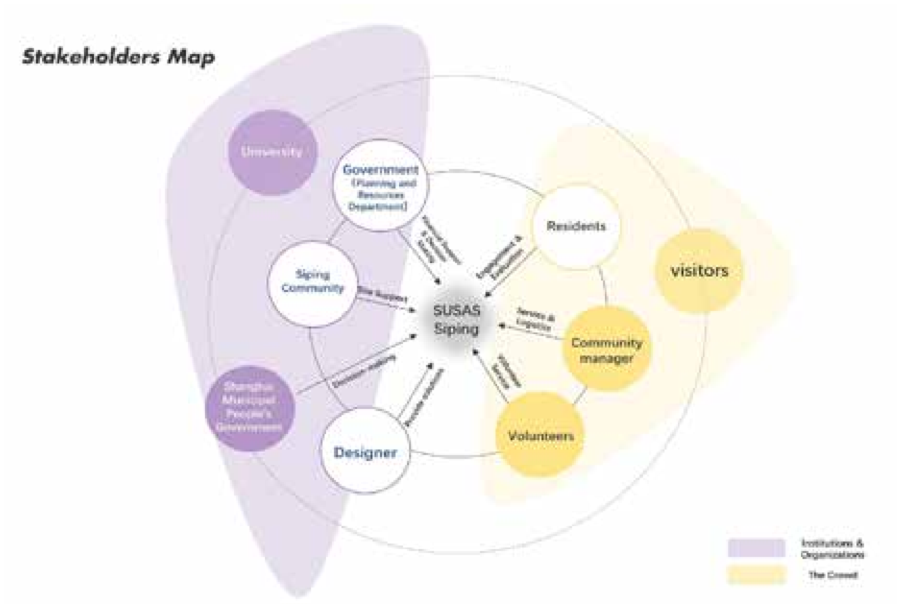

Figure 1. Stakeholder map of the co-creation process.

1. Government agencies.

Government agencies are also divided into municipal government functions and local governments in the community management sector. As the initiator of this project, the city government plays a leading role in controlling the direction of the entire project. It also plays a vital role in terms of funding and policy support. The community's local government has a more comprehensive understanding of the community. It proposes a general plan of expectations for the community and reflects the excellent reference value. At the same time, the local government is responsible for mediating communication between the designer and the municipality and conveying adequate information. Therefore the idea of combining with the top-down strategy of the government can make the whole project process go smoothly.

2. The community residents are also the actual users of the public space.

Several co-creation workshops were held before and after the project to discuss environmental issues about the community space and conceive a vision for the community's future development. They were encouraged to express their life scenes, memories, and community stories. At the same time, the community spatial environment was scored in grid-based zoning based on the daily use of the community's public space, thus categorizing the public space and laying a compelling foundation for subsequent design planning. The participation of residents also creates a direct connection between the space and its users to facilitate the restoration of social resilience.

3. Professional designers, artists, and design students from nearby universities.

The designer's role in this project is more like that of a coordinator by building a platform for community co-creation, integrating the needs of different stakeholders, and coordinating the strategies proposed by the government from the top-down and the visions described by the community residents from the bottom up. The final result is the best solution to solve the actual problem and help restore community resilience.

A curatorial approach is explored through tripartite stakeholder collaboration for systematic and sustainable regeneration planning in community public spaces. Based on several workshops, a summary of residents' opinions on the public space environment, and their votes, the final spatial scope of the design intervention was focused on a linear public street in the community. This street, the most frequently used street by the residents, became the spatial design object of this project (Figure 2).

A Community Curation Process

Curatorial Theme

Due to the lack of publicness of some spaces, there are more leftover spaces in this street, resulting in severe spatial fragmentation. Therefore, a curatorial approach was produced in the synergistic process to develop solutions through catalytic, small, and progressive steps. The leftover space is used to the maximum to meet the daily interaction needs of the community residents. The primary purpose of the curation is to make the community a "public exhibition hall" and a "community living room." The concept of a "15-minute community living circle" is conveyed to the public through an immersion experience, and the 15-minute walkable area is taken as the basic unit of urban life. At the same time, the essential public service functions and public activity spaces needed in the area are set up to form a network of community living circles within walking distance.

The main subject of the curatorial exhibition is urban furniture. Urban furniture, public art, and other public service facilities are introduced in the leftover space of the site so that they can operate as an adaptive link, connecting space with space and people with space. It generates a neighborhood effect and promotes the recovery of community resilience (Zautra et al., 2008). Meanwhile, to create a sustainable, resilient community, all exhibits will be permanently retained in the community space for residents' use after the exhibition ends (Figure 2).

Figure 2. Exhibition route and community exhibition photos.

Specific Implementation

The community exhibition of this project is run by an exhibition line that contains five parts: a systematic exhibition of urban furniture themes, a community gallery, two pocket garden updates, a series of co-creation activities for community residents, and sustainable exhibition visual materials.

- A systematic exhibition of urban furniture themes. We organized curated urban furniture currently available in the community versus urban furniture designed to address the remaining community space and meet users' needs, including a range of sitting furniture, child-friendly play installations, public art vignettes, and a sustainable exhibition of reused public phone booths. Given the proportion of people in the community, most of the exhibited urban furniture has aesthetic characteristics and practicality, aiming to solve space problems while meeting community residents' needs and improving the community's environmental quality. Through the interaction with urban furniture, we hope that community residents will experience the "small but beautiful, old but beautiful" public living room atmosphere of the community.
- A community gallery. Transformed from a community center, the community's cultural spirit and historical stories are distilled into a 100% recyclable towel material printed display. Through reading, feeling, and communicating, community residents can enhance the cohesiveness within the community and promote the restoration of social resilience in the old community.
- Two pocket garden updates. During the preliminary co-creation research stage, two street corner spaces were identified that needed to be improved in quality. Combining the needs of community residents, the two spaces were renewed and became community pocket parks.
- A series of co-creation activities for community residents. During the exhibition process, we maintained close contact with the residents. Through the exhibition's community co-creation activities, the design team enhanced the residents' emotional identification with the community. These activities include the "Poetry One Way Street" story collection, the "Community A to Z" jogging event, and the "My Favorite Community Space Collection" online and offline activities.
- Sustainable exhibition visual materials. The community exhibition upholds the concept of sustainable design, and all urban furniture will be permanently preserved in the community space. In addition to the urban furniture, the visuals of the exhibition also became a highlight. The exhibition materials are innovatively made of towels; and the road flags, display cloths, and posters can be recycled, minimizing the waste of exhibition materials and realizing the concept of green curation. The materials will be distributed to community residents by the community volunteer team after the exhibition to carry on the whole life cycle of the materials (Figure 3).

Figure 3. A community gallery and sustainable exhibition of visual materials.
Renewal Model and Resident Feedback through Co-Creation of Outputs

Renewal Model of "Exhibition for Building"
As a cultural tool, curatorial exhibitions gradually extend more artworks into open urban spaces rather than being confined to museums or galleries. Curatorial exhibitions systematically involve public art in the community, penetrate daily life, and make close contact with the public, forming a place for interaction between people and people and people and art. In this process, curatorship actively contributes to the quality improvement of urban space and the connection between people and space (Cheng et al., 2020).

Through the specific design study of this project, a new type of urban micro-renewal model, the "exhibition for building" model, is derived from the overall logic. It aims to intervene in the leftover spaces with aesthetic public service facilities in a curatorial way. It aims to catalyze the positive connection between residents and community space, reinvent the vitality of space, and improve old communities' adaptability to modernization.

Residents' Evaluation and Feedback
The curatorial activity implanted a large amount of urban furniture into the community and reserved it permanently for residents' use, solving the problem of nearly 70% of the leftover space in the exhibition area and significantly increasing the utilization rate of the leftover space. Feedback from residents during the exhibition showed that community residents were much more satisfied with the spatial environment.

Therefore, the project's conclusion is in line with the expectation that the co-curatorial approach has contributed to the community's micro-renewal and improved the residents' happiness index; it will serve as an example for more community renewal projects.

Conclusion

In summary, as China's current urban development shifts from sprawl to the sustainable development of stock land resources, many older communities can use this boom to improve their resilience in large cities. This paper focuses on collaborating with various stakeholders to participate in the renewal of old communities, effectively empowering residents and creating a new "exhibition for building" model to promote the adaptive recovery of old communities. It also combines top-down and bottom-up strategies to coordinate a curatorial perspective to improve the spatial and social resilience of the community and systematically integrate urban furniture and other facilities as a link between people and the environment. The act of curation promotes the neighborhood effect and explores the potential of curation for urban micro-renewal.

The project practice also reflects on the future of resilient and sustainable community development. From a macro perspective, this paper provides an innovative idea for urban micro-renewal that helps Chinese cities move toward more sustainable and resilient development. From a micro perspective, through the mutual coordination of government, residents, and designers, design empowers a community to meet users' actual needs and improve residents' happiness. The design thinking approach creates well-being for the residents and promotes social innovation.

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COLLECTIVE INTEREST MATRIX: CAN DESIGN BE SUSTAINABLE WITHIN CAPITALISM?

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Abstract

In the second edition of *Design for the Real World*, Papanek (1984) describes the design establishment's hostile reception of his book whereby concepts like energy efficiency and alternative, renewable energy sources were labeled "idiosyncratic pipedreams" and "an attack on Detroit mixed with utopian concern for minorities." While Papanek (1984) may have the satisfaction of being on the right side of history, he conceded that "we learn best from disasters" (xv-xvi). In *Objects of Desire*, Forty (1986) explains design's pivotal role in reducing British consumer resistance to "progress" while reinforcing social class, gender roles, and most importantly, the capitalist economy. Recent focus on "design for good" has tried to answer Papanek's call for benevolent design intervention beyond design's mass-consumer business-as-usual. However, design for the disenfranchised rarely gets the talent, time, attention, and funding it deserves precisely because of its low priority, influence, and appeal in a corporate, capitalist economy (Noble, 1979). Unbridled capitalism – and the designers that lubricate its gears – hastens the depletion of our resources, environment, and social cohesion. If designers avoid questioning capitalism's limits, our role within the system, and rethinking desirable futures (Alexander, 2020; Latour, 2017, 2019), "design for emergency" will face the same hurdles that "design for good" currently faces. When designing for adaptation, are we blind to the economic interests of our interventions? How do we reconcile conflicts between the human and environmental impact of design interventions? Should discussions of collective versus individual interests be positioned against public and private profits, against beneficial and adverse human and environmental impacts? How do we resolve conflicts and identify our assumptions, biases, and blind spots that may limit the full exploration of possibilities? Should these discussions become the norm in design education, and if so, what methods should we employ? This paper proposes a collective interest matrix for positioning design interventions.

Author Keywords

Capitalism; sustainable design; green design; ecological design; collective interest matrix; stakeholder impact matrix; design for good; design for emergency.

Introduction

> ... The economic advancement of the past two centuries is clearly remarkable, yet it is difficult to sustain, because by definition it requires constant innovation. The enduring bedrock principle of modern capitalism is this ingenuity. It produces new things, which, if successful, become durable, stable, and permanent features in the lives of modern people. Often, when such things are first experienced, they feel like "the shock of the new," but what at first is astonishing eventually becomes routine. (Murphy, 2015, p. 141)

Capitalism presents some unresolvable contradictions. Capitalism has growth imperatives for stability but cannot grow indefinitely for ecological reasons. Providing advanced economies with unprecedented wealth and productivity for the past 200 years, along with extremely high standards of living, capitalism has raised many developing nations out of absolute poverty but without the ecological possibility for the Global South to consume resources like the Global North (Alexander, 2020; Hickel, 2020).

While we hold on to technological hopes of "green growth" that would allow for economic expansion decoupled from resource use and greenhouse gas emissions, researchers are quickly proving that there is an absolute limit to this optimistic scenario (Hickel, 2018; Hickel & Kalis, 2019; Hickel, 2020a; Nardi, 2019). In short, green growth has not been able to decouple progress and resource consumption anywhere near the levels required because technology feeds the problem it is supposed to resolve through its incompressible, boundless resource and energy requirements.

This in turn has prompted a number of researchers to propose post-capitalist solutions to encourage frugal, sustainable, regenerative design (McDonough, 2003; Manzini, 2003, 2015; Mang & Als, 2012, 2015; Klein, 2015; Alexander, 2020; Hickel, 2020b; Fry, 2020; Monnin & Als, 2020, 2021; Design Council, 2020, 2021). Life cycle management, biodesign, and degrowth by design – refocusing our ambitions and processes towards more frugal, eco-responsible, and collaborative practices and solutions – have yet to become corporate norms. This is because of the efforts that would be required to adhere to consumer demands for our currently affordable privileges, conveniences, and desires: low-cost intercontinental tourism, video-on-demand, exotic and out-of-season foods, fast fashion, machine learning-enhanced home automation, etc. Willfully forgoing these modern marvels of international logistics is difficult indeed.

> ... degrowth captures an essential insight: it directly evokes, more clearly than any other term, the need for planned contraction of the energy and resource demands of overgrown or "developed" economies. That is an agenda that mainstream environmental and social discourse refuses to acknowledge, because significant contraction of energy and resource demands is incompatible with ongoing growth in GDP. (Alexander, 2020)

Some companies are moving away from consumption driven by individual ownership and programmed obsolescence to a subscription-based service model that incentivizes reduced consumption, repair, and shared ownership, like the Porsche Drive program.[1] Software companies like Adobe are also moving into this arena, reducing their need to release software updates to maintain recurring revenues from their existing user base. Now clients pay to access its cloud-based services, yielding record profits for Adobe in the first quarter of 2022. This extractive financial model allows market leaders to maintain their positions with less investment or requirement to innovate their products, and while convenience and security are enhanced with cloud-based computing compared to using a traditional hard drive, the global network of data centers needed to power these applications requires about a million times more energy than using a local hard drive (Adamson, 2017). Short of a cataclysm, capitalism will try to fill any vacuum of unmet need with most profitable cost margins, ignoring ecological imperatives when convenient.

Design for "Good"

Designers working in industry are service providers. In the best case scenario, they help define strategies and corporate visions. In worst case scenarios, they are mere executors of the specifications of others. Papanek (1984) and others (Garland & Al, 1964) put forth perceived need versus frivolous, marketing-related design as a litmus test between good and bad design practices. However, context often blurs these distinctions, especially when dealing with inclusive design that may seem like trivial conveniences to some but are performance-enhancing options to others. A smart speaker to control home lighting is a convenience for the able-bodied but a game-changing tool to anyone with mobility impairment. Two hundred years ago, there were a half-dozen formulas for soap that cleaned everything in the house, people included (Forty, 1986). Now it seems normal to have a different soap for hands, faces, hair, and intimate body parts, another for laundry, and all the different surfaces and rooms in the house. How much of this evolution is dictated by marketing versus improved performance? Would eczema-prone, acne-suffering individuals consider soap-free cleansers frivolous? We will not pretend to make these distinctions. We simply point out that utility value judgements in complex socio-technical systems are nuanced, with valid arguments on opposite sides of the debate (Norman & Al, 2015).

In this ethically-charged, possibly guilt-inducing discourse, design students have a hard time identifying their ethical stances because like all nuanced discussions, hard and fast boundaries are not easy to identify or defend. To help students clarify their designs' positioning within this complex system, we propose two successive intermediate design methods and artifacts: the stakeholder impact matrix (sim), a reworking of the methods proposed by Olander (2007); and the collective interest matrix (CIM) which we developed and explain in this paper. These methods help identify assumptions, biases, and blind spots that may otherwise limit the full exploration of possibilities and prompt discussion of potential conflicts between collective versus individual interests; public and private profits; and beneficial and adverse human and environmental impacts.

Stakeholder Impact Matrix

Freeman (1984) defines stakeholders as "any group or individual who can affect, or is affected by, the achievement of a corporation's purpose" (p. 46). By limiting stakeholders to humans – an issue we will address later – we can build upon Olander's (2007) stakeholder impact analysis tools derived from the science of construction management and economics on the decision-making power and ability to impact project outcomes. These methods and their structural underpinnings can be used to explore stakeholder networks and impacts in socio-technical systems. We build upon his approach, simplifying and reversing the order of some steps, but ultimately, we also question some underlying ground-truths.

Mitchell et al. (1997) define seven different stakeholder classes:

1. **Dormant** stakeholders possess power to impose their will but do not have any legitimate relationship or urgent claim. Their power remains unused.
2. **Discretionary** stakeholders possess the attribute of legitimacy, but they have no power or urgent claim. There is no absolute pressure for managers to engage in an active relationship, although they may choose to do so.
3. **Demanding** stakeholders possess an urgent claim but have no power or legitimate relationship. This is bothersome, but does not warrant more than passing management attention.
4. **Dominant** stakeholders are both powerful and legitimate. It seems clear that the expectations of any stakeholders perceived by managers to have power and legitimacy will matter.
5. **Dangerous** stakeholders lack legitimacy but possess power and urgency. They will be coercive and possibly violent, making these stakeholders "dangerous."
6. **Dependent** stakeholders have urgent and legitimate claims but possess no power. These stakeholders depend upon others for the power necessary to carry out their will.
7. **Definitive** stakeholders are those that possess both power and legitimacy. They will already be members of an organization's dominant coalition. When such a stakeholder's claim is urgent, managers have a clear and immediate mandate to attend to and give priority to that claim (Olander, 2007, p. 279).

Once the full stakeholder network has been identified (including those in the realms of production, mediation, distribution, reception, oversight, and funding), Bourne and Walker (2005) propose the vested interest impact index ($VIII = \sqrt{(v*i/25)}$), where the vested interest levels (v – probability of impact) and the influence impact levels (i – level of impact) are qualitatively defined on the following scale: 5 (very high), 4 (high), 3 (neutral), 2 (low), and 1 (very low) (Olander, 2007). These vested interest impact values can be used to plot the various stakeholders within the stakeholder impact/probability matrix (Figure 1).

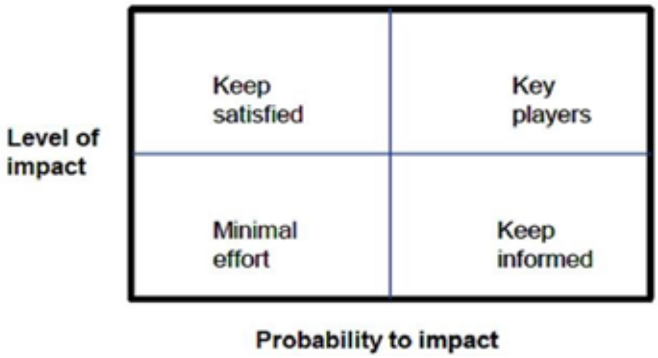

Figure 1. The stakeholder impact/probability-matrix (Olander, 2007; Johnson & Als, 1999).

These stakeholder mapping tools help identify obstacles to development, taking for granted that development *is* the end-goal. This basic assumption is unsatisfactory and ecologically inadequate regarding the production of reliable, comprehensive information to help environmentally conscious policy makers, producers, and consumers in selecting sustainable products and production processes.

While human-centered stakeholder networks may be mapped and evaluated with the SIM, we argue that a more expansive vision of stakeholders – beyond people – is necessary to evaluate impacts to organic ecosystems as well as artificial, intangible ones like a community's reputation, attractivity, diversity, credit rating, etc. Life cycle assessments and carbon footprint measurements have developed in this void, but this terrain is still fraught with shortcomings and requires our ongoing attention (Roy & Al, 2008).

Collective Interest Matrix (CIM)

To identify a design proposition's economic positioning, we would like to propose a second intermediate design tool: the collective interest matrix (CIM) which inserts itself into the ideation phase. CIM looks at two axes: sources of capital and value creation. The first axis looks at a project's funding sources and identifies who assumes the risk during the project's development phase. The second looks at the value creation: who benefits most from this project and who owns the intellectual property (IP). Note that there may be multiple financing sources as well as multiple recipients of value creation and IP ownership in a single project. Below is a blank CIM template (Figure 2). The CIM template tries to identify if there may be conflicts of interest between a project's capital providers and its end goals.

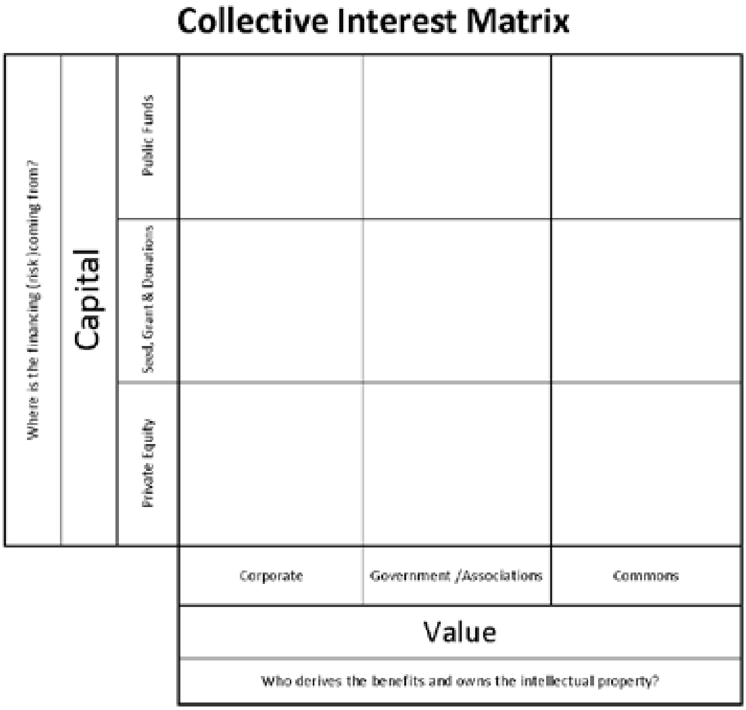

Figure 2. Blank template to be filled out in the design ideation stage.

CIM's capital axis is split between three types of financing sources:

1. **Private:** Financing which includes private equity investments as well as in-house corporate financing and business loans.
2. **Public:** Financing derived from taxes, bonds, investments, etc. which are controlled and distributed through public agencies.
3. **Seed money, grants, or donations (SGD):** Funds drawn from personal savings, grants, or donations of time or money.

On the value axis, we also identified three categories of value recipients or those who derive the positive impact from the project. These value recipients may be independent and different from those who own the intellectual property.

1. **Corporate:** To be used when the end-goal is corporate profits, possibly related to branding. IP ownership and value creation are often directly related.
2. **Government/associations:** The government and association realm organizes itself to serve specific needs or goals in the community that may be necessary but not financially lucrative enough for corporate interests.

3. **The commons:** This category works toward the common good by adding to the cultural and natural resources accessible to all members of a society. Work by international non-governmental organizations (NGOs) and work produced under Creative Commons licensing typically fall under this category.

Together, these two axes create a 3x3 matrix whose intersections could help identify new, creative financing options or highlight potential conflicts of interest between the project's end goals and its financial backers. CIM is an internal, intermediate object in that it is meant to be used to structure one's reflection rather than as a tool to communicate with external stakeholders. Like a comprehensive SWOT (strengths, weaknesses, opportunities, and threats) analysis, some unflattering analysis could potentially be integrated into this matrix and it should be considered an internal working document.

In Figure 3, we have identified the types of organizations and projects that may be located at the different matrix entries. Starting from the upper left, we will look at the dynamics between capital and value at each junction. Each entry will be listed as **capital** / ***value,*** followed by an example of a project or funding organization.

1. **Public** / ***corporate:*** Public financing to boost corporate innovation through research and development funding managed by public agencies like national research organizations. The belief is that investment in corporate innovation leads to job creation and an increased tax base.
2. **Public** / ***government-associations:*** Projects for and funded by public agencies. This can include government investment banks, the military, utility providers, etc. Public funding of NGOs may make them less politically independent.
3. **Public** / ***commons:*** Projects enacted through public policy and investments that sustain cultural production, transformation, and protection of natural resources, and investments in public infrastructure. The United Nations Sustainable Development Goals (UN SDGs) push for sustainability, but with economic development as goal #8, that is not sustainable (Hickel, 2019a).
4. **Seed money, grants, and donations (SGD)** / ***corporate:*** Corporate research and development financed by tax refunds, Kickstarter, and go-fund-me projects, self-financed start-ups, etc.
5. **SGD** / ***government associations:*** Associative projects for community development funded by grants and donations; special interest groups and political action committees also fall in this sector. Examples include projects initiated by universities and students, like the Linux kernel and other GNU general public license software development (self-funded and open source).
6. **SGD** / ***commons:*** NGO projects for ecosystem protection and cultural preservation, funded by grants and donations.
7. **Private** / ***corporate:*** Traditional corporate and capitalist activities that focus on growth, maximizing return on investment (ROI), and protection and expansion of IP assets. Private funding and IP ownership

bring risks for conflicts of interest when developing socially and environmentally responsible projects. This capital/value conflict is most often the source of greenwashing and ethics-washing charges against corporations.

8. **Private / *government associations:*** Consortium-based organizations like the W3C that work towards shared IP and cooperation for international standards and the open source projects that may arise from their common goals. International tensions may arise from over-represented nations in certain consortiums.
9. **Private / *commons:*** Open source, corporate-driven projects like Apple's Swift programming languages, Google Chromium and TensorFlow, Pytorch, publication of corporate machine learning algorithms, etc. These projects harness improvement to source code by releasing it to the community in exchange for relinquishing corporate IP rights. This does produce some tension within the open source community.

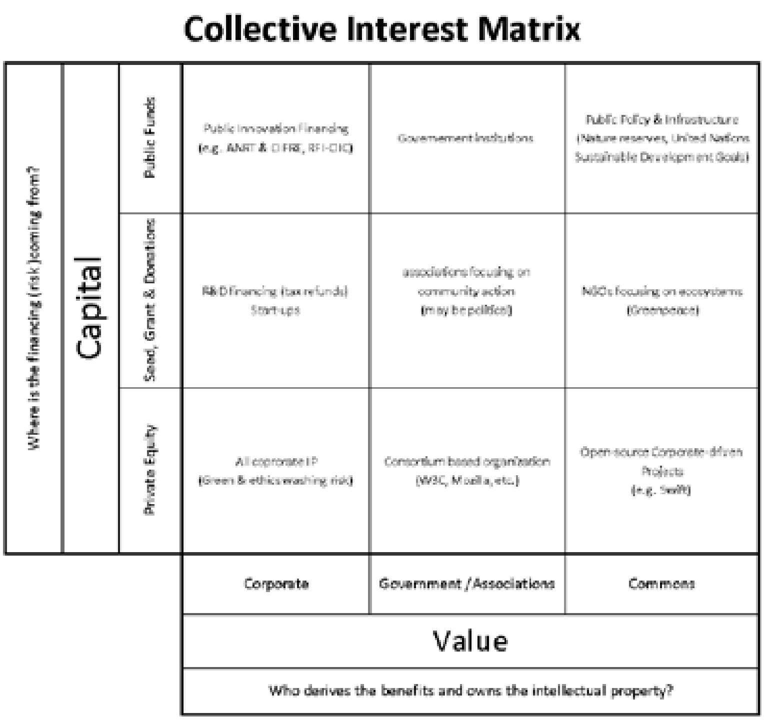

Figure 3. Collective interest matrix with various types of projects, design interventions, funding partners, and/or recipients found in each respective entry.

Conclusion

In this paper, we propose addressing the difficult tensions between capitalism and eco-responsible, sustainable design by building upon two intermediate design tools: the stakeholder impact matrix (SIM), derived from Olander (2007), and the collective interest matrix (CIM), which we developed.

With the SIM, we identify the seven categories of stakeholders: dormant, discretionary, demanding, dominant, dangerous, dependent, and definitive. Once the stakeholder network has been identified, values can be assigned using the vested interest impact index (ViII = (v*i/25)) and plotted on the stakeholder impact/probability matrix (Figure 1). Moving beyond its inherent development-driven groundtruth, non-human stakeholders who will be impacted by a design proposal should be identified to evaluate impacts to organic and socio-technical ecosystems. Refining this process will be the next step in our research.

Once the stakeholders have been identified, the collective interest matrix (Figure 2) can be plotted to identify possible sources of capital, who will assume the risks, who derives the benefits from the project, and who owns the intellectual property. When aiming for a socially and environmentally responsible design project, the CIM can identify potential conflicts of interest while still in the ideation stage, open up ideas about other funding possibilities, and help guide development towards mutually-beneficial, socially and ecologically responsible cooperation between the sources of capital, the beneficiaries of the design, and the IP owners. However, it remains the designer's responsibility to assess and ultimately determine the social, economic, and environmental end goals, impacts, and trade-offs of their propositions.

We humbly propose these intermediate methods and tools to the design community to extend ways of looking at design's impacts, and look forward to getting feedback on possible refinements and improvements.

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DEFINING ECOLOGICAL CITIZENSHIP: CASE-STUDIES, PROJECTS, & PERSPECTIVES ANALYSED THROUGH A DESIGN-LED LENS, POSITIONING "PREFERABLE FUTURE(S)"

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Abstract
A citizen is a member of society who undertakes duties and obligations. The authors define ecological citizenship (EC) as accessible activities and skills which establish sustainable practice(s) and/or address ecological inequalities. Unsustainable practices (and consequences) are not constrained to individual countries, single industries, or discrete societies. Our life-supporting ecosystems (for example, the oceans we eat from and the air we breathe) are impacted by contemporary resource exploitation, pollution, material misuse, and inadequate protection.

We are (all) citizens of the world, with the natural environment sustaining all life on earth. Our human existence is intertwined with our environment; we live in and are "citizens" of our environment. EC fosters positive ecological behaviours involving and benefiting communities through individual and collective action(s). Author Ezio Manzini (2019) advocates that design's contemporary role and purpose is to "create the conditions" to enact change.

We also describe a new network, Ecological Citizens+ – funded by UK Research & Innovation – which aims to catalyse sustainable practices in the digital economy through activities which unite diverse groups of people to address a sustainable digital society. This network unites community-focused approaches, including citizen science, activism, collective learning, advocacy, design strategies, manufacturing, environmental science, and engineering practices. We describe the activities that we will develop to cocreate tangible outputs that are scalable and actionable.

This position paper outlines transdisciplinary approaches in addressing environmental challenges that benefit communities, industry, academia, and other species. EC draws on previous projects, contemporary literature, and multidisciplinary perspectives. The EC position is "post sustainability," exploring practices mitigating consequences and "desiloing" expertise. EC offers new research topics and supports tangible public roles, all within contemporary sustainable challenges. This position paper offers signposting to enable community and public agency, challenging hegemonies rather than adopting conventional practice(s).

Research Objective

The authors analyse interdisciplinary literature and case studies defining "ecological citizenship," resulting in design-led "preferable futures." The authors built off contemporary material, creating transferable contemporary "design values."

Author Keywords

Design-led; cross-disciplinary; citizenship; post-sustainable; futures; agency; citizens.

Introduction

Our relationships with resources, materials, and the natural world(s) are unsustainable. Nature's function(s) and our interaction(s) are no longer intertwined but are critically codependent in order to sustain all life on earth. Personal wildlife experiences impact our "nature connectedness" and can steer our subsequent action(s). We unite current territories, design literacy, citizen science practices, and contemporary issues defining "ecological citizenship" (EC) – an activity or a skill that anyone can do which helps establish sustainable practice(s) and address ecological inequalities. This includes community-led sustainability approaches leading to scalable, transferable "design values" for wider application(s).

We need skilled and critical producers, consumers, empowered citizens, designers, and decision-makers. Such sustainability approaches must mutually benefit citizens, ecological environments, non-human species, and wider society. Design (as a discourse) is transitioning from capitalist approaches to providing experiences revolutionising behaviours through "interactions' transforming behaviour for positive natural world impacts" (Burke et al., 2018). Professional designers must design for longevity as opposed to "throwaway" societies, enabling decision makers to become conscious consumers.

The authors position and present ecological citizenship, delineating a contemporary approach beyond sustainability practices. The territory is valuable as U.K. government "austerities have stripped local municipalities capacities" (Slawson, 2019) to "limited resource provision" (Oxfam, 2013), leaving third sectors woefully "under capacity pressures" (Hyndman, 2020). In summary, citizens cannot rely (solely) on governments. We advocate for extending citizens' agency into activities impacting them. Our approach presents opportunities for community-led actions, leading to a "distributed environmental sustainment" through EC. EC is defined as "activities that go beyond your own agenda, benefiting the wider ecologies, systems or communities surrounding you" (Phillips et al., 2020). EC contextually includes donating digitally captured air quality data to a wider audience(s) or eating only seasonal food, reducing impacts of exported non-seasonal grocery production. The authors seek to empower stakeholders, enabling responsibility and care for creative ways of living together with animals, people, and plants through design. The authors guide the readers through literature, the design space, contemporary examples, and preferable futures, defining EC and its values.

Citizenship is defined as contributions towards the lives of others outside of volunteering or without relying on the kindness of individuals. It is noted that we do not use the term citizen to denote legal status of people in a country, though we recognise the term is problematic (see Eitzel et al., 2017; Cooper et al., 2021). In *Citizens,* Alexander et al. (2022) clarify,

> To be a citizen is to care, to take responsibility, to acknowledge one's inherent power. To be a citizen is to cultivate meaningful connection to a web of relationships and institutions. Citizenship benefits from a free and expansive imagination, the ability to see how things could be. (p. 11)

Citizens are literally "together people" (translated from Latin), humans defined by their togetherness. All "life on Earth is an ecosystem, and it could be an ecosystem of generosity, a virtuous circle. If we improve things at any point, we improve them at all points" (Alexander et al., 2022, p. 12). In *The Politics of the Everyday,* Manzini (2019) states we should focus on "project-centred democracy, meaning a participatory enabling ecosystem in which everybody can develop their projects and achieve results" (p. 118), i.e. designing conditions for others to excel. Public interest technologies (PITs), an emerging design discipline, empower communities and municipalities alike, creating "optimum" conditions. PITs enable data sharing for the greater good, leading to "evidence-based" societal change. PITs inform the digital economy and "how data is forming a currency that people want a stake in," benefiting human and non-human species rights (McGuinness & Schank, 2021). In *Ecological Justice,* Weston et al. (2012) state "human rights advocates champion the ecological rights of future generations" – our human rights and ecological justice are intertwined. Simply put, "our societies [and] descendants depend on achieving ecological justice for future generations" (Weston et al., 2012, p. 43), i.e. we must protect future generations through ecological citizenship. Design practice(s) uses design futures, a process of scoping new territories. Design futures (or foresight) work has three laws: "1) the future is not predetermined, 2) the future is not predictable and 3) future outcomes can be influenced by our present choices" (Voros et al., 2001). We leverage Voros et al.'s (2001) preferable futures, concerned with "what we want to happen." These futures are emotional rather than cognitive, being subjective and derived from value judgements (Voros et al., 2001). These instances of "future(s)" should be determined by all citizens who suffer from the impacts of polluting industries, practices, and exploitative politics, not just the privileged few.

Our Natural Environment

Nations typically measure economic success in GDP but fail to measure impacts on nature or sustainability improvements. 2021 witnessed rising public concern regarding nature, with nine out of ten adults in England concerned about increasing threats to natural environments and biodiversity loss (Natural England, 2019). Sprawling cities (Cox et al., 2017), funding reductions (Burke et al., 2018), and extended working hours (Ganster et al., 2018) have transformed our relationship with natural systems (Richardson et al., 2018). We are distanced from protecting and/or connecting with our surroundings by an "othering" of nature (Uggla et al., 2012). Traditional nature relationships were defined by food (Uhlmann et al., 2018), forest (Cincinelli et al., 2019), seasonality, and self-sufficiency (Kelobonye et al., 2019). It has been suggested that two hours of nature engagement could join "five pieces of fruit a day" as official health advice (Carrington, 2019). The benefits of nature engagement(s) include community forming (Moss, 2012), including building connections and relationships between youth (Muñoz, 2019), opportunities for play (Brown et al., 2017), understanding of risk, and connectedness (Lumber et al., 2017). It also provides economic benefits (Bockstael et al., 2000). The Office for National Statistics estimated the U.K.'s "nature capital" at over £1.5 trillion (approx. US$1.776 trillion) with rural tourism alone worth £14 billion (approx. US$16.572 billion) and 17% of U.K. tourism involves wildlife watching (Juniper, 2013). There are many health benefits from contact with nature, e.g., reduction in ADHD, improved well-being (McEwan et al., 2019), and mental health (Cox et al., 2018). Increasing nature engagements could save the U.K. health service £2.1 billion (approx. US$2.486 billion) annually and is dubbed nature's health service (Moss, 2012). The authors of this paper advocate for "sustainment" or embedding sustainable proposals within and for communities over wholesale redesign strategies.

Sustainment implies an "economic paradigm that enfolds redistributive justice, but its initiation requires change" (Fry, 2010). The Covid-19 pandemic presented alternative world(s), with "A sharp dip in air pollution across China, Europe, and the US, with carbon emissions from the burning of fossil fuels [presenting a] record 5% annual drop and Venice waters [were] clear" (Milman, 2020). This demonstrates rapid changes can happen, although systems quickly returned to pre-pandemic states. The authors promote designing for and with ecological systems which actively preserve and propagate people's actions. We over-manicure environments; in the U.K. in 2016, a 220% increase in artificial grass sales has occurred, impacting local wildlife (Laville, 2016). Contemporary *BBC SpringWatch* programming comments "saving wildlife starts in your back garden" within their "Garden Watch" campaign's objective to call communities to action (BBC, 2019). The combination of the biodiversity and climate crises, our disconnection from nature, and underfunded charities unify the need for a "strategic re-design" enabling citizens to assume a role in sustaining natural worlds. Ecological citizenship is not a metaphorical "silver bullet" fixing challenges, but rather unites design value and cross-discipline perspectives, and requires carefully crafted collaborations to succeed. In summary, the natural world is hugely important for human life on earth, and our lives are intertwined and co-dependent on our environment. To continue coexisting with nature, we must empower citizens to comprehend their impacts and inform subsequent actions.

Our Resource and Material Relationship(s)

Our relationship with the natural environment is distanced by our modern lives, material uses, and perceivably time-poor lives. In 1994, photographer Peter Menzel documented everything citizens owned. Menzel's (1994) portraits exhibit the breadth of materials and products we own, demonstrating our belongings and material interconnectedness, regardless of location or culture. Contemporary products (artefacts) are built within systems, using multi-materials and subassemblies reliant on global resourcing and transportation. Traditional processes are disrupted by circular economies (Geissdoerfer et al., 2017), regenerative processes (Wahl, 2019), design for disassembly (Crowther, 2005), and planet-centred design (Jones, 2022). Material ownership requires redefining "material custody," comparable to architectural "listed buildings" (Williamson, 2010). Our material and resource use can be framed as an act of "citizenship" through custody, use, and repair. The Materials Science Research Centre (Royal College of Art) focuses on the invention and experience of materials to address real world challenges, specifically environmental sustainability and human health and wellbeing. Systems approaches allows us to create couplings between materials circularity, supply chain configuration, and consumer experience to propose an alternative model for apparel that will reduce the consumption of material resources and associated pollution, and to grow wellbeing: economic (equitable prosperity), social (community and identity), and environmental (enhancing the health of our planet and its capacity to support life).

Ecological Citizenship (EC)
Heller & Vienne's (2003) *Citizen Designer* states designers should "develop solutions based on direct interaction with individuals," transforming cultural approaches. Culturally we are disconnected from material value and underestimate the damage of extracted natural resources in objects. The disconnection creates a loss of "consumption perspective," impacting our choices (Young et al., 2019). We advocate for "ecological citizenship," transcending consumerism, impacting culture, enacting sustainable change, and encouraging resilience. An EC example is voluntourism, combining tourist locations and volunteering to benefit localities. This is important work, as tourism can be damaging to local ecosystems. For example, in 2019, the Faroe Islands closed to reduce impacts of tourism on wildlife, thereby conserving landmarks and habitats {1}. EC should be embedded within communities of all sizes: urban and suburban, from all social classes and cultures.

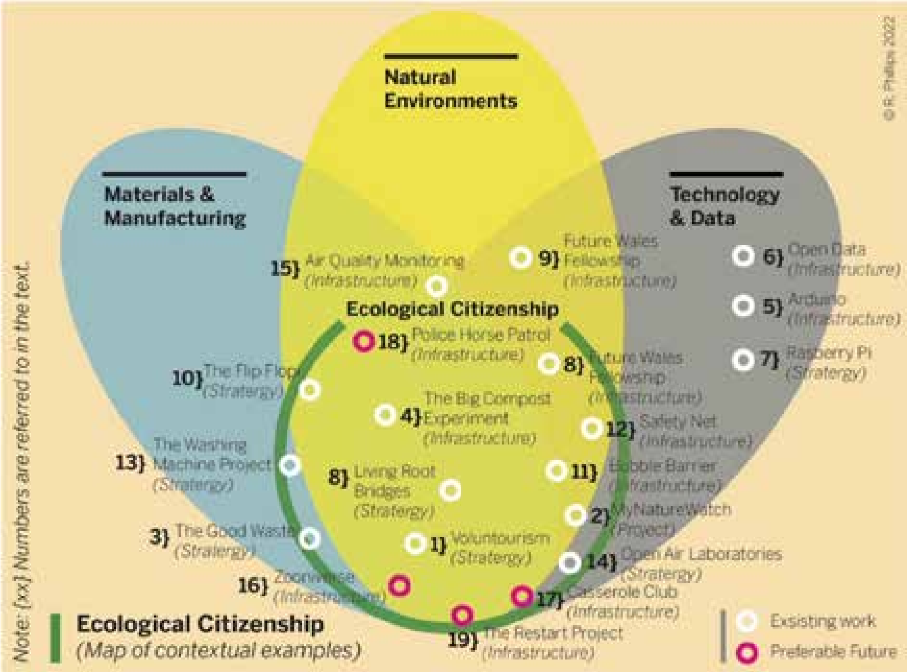

Figure 1. Contemporary examples within the ecological citizenship framework. *{xx}* numbers are in the text.

This article guides readers through interdisciplinary examples, grounding the EC space. We hope this will inspire designers, communities, charities, and other organisations to leverage scalable and transferable "design values." Figure 1 unites our frame through materials and manufacturing, natural environments, and technology and data. There is immense value in providing citizens with (appropriate) explorative systems to environments they do not understand with interactions they do. Design is the practice of sensemaking, interaction, and intention(s) to multiple stakeholders. These are complex intertwined situations; for example, after the 2021 Glastonbury festival, "drug traces from on-site urination harmed rare eels, [as] scientists found dangerous levels of MDMA in nearby rivers" (Snapes, 2022). Unknown interactions proliferate, exacerbated by natural world disconnections. Another challenge is how citizens undertake roles within their ecological surroundings over time. Historically, recycling "waste" was conceptually alien but now is resourced by municipalities. In time (hopefully), citizens' ecological responsibilities will also be resourced. The unification of our material and resource use, the state of nature, and new digital opportunities present design-led opportunities for "citizens." Part of design's role is translating and communicating potential climate impacts – making tangible the intangible – thus enabling citizens to act.

Contextual Ecological Citizenship Example(s)

Design-Led Approach

Design (as a discourse) is transitioning from capitalist approaches to providing experiences revolutionising behaviours and producing "interactions' transforming behaviour for positive natural world impacts" (Burke et al., 2018). The design territory is valuable as U.K. government austerity measures have stripped local municipalities' capacities (Slawson, 2019) to "limited resource provision" (Oxfam, 2013), leaving third sectors woefully "under capacity pressures" (Hyndman, 2020). In summary, citizens cannot rely (solely) on governments. We are not advocating for resourcing "cheap community labour" – note that running citizen science projects is often costly and time-consuming (Alfonso et al., 2022) – but extending citizens' agency into activities impacting them. The design space is intertwined with consequences and impacts. The "transition to a sustainable society requires design approaches, informed by new and different values" (Irwin et al., 2015). Often non-design literate or familiar parties cannot always see the potential, so it is incumbent on designers to "create the conditions." The collaborative economy is defined "as practices and business models based on horizontal networks and participation of a community," fostering transition to more sustainable futures (Manzini, 2019). These design-led "technologies" are not just smartphone apps but embedded propositions in places, communities, and institutions. The examples included in this paper illustrate projects across the design discipline.

My Naturewatch {2} The My Naturewatch[1] (NW) project features an accessible do-it-yourself (DIY) camera trap, fostering beneficial nature engagements regardless of location, technological, and/or wildlife expertise (Figure 2). NW – designed by the Interaction Research Studio, with engagements led by the Royal College of Art, Design Products programme – is an EC example. Engaging with NW is an act of ecological citizenship, as participants actively rewilded gardens and instilled wider impacts. NW camera traps used off-the-shelf parts and can be assembled in anyone's home, without "specialist tools." The cameras are repairable, reusable, use CE-certified components, and utilise components from schools. The NW project fosters "active community engagement," a form of citizen science (CS), in the scenarios where data was used for scientific purposes. NW embodies inclusive design in the digital age as the activity engages a wide demographic, and can be used by all.

GoodWaste {3} GoodWaste[2] (GW) transforms "waste" materials into interiors and objects through design. They intercept industrial waste before it is sent to landfills, integrating strict circular economy principles. They believe in social sustainability as much as environmental sustainability, balancing their commercial output with social impact initiatives, bringing local communities into the design and making process. Selfridges commissioned GW to produce items (made from local waste) that were sold in store and online, providing a vision of a local, circular production model, furnishing homes with offcuts from neighbouring industrial sites. The GW is an EC example embodying reuse and upcycled material, and challenges material production.

The Big Compost Experiment {4} The Big Compost Experiment[3] (BCE) investigates the role and effectiveness of biodegradable and compostable packaging. The experiment consists of a short survey, then asks participants to place biodegradable plastic items in their compost under controlled conditions and report on its status and breakdown.

Participants help determine the viability of biodegradable and compostable plastics, feeding directly into a "composting map." The BCE actively includes participants in the process of learning about biodegradable plastics and enables citizens to assume a role in contributing to its development.

Design-led examples contribute to design specifically by:

- Giving people agency, sustainability, responsibility, and accessibility through digital tools that are available regardless of finances or status.
- Acting as a catalyst for alternate actions that are adaptable and appropriate.
- Serving as a mediator between technology and people.

Finally, it is imperative to consider how people are upskilled to inform their decisions, rather than being dedicated to technology and people. We must consider upskilling people to inform their decisions, rather than dictating to them.

Figure 2. Design-led projects embodying ecological citizenship, material, manufacture, and interaction attributes.

Technologically Led Approach

We use the term "technologies" broadly, encompassing goods, materials, and interventions that transition us to more sustainable practice(s) but are not exclusive to "powered artefacts." Technology can enable environmental resilience and has transformed data transparency, public agency, and accessible data monitoring (Pratapa et al., 2022). Accessible tech has become publicly distributed with countless hardware and application programming interface propositions including Arduino {5}, Open Data {6}, and Raspberry Pi {7}.

These infrastructures transform our civic role with technologies, their use, application, and delivery. Public interest technologies (PITs) empower public stakeholders and municipalities (McGuinness et al., 2021). PITs unravel "intractable problems, through design, data, and delivery, thus providing user agency and yielding wider societal benefit(s)" (McGuinness et al., 2021). The authors of this paper question how (and if) digital technologies can transition "public(s)" to more "sustainable approaches" through digitally sustainable society approaches. Technologies producing data provide legacies and interoperability and yield a long tail of our physical actions.

Technology does not provide all the solutions, and to believe so is folly (Morozov, 2013). Tech requires context, stakeholder access, transparency, and appropriate consideration for its environment(s). Finally, technological "appropriateness" means deeply considering technological interventions as befits their circumstances. An example of this is U.K. road markings painted directly on asphalt (People Are Awesome, 2020). The reflective paint is a simple interface for a complex system; however, Highways UK currently reproduces the signage by hand, i.e. they are cost effective, efficient, do not require power, and are used appropriately. *Lo—TEK, Design by Radical Indigenism,* demonstrates "appropriateness" as the interconnectedness of communities, natural worlds, and knowledge (Watson, 2019). Appropriate technological examples include "living root bridges" {8} – suspension bridges formed of living plant roots – in Meghalaya, leveraging Indigenous material knowledge, structures, and ecologies (Watson, 2019).

The authors believe that EC technologies enable stakeholders to make transitional choices, mitigate negative consequences, and empower local agency in different localities. In Wales, the *Well-being of Future Generations Act* (2015) recognizes that cultural capital is an asset and aims for a society that promotes and protects culture (Future Generations, 2020). At the time of writing, we understand Wales is the only country in the world with legislation requiring public bodies such as local authorities and health boards. This puts long-term sustainability at the forefront of their thinking and requires them to work together with the public, enhancing wellbeing. One of the seven wellbeing goals from the *Act* is "a Wales of vibrant culture and thriving Welsh language" (Future Generations, 2020). Technology and "arts play a key role in fulfilling goals and also contribute to a globally responsible Wales, resilient and prosperous more equal Wales of cohesive communities" (Future Generations, 2020).

One example is the *Future Wales Fellowship* {9}, an opportunity leveraging art to demonstrate climate change impacts on everyday life. Fellows are given opportunities to develop artistic and technological works, challenging people's perception of climate change and encouraging people to live more sustainable lifestyles. The fellows explore the impact(s) of climate change on the people of Wales by focusing on the three main themes of energy, food, and transport (Jerwood Arts, 2022). The value of the circular economy as a business model also drives ecological citizens by mapping practical projects, i.e. Flip Flopi (Larsson, 2019) {10}, encouraging plastic reduction through the creation of a sea-worthy boat made from flip flops and other discarded plastic. "The Flip Flopi 500-kilometre expedition captured global media attention, inspiring the government, NGOs and orgs to act against single-use plastic" (Northumbria University Newcastle, 2018).

Technologically Led Examples

Bubble Barrier {11} The Bubble "Barrier"[4] creates an upward current, directing plastic detritus to the surface. Placing the barrier diagonally across rivers pushes plastic debris into a catchment system. The components work in unison: 1) the bubble curtain provides vertical airflow adapted to the flow dynamics of the waterway; 2) the air supply of the bubble curtain is created by using compressed ambient air; 3) the catchment system retains gathered detritus. This provides an EC example on a town or city scale, considering how the technological intervention can be removed (without harm) over time.

Safety Net {12} SafetyNet Technologies[5] is an LED system enabling experimentation into how light can segregate fish by age and species. It aids in the reduction of undersized bycatch for trawler fishing, helping fisheries catch the right fish. The industrial application enables fishing fleets to make proactive decisions, caring for environments they financially rely on.

The Washing Machine Project {13} The Washing Machine Project[6] is a world-leading organisation, uniting innovation, research, and development to solve the world's pressing humanitarian challenges. They provide displaced and low-income communities with accessible, off-grid washing solutions. Their mission empowers women to reclaim their time, transforming their lives. The project improves people's quality of life, offering a repairable solution.

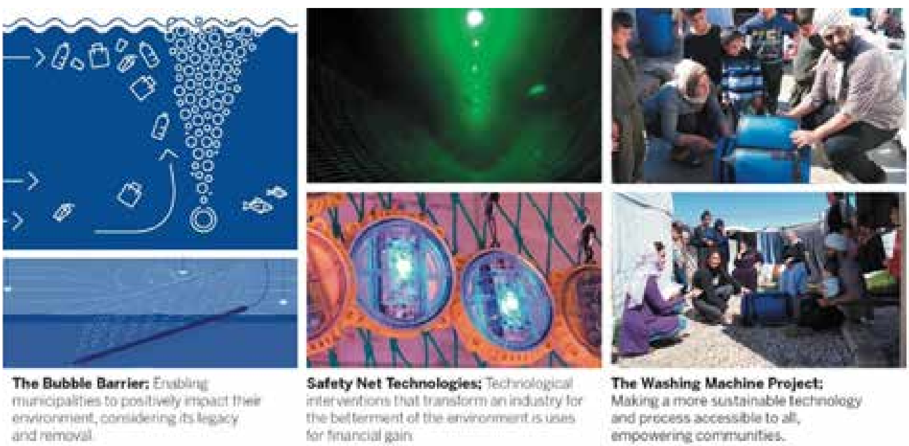

Figure 3. Technology-led projects include analogue and digital processes, tied together by ecological citizenship.

In summary, the technology-led examples are created to be appropriate for their environment, cost-effective, and solely driven by the least amount of intervention. They work for fixed periods and are designed for exit (i.e. once challenges are solved, they remove themselves).

Citizen Science-Led Approach

A method which can combine design, technology, and the natural environment is citizen science. "Citizen science" emerged as a term in the 1990s but has been around for centuries – it is when non-professional scientists or volunteers do research to answer scientific questions (Dickinson et al., 2012). Over the past few decades, however, the number of citizen science projects has burgeoned. This is partly due to the rise in ownership of personal devices connected to the internet and other technologies (Newman et al., 2012). Many citizen science projects focus on recording features of the natural world, for example, volunteers noting down the emergence of cherry blossoms (Miller-Rushing et al., 2012), the arrival of migrating birds, or logging weather (Figure 4). Benefits of using citizen science approaches can be divided into those for science, for participants, and for wider society. Benefits for science include that it can be a useful way of collecting data over wide geographic areas, or from places professional scientists cannot usually reach (for example, private gardens).

The act of participating in a citizen science project can give people new knowledge and skills – i.e. about the environmental topic being explored – provide a space for social connections, and generate locally relevant data. It can also encourage people to change their behaviour; for example, recording butterflies encouraged a shift to more sustainable gardening practices (Deguines et al., 2020). Citizen science has often been described as a democratising movement, a way of bringing diverse voices into the scientific process and amplifying their causes, benefiting society. Citizen science approaches are being used to help achieve the United Nations' Sustainable Development Goals (see Fritz et al., 2019). Data collected by citizen scientists are being used for environmental protection (Owen & Parker, 2018). There are different forms of citizen science, from contributory projects where volunteers mainly get involved in collecting data as instructed by scientists, to co-created projects where volunteers can be involved in all stages of the scientific process, from project inception to completion (Bonney et al., 2009). These co-created projects have the most potential to be transformative for participants (Ramirez-Andreotta et al., 2015).

Citizen Science-Led Examples

OPAL {14} Open Air Laboratories (OPAL) was a U.K.-wide citizen science project which supported individuals, community groups, and schools in exploring their local environment through surveys of aspects like earthworms and soil types. One million people participated and learned about their local area, collected data that was used locally for decision-making, and contributed to novel research (Lakeman-Fraser et al., 2016).

Air Quality Monitoring {15} Taking place in Nairobi in 2016 at the request of local residents, this project used low-cost sensors to highlight the high levels of particulate matter pollution. As a result of this citizen science project, the Kenya Air Quality Network was formed (West et al., 2020) and a new Air Quality Bill for Nairobi will be in place in 2022 (SEI, 2022).

Figure 4. Citizen science-led examples demonstrate the importance of creating custodians within communities and internationally.

Preferable Future(s)
The authors built-off cross-disciplinary references, contemporary projects, scoping work, and extensive literature review.

1) Zooniverse (2013) {16} is a platform enabling crowdsourcing and analysis of data and imagery. The platform shares webcam footage with public members who visually identify species and/or anomalies for scientific purposes. We see potential for digital economy "Saturday jobs" where people earn money from data-gathering activities. Examples include digital beach check-ups through publicly owned drones, water quality checks, earning volunteer accreditation(s) or finance, or "ground truthing" satellite data for local and global environmental protection. These would integrate motivations, communities, and activities for mutual gain.

2) Casserole Club (n.d.) {17} allows people with excess food to share meals with others, building communities and care. The authors can foresee building digital systems for sharing food (leveraging voluntary purchasing data), thereby reducing food waste before shopping, particularly if applied in dense populations and/or seen as a public resource. The challenge is designing technologies to evolve transitional behaviours – i.e. that remove themselves – when users' subsequent actions have transitioned.

3) Police Patrol (Weston, 2020) {18} redirects existing police horse patrols in public park areas as trotting promotes wildflower cultivation, offering a mutually beneficial preferable future while leveraging public services to serve communities. We see methods to digitally connect urban wildlife corridors, leveraging people's gardens or public spaces, providing evidence and biodiversity overtime via key stakeholders, schools, councils, and private gardens. This enables the public to witness positive consequences, thereby promoting community custody.

4) The Restart Project (n.d.) {19} advocates to reduce e-waste, legislating for training and repair culture. Contemporary E.U. laws insist manufacturers provide "access to spare parts" for ten years. Manufacturers could provide digital repositories of (intellectual property-controlled) parts and repair techniques, accompanied by augmented reality applications. Digital experiences could enable users to record DIY repair actions (supported by manufacturers), safeguarding users rights while maintaining manufacturers' guarantees and industry standards.

Figure 5. Scenarios of preferable futures based on equitable and accessible ecological citizenship.

Values *(Preferable Futures)*

We dissected preferable futures, examples, and literature and created design-led values, defined by interdisciplinarians:

1. **Accessibility:** Our collaborative vision intends to create, foster, and instil cutting-edge approaches, creating public benefit.
2. **Nothing for us without us:** Working *with* communities.
3. **Trans-disciplinary:** Working beyond academic institutions with cultural locations, community industries, and third sector organisations. Working with experts alongside contemporaries and communities, giving people choice over their destiny.
4. **Consequence considerate and appropriate:** Designing for grounded contexts within "real-world" challenges, through appropriate/accessible materials and technologies. Seeking diversity, inclusion, and environmentally informing best practices.
5. **Designing for exit:** Create ambassadors, training programmes, CPDs, and other resources. We are intent on leaving elements of the network to be self-sustaining and growing positively.
6. **Design-led:** Informed by contextual issues, community experts, and scientific evidence. Experimentally defined, pushing boundaries but evidence-based.

7. **Research scoping:** Our mission is to foster appropriate territories and instigate them, strategically uniting "unusual suspects."
8. **Open to strategic serendipity:** Working within a defined remit, we are keen to explore the edges and beyond. We encourage others to be open and undertake strategic decisions to try new initiatives.
9. **A catalyst:** A process that increases the rate of change, transition, and activities.
10. **Designing the conditions for regeneration:** Fostering positive transitions that impact all other species, helping communities set their own key performance indicators and evaluation criteria, and cooperatively tracking value, benefit, and impact.
11. **Agency:** To provide individuals and participants with the tools to help people have a voice on the sustainability of their environments.
12. **Citizen co-created:** Creating activities that include people, with theintent to continue activities well beyond the EC project's funding period. Nothing for us without us.
13. **Ensure fair oversight:** Providing an infrastructure that sits above the project and works in the best interests of all stakeholders.
14. **Redistribute technologies:** Work to ensure that outputs are accessible, with source code and/or platforms that can be leveraged by others (internationally).
15. **Design for regenerative action(s):** Creating outputs that constantly consider the regeneration of communities, digital societies, and the planet, with the objective of being a good ancestor.
16. **Creating stories of hope:** Counteracting feelings of helplessness, giving people agency to make positive change.

Discussion

The authors believe that we are (all) allowed a voice in the environment(s) that impact us – for example, we are all entitled to vote on the advocates that represent us. Covid-19 changed our traditional relationships as we became responsible for the health of others through our actions (i.e. mask-wearing, distancing, hand washing, and gatherings). This EC space is rarely explored through design-led approaches as the spaces are driven by capitalism, and EC is not a capitalist approach. These types of intervention would usually be "custodian-led," i.e. the council, municipality, etc.; however, the authors believe "community-led interventions can be impactful" (Koss, 2020). This work explores mechanisms to engage with the material and natural worlds, inspiring proactive, mutually beneficial interaction(s) and encouraging behaviour that causes less environmental harm. Conventional practice (in this space) is mainly conservation-led and/or education-led, often dictating processes without agency. Non-design literate or familiar parties cannot always see the potential, so it is reliant on designers to create the conditions. For example, the collaborative economy is defined "as practices and business models based on networks and community participation," fostering transition to sustainable future(s) (Manzini, 2019). These "technologies" are not an app but embedded propositions in places, communities, and institutions. They should also evolve and consider how they design themselves for exit over time. Design proposals work within deployable and accessible means and could be digital-only items. Design practice "is centrally located in society's agendas by discourses of the creative economy" (Cope et al., 2011). Designers are increasingly engaging people's experience(s) as "design puts people first, challeng[ing] thinking and making lives better" (Design Council, 2020). In this paper, the authors combine ecological citizenship, our material relationships, and nature relationships, all of which present a frame for design opportunities and a transference of people becoming "Ecological Citizens," promoting local and global nature (Phillips et al., 2020).

This work questions mechanisms that engage within the natural world, inspiring proactive, mutually beneficial engagement(s) to do less harm. Human-wildlife conflict and coexistence demonstrates the challenges of coalescing human-wildlife interactions, asking, "can novel methods and emerging technologies such as mobile phones, social networks, and drones inform human–wildlife coexistence?" (Nyhus, 2016). In 2016, an independent study reviewed 274 articles published between 1981-2015 on the effects of human recreation on a variety of animal species across all geographic areas in the United States and recreational activities. The study found "decreased species diversity, decreased survival, reproduction, or abundance of species, and behavioural or physiological disturbance, such as decreased foraging or increased stress" (Guiden, 2016). Given this, are we simply documenting a mass extinction, or can we inspire everyone to be ecological citizens and put us on a new path of sustainability?

The challenge is how public and novice interactions are scaled and what are their impacts? The United States National Park Service (2020) has a proactive response to "recreate responsibly," encouraging people to "investigate prior to travel, know your [personal] limits, [and] if you bought it take it home" (regarding litter). There is an inherent link between "increasing public access without knowledge," yielding negative impacts on surroundings. Scientists linked Covid-19 to wild animals "transfer[ing] viruses to other animals as natural habitats shrink, wild animals concentrate in smaller territories, such as homes and barns" (Watts, 2020). On 18th May 2020, thousands of visitors "descended on [U.S.] Yellowstone national park, opening for the first time since the coronavirus pandemic," yet their refusal to socially distance or wear masks demonstrates uncharitable perspectives on the natural world (Gilbert, 2020).

An enhanced relationship "between people and nature staves off a collapse of all life-supporting ecosystems" (Bucher, 2020). Pet ownership or custody has risen in the U.S. and U.K. since the pandemic – with an estimated "900 million dogs in the world, with 89.7 million pet dogs in the US" (Kiss, 2019) – yet it raises challenges by disrupting ecosystems. Known as "livestock worrying, dog attacks on farm animals result in fatal injuries. Distress of a chase can cause sheep to miscarry lambs and sometimes die from exhaustion" (NFU, 2020). The U.S. Centers for Disease Control and Prevention says, "dog waste can spread diseases including campylobacter, tapeworm, hookworm, roundworm, giardia and E. coli" (Kiss, 2019), and urine and faeces can cause habitat-changing eutrophication on popular dog walking routes. The most recent figures of creatures killed by cats from the Mammal Society estimate that annually, "UK cats catch up to 100 million prey of which 27 million are birds" (RSPB, 2020). In summary, we must re-question our values and approach to the natural world, and the challenge is who (if anyone) should dictate terms?

The Royal Horticultural Society (RHS) (n.d.) states "there are 1,377 non-native plants in the UK, but only 108 (8%) are considered invasive." Invasive species change ecosystems and habitats with non-biotic effects, such as reducing water flow leading to flooding or pH change or the chemical composition of the soil, lock up nutrients, outcompete native species either by habitat change or spreading rapidly crowding out slower growing species, threatening long-term species survival. (RHS, n.d.)

Our materials, pollutants, and abundant litter cost us; "clearing one bag of roadside rubbish costs £40 [approx. US$47] because of road closures" (Coward, 2018). Wildlife experts stated that "public" interactions need to increase over time, as we should aim to engage new participants and foster their literacy of contextual needs and localities.

Finally, we must enable wildlife to stay "wild." The Natural Health Service recounts "a [human] couple approaching a red stag, grinning with a selfie stick, the beast weighing 200 kilograms, could move at 40 miles per hour, and was so full of testosterone that he would chase and potentially gore them" (Hardman, 2020). In summary, we cannot dictate to people. We (the public) need retraining in uncommon natural circumstances, our material use as both is not part of our common sense nor (for most people) part of our cultural upbringing.

Conclusion

We believe that we are in a transition to more "ecologically centred times." Transition design provocation(s) believes that "while many have called for design-led societal change, few have articulated how to undertake and lead/catalyse such change, nor have they identified the areas of knowledge and investigation required to do so" (Irwin et al., 2015). Transition design should be based upon "a deep understanding of the social history of technology, and a post-planning approach to how the introductions of new technologies impact society" (Irwin et al., 2015). Rather than just "being more sustainable," we endeavour to explore how people can take individual or collective action(s). The approach builds the opportunity for "citizenship" by creating catalysts and legacies.

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[6] https://www.thewashingmachineproject.org/

DESIGN ACTIVISM: ARE WE DOING ENOUGH?

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Abstract
Design has always expressed itself through its cultural intervention in society, accompanying or inducing technological innovation, changing behaviors and shaping the artificial world in which we live, imbuing it with new meaning and sensemaking. Regarding design for social innovation, there is now a new wave of social innovations more concerned with the environment, with younger generations taking the lead and taking action. There is also a general perception that society and companies are more active and participatory in actions to defend the planet, but are designers following these changes? This paper reflects on the role of designers in this environmental crisis and how participatory and collaborative methods are crucial to tackle this emergency.

In fact, in just one decade, new societal realities have emerged, and design has striven to keep up with them. In that context, it has enabled the emergence of technological and then social and cultural innovations, more and more necessary when we witness the planet giving signs of exhaustion in ever shorter cycles, illustrated by global climate "weirding," oceans of plastic that start to infiltrate the food chain, etc. – not to mention that the overshoot day (Earth's resource budget) arrives earlier every year.

This clearly signals that it is strikingly urgent to act to protect our shared home, even if it is not really new for those that have been involved in this field of design, from Papanek to the Desis Network. What is fundamentally different is the urgency of taking action and the way people are self-organizing to tackle this problem. There are signals that – collectively – it is possible not only to "fix" the problem, but to regenerate the planet. Even if some actions are more palliative (tackling the results and not the underlying causes), they highlight a collective desire to address and solve the issues. Given the unpredictability of events and the speed of change, designers should be more proactive than ever. Designers have the ability and capability to observe the world and find solutions to problems, to anticipate other problems, and more importantly, to devise opportunities to innovate and avoid future problems. Are we doing enough?

Author Keywords
Design for social innovation; activism; sustainability; environmental crisis; circular economy.

Introduction

Design has always expressed itself through its cultural intervention in society, accompanying or inducing technological innovation, changing behavior and shaping the artificial world we live in, imbuing it with new meaning and new production of meaning. The recognition of design as a discipline that cuts across several areas of knowledge positions its spectrum of activity at the intersection of the social sciences, humanities, arts, and engineering, and in a multidisciplinary and interdisciplinary space that crosses several strands: from communication to industrial design to service design to web design to interior design to fashion design, etc.

It is in this wide range of areas of action that design has also found micro spaces of action, often complexifying its own definition and the affirmation of the discipline itself. For a long time, the designer was seen as a "problem-solver," although their activity is much more than that of a "problem-solver." A designer is a creator of opportunities in order to prevent future problems, and much more importantly, they are a cultural mediator, a creator of senses, giving new meanings to things and contributing to the construction of a more beautiful, pleasant and sustainable world.

Designers not only have the ability to observe the world and anticipate problems, but also to create opportunities to innovate and find new solutions. They are an inseparable part of the ecosystem that builds our artificial world, so they must infuse their work with the motivation and will to design for the common good.

Environmental Problems

The current environmental emergency is a clear sign of how unsustainable the behaviors are that result from a production-consumption system based on planned obsolescence and the design of disposable products (Brown, 2000). The damage that we inflict on the planet and the depredation of natural resources is immense – 15 years ago it was estimated that for each tonne of products manufactured, 30 tonnes of waste were produced, and 98% of these products were discarded after 6 months (Datschefski, 2001). It is clear that this system is not sustainable from an environmental, social or even economic perspective. These concerns are not recent and the evidence is even less so. In the 1960s, Rachel Carson's book *Silent Spring* exposed the impact of pesticides in agriculture; in the 1970s the report *The Limits to Growth* from the Club of Rome and the book *Design for the Real World* by Victor Papanek marked a period in which the design community began to intervene more where environmental issues are concerned; during the 1990s, authors such as Alastair Fuad-Luke and Ezio Manzini began to systematize the design culture on this issue. The principles of environmental sustainability and circular economy today are (or should be) a reference in design training, considering that designers are agents of change and have the opportunity to reverse many of the harmful actions resulting from the profession, improve design training and education, and inform society and the business world about the active role we have in designing a more sustainable planet.

Good design anticipates problems and prevents them from happening. We know that incremental innovations happen every day and many of them increase our quality of life and comfort, feed the economy and keep many jobs. But radical or disruptive innovation is what can actually bring change to a system in crisis. It requires a break with the established status quo to make way for the innovation that will bring about changes that will have a positive impact on the environment.

Kate Raworth (2017), author of *Doughnut Economics*[1] (Figure 1), argues that twentieth century economic thinking is not prepared to deal with the twenty-first century reality of a planet that is on the brink of climate disruption. Economic growth needs to be seen as a means to achieve social goals within ecological limits, rather than an indicator of success in itself or a goal for rich countries (Raworth, 2017). Designers have an active role to play in this new world, promoting change through design-led innovation processes.

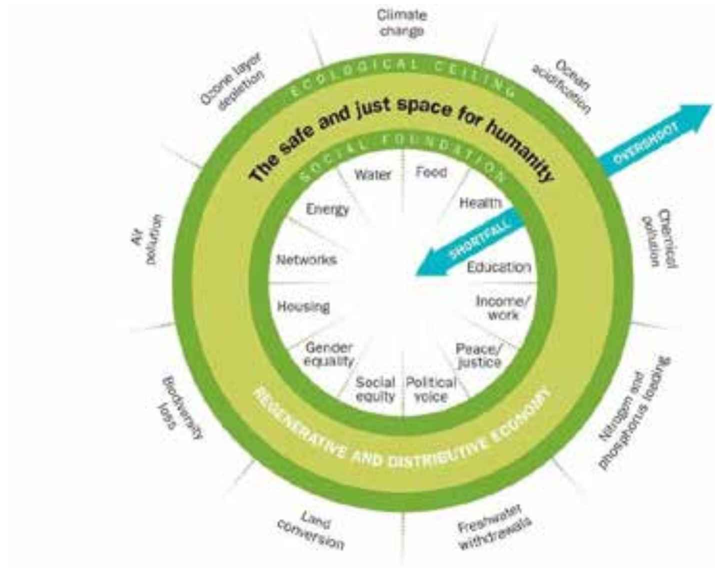

Figure 1. Diagram of Doughnut Economics (source: https://time.com/5930093/amsterdam-doughnut-economics/).

From Social Innovation to Design for Social Innovation

Although the topic of social innovation has been around for more than 15 years, only in the last five years has it reached the political limelight in Europe, be it via the E.U.'s financing policies or via the adoption of social innovation strategies by many governments, especially in countries where the welfare state places a heavy burden on the system. It is precisely due to a failing welfare state, particularly in Europe, that many citizens have organized themselves to collectively and collaboratively address problems that the government is unable to tackle (due to an aging population and declining birth rates, the lack of financial resources is aggravated by successive economic and migratory crises, among other factors).

According to Mulgan (2007), innovation is imperative when problems are getting worse, when systems do not work or when institutions reflect past rather than present problems. Among several definitions to explain social innovation, we can use Mulgan's (2007) – new ideas that work to meet pressing unmet needs and improve peoples' lives – or the one from DESIS Network:[2] social innovation can be seen as a process of change emerging from the creative recombination of existing assets (social capital, historical heritage, traditional craftsmanship, accessible advanced technology) and aimed at achieving socially recognized goals in new ways. A kind of innovation should be driven by social demands rather than by the market and/or autonomous techno-scientific research and should be generated more by the actors involved than by specialists. These new ideas have given birth to new forms of social organization and are more innovative and in line with sustainable development and a more active civic participation.

Observing contemporary society, cases of social innovation are continuously emerging in the form of new behaviors, new forms of organization and new ways of living that indicate different and promising developments. Social innovations are very important because they advance behavioral changes, without which it is impossible to tackle the problems society as a whole faces. It is possible to find technological alternatives to minimize our carbon footprint, for instance, but if people do not change their behaviors, technology will eventually run out of options. It can be acknowledged that the best way to manage change is not just through implementing new policies for whole populations but through testing and experimenting on a small scale, often involving civil society and social entrepreneurs (Mulgan, 2007). This can be a major opportunity for the intervention of the design community that is interested in developing innovative sustainable solutions for everyday problems and that wishes to promote, diffuse and eventually replicate those innovative ideas. This new approach can be instrumental in solving many of society's most complex problems, but its emergence is not without controversy. Some argue that it is not design because it does not look much like design in the familiar sense of the word – its outcomes are not always tangible, and they can be adapted and changed by people as they use them (Design Council, 2006).

From Social Innovations to the Planet

Regarding design for social innovation, there is currently a new wave of social innovations more concerned with the environment, with younger generations taking the lead and taking action. There is also a general perception that society and companies are more active and participative in actions to defend the planet. But are designers following these changes? Given the unpredictability of events and the speed of change, designers must be more proactive than ever. Designers have the ability to observe the world and find solutions to problems, to anticipate other problems and, most importantly, to devise opportunities to innovate and avoid future problems. As Saint-Simon[3] phrased it, history consists of a succession of social orders; the movement from one order to the next is triggered by the rise of a new class. Different ideas fit different periods of history. The first of the leading peculiarities of the present age is that it is an age of accelerated transition. Mankind has outgrown old institutions and old doctrines and has not acquired new ones yet. What we are seeing is society is trying to acquire new ones, and this is possible through the rise of new ways of doing things. The new generations, and in particular Generation Z,[4] have a different view of the world from the generations that preceded them and believe they will have a decisive role in fighting climate change. In 2019, *Time* magazine[5] selected Greta Thunberg (Figure 2) as person of the year in an affirmation and recognition of the activism of these new generations and the power that civil society has in political decisions. It was visible during COP26 (Figure 3) in the power of the masses with daily demonstrations in the streets of Glasgow.

Figure 2. *Time* Magazine: Person of the Year (source: https://time.com/person-of-the-year-2019-greta-thunberg/).

Figure 3. COP Generation Z Manif at COP26 (source: https://news.sky.com/story/cop26-tens-of-thousands-expected-to-march-in-glasgow-alongside-millionsmore-around-the-world-in-global-day-of-action-for-the-climate-12461258).

Manzini's text "Social Innovation for the Planet" (DESIS Network, 2019) issued the challenge to the design community, putting climate and environmental sustainability at the center of our academic and research practice. The need and urgency to reorient design teaching and research activities is inevitable at a time when we are experiencing an unprecedented environmental crisis.

Design for social innovation and design for sustainability usually go hand in hand. But design for social innovation differs from design for sustainability in the sense that the latter tends to have a more technical approach to intervention and construction of the artificial world while the former tends to have a more "liquid" intervention, allowing it to influence the way people organize themselves and are called to act on behalf of a common wellbeing.

If we take a closer look at some cases of social innovation developed by Desis Labs (Figure 4) and other communities, we can see they have positive and enduring side effects and even a regenerative principle at its core, mainly in urban areas. In other cases, like in the ever-so-sustainable Scandinavia, the city of Helsinki is piloting an initiative dubbed Think Sustainably, an innovative sustainable city guide[6] to tackle climate change with the collaboration of all citizens. Cities are responsible for a high percentage of natural resource consumption, and we need to challenge the design community to design systems based on social innovations for a regenerative city in order to innovate, not only with "quick fixes" but mainly in creating, collaboratively, regenerative and renewed solutions for urban life, based in a circular flow of local and natural resources.

Some of the bottom-up climate change movements must be supported by the community of designers with the same energy and drive that have led their interventions in the areas of social innovation. The design community must pull together and embrace a leadership role – both through knowledge and practice – to find solutions that will help regenerate the planet.

Regenerate and repair actions should happen in tandem: on the one hand, designers must work to diminish the ecological footprint of production, use finite natural resources wisely, clean up the excesses of consumption and recycle, reuse and repair instead of producing new "future" waste; on the other hand, they must support and design suitable processes to assist existing groups of self-organized citizens in their efforts to save and regenerate our common home.

From Active Citizenship to Design Activism

This kind of action starts with responsible citizens who play an important role in civil society, and they are not very different from active citizenship interventions by some design professionals. Design "activism" is actually the essence of design, of good design, of design for the common good. Design centered on people and respect for the planet helps to create a positive impact on society in general due to the power it has to change behavior and, in particular, on the designer who helps to build the artificial world around us and who should have in his or her essence this motivation and will to design for good – for the common good. Design activism is about being proactive and not reactive and, as has been referred to before, designers have this capacity and ability. Design culture has always introduced changes in people's lives, even if it has sometimes produced unintended negative consequences in the way people relate to themselves through and with objects (Baudrillard, 1997). Thus, the quality of being proactive means, in this context, introducing positive change by solving complex problems and anticipating emerging problems. However, it would be naive to think that designers can do all this alone, since it is recognized that complex problems cannot be approached from a single point of view. This requires collaboration and the ability to be collaborative and to enable collaboration.

From Anthropocene to Post-Anthropocene

Tim Brown[7] and IDEO[8] made design thinking notable for its human-centered approach to innovation during the creative process. In just a decade, new social realities have emerged and design has sought to keep up with them. In this context, it has enabled the emergence of technological then social and cultural innovations. It has become clear that the actions taken by one individual affect the rest of the community and society as a whole, and today the debate centers on the need for human beings to no longer be (or should no longer be) at the center of design activities, but rather the planet and all its life forms, human and non-human. The planet should be at the center of our research and design activities, putting environmental sustainability, climate emergency and the post-disaster condition on the agenda of design schools, but also professional practice. This is an urgent need when we witness the planet showing signs of depletion in ever shorter cycles (the earth overshoot day happens earlier every year) and illustrated by frequent global climate disasters such as floods, fires and plastic islands in the middle of the oceans that are starting to infiltrate the food chain, etc.

These phenomena are nothing new to those who have been working on and researching this topic for the past 40 years. What is fundamentally different is the urgency of taking action and the way people are self-organizing to tackle this problem. There are signals that collectively it is possible not only to "fix" the problem but to regenerate the planet. Even if some actions are more palliative (tackling the results and not the underlying causes), they highlight a collective desire to address and solve these issues. Similar to other social innovations that have their as main driver the lack of governmental response to social, economic or environmental issues that people are faced with in their everyday lives, these self-organized actions to clean beaches, plant trees, etc. stem from the realization that political leaders are failing to deliver the necessary change with the required speed.

Conclusion

For these strategies to have a timely impact, it is crucial for design schools to rethink curricula and teach the unconventional so that future designers can influence the "web of life" and move towards community innovation (Escobar, 2018). Designers need to be able to recognize and navigate complexity, adopting a non-anthropocentric approach and contributing to the construction of a more-than-human and sustainable world. This construction implies that designers have the ability to function as mediators in the processes of creation and innovation.

Designers must foster participative projects where it is possible to conceive and develop contexts favorable to participation, cooperation and collaboration among all actors involved in a solution. This is not an easy task, as designers must be open to the visions and opinions of others and be able to transform and adapt them to desirable outcomes. Merging the needs and aspirations of people with the goals of local authorities and other institutional actors is not a simple task, as most of the time they may seem opposed and disconnected.

But to counter this apparent disconnection and opposition, design has its own "designerly" approach; through scenario building (the ability to make problems and ideas visible), creating structures to give visual meaning to complex information and sharing this work in progress with others, even intangible concepts can be visualized, creating a common platform for strategic discussion and building a shared, participatory and collective vision.

Designers must be versatile and able to work in transdisciplinary teams, to work and collaborate with other professionals and the people who will be part of a solution. In other words, designers must act as an interface between different actors, as facilitators of ideas and interrelationships, able to mediate diverse points of view and make them intelligible, thus facilitating collaboration between diverse actors who are intuitively and spontaneously involved in the "diffuse design" that characterizes modernity.

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[1] The name refers to the visual structure of a doughnut, in which the hole in the middle represents the social aspects for maintaining a good quality of life, while the outer circle is an analogy for planetary boundaries.

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[3] http://www.britannica.com/EBchecked/topic/518228/Henri-de-Saint-Simon

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[7] https://designthinking.ideo.com

[8] https://www.ideo.com/post/design-kit

DESIGN FICTION AND THE ECO-SOCIAL IMAGINARY

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Abstract
Drawing on Castoriadis' (1975) notion of the social imaginary, the creative intersection of graphic design with the socio-historical field is framed in this paper, not as a utopia but as an innovative and pragmatic liberation from the unshakeable reality of the everyday. The macho "reality" of survival in a world of financial insecurity, police harassment, and racism situates sustainability, community, and caring for the planet or elderly as less important or soft, as mass media responses to the Intergovernmental Panel on Climate Change report attest. Even the "reality" of design education is determined by precarious labour markets and the commodification of knowledge in the neoliberal university. In this context, the conceptual capacity for alternative modes of problem-setting and solving is critically delimited. Design fiction is introduced in this paper as a research method that facilitates a radical adaptation of the social imaginary for design students' educators and/with local communities. In so doing, fiction reveals alternative modulations of our local identities and future formulations, in relation to climate change/disaster. Within the social imaginary, fiction intervenes as a catalyst for collective transfiguration, adaptation, and innovation, a re-envisioning of design's relationship with the "real" in light of a new urgency to move forward in a new trajectory.

The strategic role of fiction is explored and evaluated in two contexts; firstly, as the research method employed in a design educators' conference in the U.K. (Graphic Design Educators Network, *Ideas of Revolt*, 2017). In this context, alternative socio-political scenarios (utopia, dictatorship, monarchy, communism) are examined in an action-based workshop on the speculative possibilities of art school as a concept and place. The mythical capacity for creative autonomy and/or revolt is considered through collective modulations of graphic design practice: problematised and unpicked by design academics from across the U.K. in an effort to understand the core needs of the art school experience. The underlying principles, purpose, and potential of the art school are thus interrogated as more of an open concept, unconstrained by the "preconstituted" boundaries of the "impossible." The second case study analyses and evaluates the role of digital technologies, such as video, augmented reality, and virtual reality in the Sankofa City project, a community-university collaboration based in a historically Black neighborhood in South Los Angeles. Not only are collective, cooperative, and codesign research methods a feature of this project, but fiction plays a key role in giving the local community permission to imagine and make tangible their alternative futures in a profoundly eco-social imaginary. Fiction is thus a form of everyday agency, helping us move beyond the impasses of the real to embrace radically new stories about designers as critical agents. A new social imaginary is proposed in this context as a catalyst for adaptation to facilitate change, pivoting from the assumptions of the real towards a new imaginary in which our relationship to the

planet's natural resources is as interwoven as our collective identity within each current micro or macro social network.

Author Keywords
Social imaginary; design fiction; eco-social; world-building; community; co-constructing.

Introduction
Situated in-between commerce and culture, public needs and private interests, graphic design contributes to a continuous process of shaping both our visual and our conceptual horizons (Drucker & McVarish, 2009). The stories that design tells us about yesterday, today, and tomorrow – the world and our place in it – are interwoven with the "fictional functions and functional fictions" (Dunne & Raby, 2008) of advertising, marketing, product design, and visual communication. Contradictions are implicit in this narrative process, which is simultaneously "instrumental in the rise of capitalism and neoliberalism" (Laranjo, 2017, p. 3) while also making claims for social, environmental, and/or political change. Such contradictions are not new, as the *First Things First* manifestos (1964, 2000, 2014, 2020) attest. In the original *First Things First* of 1964, Ken Garland and twenty-one signatories called for a "reversal of priorities" towards a more purposeful and worthwhile application of the designer's skills and imagination. By 2000, the destabilising impact of capitalism and consumerism on the social/civic sphere were contributing to "a reductive and immeasurably harmful code of public discourse... The scope of debate is shrinking; it must expand. Consumerism is running uncontested; it must be challenged" (Dixon et al., 1999, para. 5). More recently, an online *First Things First 2020* edition explicitly links design with unethical capitalism and ecological disaster: "Our time and energy are increasingly used to manufacture demand, to exploit populations, to extract resources, to fill landfills, to pollute the air, to promote colonization, and to propel our planet's sixth mass extinction" (O'Brien et al., 2020, para. 1).

Yet surely a cognitive dissonance arises in the mind of the student designer who is increasingly tasked with reducing material consumption while strategically being positioned by successive governments as the champions of urgent and perpetual economic growth devoid of socio-ecological cost? Indeed, current political discourse in the U.K. either ignores the climate crisis completely or explicitly (re)brands the net zero climate target as "unilateral economic disarmament" (Merrick, 2020). Citing the negative impact on U.K. industries and criticising businesses that prioritise social justice over production and profits, Kemi Badenoch, one of the candidates for the Tory (Conservative Party) leadership, vowed to axe the climate commitment should she be elected. When economic growth, rather than social needs, is entrenched as the driving force of politics (Giroux, 2014, p. 13), and U.K. counter-terrorism police place the non-violent climate activists Extinction Rebellion (XR) on a list of extremist ideologies (Dodd & Grierson, 2020), radical socio-political action is needed from designers.

However, sustained evisceration of collective social agency has formed an ideological attack on the capacity of (young) people to even imagine a different, more critical mode of subjectivity and/or an alternative mode of politics (Giroux, 2014, p. 14). For Giroux (2011) there is a need therefore to "mobilize the imagination and develop a language of possibility" beyond a "culture of conformity and the passive absorption of knowledge" (p. 5). In a more participatory mode of professional design practice and engaged pedagogy, designers are called on, not only to write and/or sign manifestoes, but to act as critical agents in the social sphere (hooks, 2011; Giroux, 2011). Critical pedagogy and critical design converge in this context as a means of challenging narrow assumptions, preconceptions and givens about the role design plays in everyday life, to paraphrase Anthony Dunne and Fiona Raby (2007). For Dunne and Raby (2001), the rapid expansion of technological media has not been matched by sustained critical insights into the impact and consequences of the plethora of artefacts and interfaces that are infiltrating all areas of our lives:

> We need to develop a parallel design activity that questions and challenges industrial agendas... Critical design, or design that asks carefully crafted questions and makes us think, is just as difficult and just as important as design that solves problems or finds answers. (p. 58)

The role critical design could play in design practice and education was initially developed by Dunne and Raby in the publication *Hertzian Tales* (1999), followed by *Design Noir: The Secret Life of Electronic Objects* (2001), which popularised a more challenging, and subsequently speculative, mode of product and industrial design. As the techno-cultural and political conditions of design are constantly changing, the need to critically analyse and question the impact of design products and technologies on social behaviour, cultural hegemony, labour, and leisure becomes more pressing. Culture is embedded into design interfaces, as are the neoliberal narratives of individuality, consumer choice, and a preoccupation with the now. Dislocated from our socio-historical past and industrial legacies, we are further discouraged from engaging with the incontrovertible impact of today's actions (or inaction) on tomorrow's (natural) world. A critical approach is pertinent to the overarching theme of this conference in the adaptability of critical thinking to changes of circumstance, place, and time, based on an "assumption that knowledge and power should always be subject to debate, held accountable, and critically engaged... critical pedagogy forges critique and agency through a language of skepticism and possibility" (Giroux, 2011, p. 172).

In "Criticality Meets Sustainability," Ramia Mazé (2008) identifies an intersection between sustainability and critical design in the production of discourse which contests rather than affirms or acquiesces to mainstream or traditional notions of production and consumption (p. 7). Critical design, which is connected to speculative design and design fiction, challenges the status quo and seeks alternatives to those practices which appear natural and/or inflexible to change by addressing the "ideological foundations" of the discipline (Mazé, 2008). In a discursive process of redirecting design's powerful and persuasive forms towards a more reflexive pedagogy and professional practice, new perceptions, behaviour, and cognition of (graphic) design are sought, which reconfigure and re-imagine relations between design, society, and ecology. What this paper explores is the affordances of the social imaginary as an extension of the popular imagination, given shape and form as a research method. This method will be considered in two practice-based examples; the first draws on a critical pedagogy to re-imagine art school and design education in a series of fictional and/or speculative scenarios. The second example focuses on a method of co-designing "infrastructures of the imagination" with local communities through emerging technologies (Baumann et al., 2017).

Shaping Design and Future Thinking

Understanding graphic design's social configurations and its intersections with everyday life is crucial to uncovering the infinite varieties of possibility – in both pragmatic and conceptual formulations – that can emerge from discursive relationships around education, politics, culture, and the environment. Through its multiplicities of expression and production, design gives form not only to the concrete commodities of our everyday but also to the more amorphous values, ideas, and ideals of the social experience. As Cameron Tonkinwise argues, "the human condition is conditioned by designers; every designed product or system in turn designs certain kinds of humans, or at least certain ways of being human" (Auger, 2019, para. 5).

The oppositional tension between the real and ideal – or indeed, possible – has been exacerbated by capitalism's colonisation of "the dreaming life of the population" (Fisher, 2009, p. 12) in which "capitalism [now] seamlessly occupies the horizons of the thinkable" (Fisher, 2009, p. 8). In this neoliberal framework, "instability is a constant," creating a state of crisis which is normalised through news media as the "way things are" (Fisher, 2009, p. 33). The perceptual boundaries of possibility afforded by the "real world" seem to have shrunk "to an overall opposition between reality and ideas; ideology and the imaginary stand together on the side of ideas constituting a sort of ethereal medium which veils the hard reality of material production" (Thompson, 1984, p. 16). Why is "reality" hard while ideas are soft? What counts as the "real," and conversely, what seems possible at any point in the social field is defined by a series of political and market-based determinations. Indeed, as Cornelius Castoriadis (1987) argues in *The Imaginary Institution* (first published 1975), the boundaries of what is deemed "possible" or "impossible" are preconstituted: they appear definite and distinct (p. 263). The current state of "capitalist realism" frames poverty, famine, and ecological catastrophe as inevitable parts of our reality "while the hope that these forms of suffering could be eliminated easily [is] painted as naive utopianism" (Fisher, 2009, p. 16). Fisher (2009) argues that "climate change and the threat of resource-depletion are not being repressed so much as incorporated into advertising and marketing" (p. 18). Passive consumer stupefaction in response to the climate crisis presupposes that the earth's resources are "infinite" and that "any problem can be solved by the market" (Fisher, 2009, p. 18). In this market-based landscape, "the relationship between capitalism and eco-disaster" is, by its very nature, "opposed to any notion of sustainability" (Fisher, 2009, p. 19).

Far from there being no alternatives to the "reality" of austerity, poverty, and the disparity of wealth and healthcare, this paper proposes a localised, community-based politics of the imagination in which individuals act as critical agents in their own social environment. Instead of working with assumptions of catastrophic environmental inevitability, stunned into inaction by the "pervasive sense of exhaustion, of cultural and political sterility" (Fisher, 2009, p. 7) which constrains thought and action, a more co-constructed eco-social narrative is proposed as a "new (collective) political subject" (Fisher, 2009, p. 53). By transgressing the sphere of the real and the ideal, the social imaginary is framed in design research as a narrative worldmaking process that synthesises fiction with the real in a profound realisation or recognition of our inherent capacity to adapt and co-construct visions of our future.

As future thinkers, designers give shape to the world of ideas by working with tomorrow's realm of the possible while simultaneously incorporating the consumer pragmatics of present-time reality. Dunne and Raby (2008) have built a critical practice around the role that design products play as "the currency of today's consumer society, they surround us, shaping and mediating our experiences, dreams, fantasies and desires" (para. 4). Products are conceived as props to "hint" at imaginary/future worlds through the "world-constructing" aspect of fiction that remains purposefully incomplete to allow readers and participants to complete the construction of their own world (Dunne & Raby, 2016, p. 56). The collective, or at least cooperative, space in which we (re)imagine ourselves can be built around the products, technologies, and artefacts of design by exploiting the space of meaning that fiction offers: "design fiction objects are totems through which a larger story can be told, or imagined or expressed. They are like artifacts from someplace else, telling stories about other worlds" (Bleecker, 2009, p. 7).

By contrast, graphic design's in-between status enables its position and configuration to constantly be adapted to new and diverse contexts or conversations. This field of design is thus able to construct a bridge between the present and the future, the real and the possible, it occupies a space seeking connections with an audience and client (Chimero, 2012, p. xiv). The act of shaping meaning through design is a discursive, generative and collaborative process: "design springs from a complex social ecosystem created by multiple parties' interests weaving together to produce" an outcome drawn from a multiplicity of responses (Chimero, 2012, p. xiv). The scope of potential responses is as infinite as the imaginative exchange in the client-designer-audience network which converges the social with the imaginary through design (Chimero, 2012, p. xiv). But what kind of future are research labs and technology industries shaping? By working with future possible scenarios for product and interaction design, Dunne and Raby use an intellectual framework informed by critical thinking to consider more holistically the socio-cultural and environmental implications of design.

Design Fiction and the Social Imaginary

By reconfiguring the "thingness" of the design process to produce new stories, positions, ideologies and epistemologies instead of ever-more disposable consumer goods, we can make space for the change needed to embed community resilience and forge a different, more sustainable route through life. Rather than powerlessly accepting the world as it is, new worlds of the imagination can be generated through design discourse and given shape – through accessible tools such as word and image – to create new paradigms of thought and action. Design (fiction) is thus capable of not only becoming a way to redirect our trajectory toward a desirable future, but also working to "establish the vocabulary we use to define the terms of our engagements with one another" (Chimero, 2012, p. 62). As Umberto Eco (2016) says, "every work of fiction aims at saying something about our world" (p. 12).

Castoriadis' notion of the social imaginary refers to a set of commonly held values, institutions, signifying images and symbols that create/construct a community's own existence, or "reality." For Castoriadis, the socio-historical world is a "world of human action or 'doing' (faire). While action always stands in some relation with knowledge (savoir), that knowledge is never exhaustive or absolute" (Thompson, 1984, p. 19). The process of social-historical action, of doing and representing through signifying (visual) language, forms many parallels with the process of designing (Castoriadis, 1987, p. 249). The social imaginary is conceived here as a process of making-through-thinking itself by drawing on the resources (human, intellectual, imaginative, practical, technological) that already exist within each community, similar to the world-building of design fiction: "the social imaginary must assemble-adjust-fabricate-construct itself as society and as this society, it must make itself be as society and as this society, starting with itself and with what 'is there'" (Castoriadis, 1987, p. 260).

Design thinking and local communities are simultaneously changeable but also situated in time and space/place. Notions of place are determined by the social-historical and cultural narratives of each community. These stories are shared and adapted to new places and people drawing new characters into the narrative tapestry of each community's social history and future. Acknowledging our interconnected dependence in a shared story adds richness and depth to a situated tale of human existence and destiny. The social imaginary is not a mirror image or reflection of what is already in that place but "the creation, ex nihilo of figures and forms" through "symbolism, tradition, and myth" (Thompson, 1984, p. 23). In *Studies in the Theory of Ideology*, John B. Thompson (1984) frames the social imaginary as the "creative and symbolic dimension of the social world, the dimension through which human beings create their ways of living together and their ways of representing their collective life" (p. 6).

Thompson (1984) is critical of pervasive notions of ideology as a singular set of collectively shared "values and norms" instead arguing for a "mobilization of meaning" (p. 5) in a more plural or multi-layered dimension of the social imaginary. In the face of corporate powers which are shaping contemporary narratives of climate crisis, a mobilization of the imagination affords the development of "a language of possibility in which any attempt to foreclose on hope could be effectively challenged" (Giroux, 2011, p. 5). In the context of the imaginary, Thompson argues that ideology forms a network of relationships between autonomous adults operating through language and that (visual) language is a medium of social action. He rejects the notion of ideology as "pure illusion, an inverted or distorted image of what is 'real'" – but rather embeds ideology as a core component of the social world, "a creative and constituent element of our social lives" (Thompson, 1984, p. 5-6). The creative intersection of graphic design with the socio-historical field is framed in this paper not as a source of utopian illusion but as a liberation from the unshakeable "reality" of the everyday.

A distinction is made here between the limited horizons of the imagination that lead to "nihilistic hedonism" or repudiating the idea of positive ecological change as a "dangerous illusion" (Fisher, 2009, p. 5) and fiction as a strategic and pragmatic socio-cultural tool. Within the social imaginary, fiction plays an active role in collective transfiguration, adaptation, and innovation, a re-envisioning of design's relationship with the "real" in light of the climate emergency. In this context, the conceptual capacity for alternative modes of problem-setting and problem-solving is critically delimited. From the "reality" of (U.S./European) design education, determined by precarious labour markets and the commodification of knowledge in the neoliberal university, to underfunded local communities whose social bonds have been severed by neoliberal visions of competitive individuality and/or the effects of Covid, the relationship between the real and the possible needs urgent rebuilding from within.

Designers pride themselves on their adaptability, mental agility, creativity, and value to the civic and commercial spheres, but heeding the warnings of Mark Fisher and Henry A. Giroux – without reclaiming our critical agency to act on and change the reality of the immediate future, our stories will fail to form legitimate alternatives. This next section will look at how design fiction, or rather the strategic intervention of fiction in the context of the social imaginary, can operate as a catalyst for collective agency, adapting design processes to a more co-created and generative remodelling of who we are and the stories that we choose to live by as a social form of doing.

Design Fiction in Context

The "every day is constructed through the deployment of fictions to form and direct every part of our lives" (Shaw & Reeves-Evison, 2017, p. 7). It makes scenarios real enough to feel possible, inspiring dialogue and interaction. The audience, a group so often equated with passive consumption, are transformed into active agents co-creating their own future imagery in a process similar to a social semiosis in which meaning can be continually enriched by reconfiguring "old" signs in new operations (Kress & Leeuwen, 2006, p. 13). The diversity and multiplicity of resources available to each social imaginary can be transformed into new meanings by all signmakers, whether designers or the public in this process. Design is framed in this cultural context as an in-between component, connecting individuals within a group, acting as a bond or bridge within a community or society, not only linking people, but also ideas. By identifying or choosing the moving parts that we need to tackle each problem, "we can begin to strategize how to make this movement sway together" in the form of a social "dance" (Chimero, 2012, p. xiv). Designers and ordinary people thus cooperate to imagine their social existence and surroundings not through theory but through "images, stories, and legends," tools that are central to visual communication and design practice (Taylor, 2004, p. 23).

Ideas are rooted in the material conditions of social life, therefore the strategic role of fiction is explored and evaluated in two contexts; firstly, as the research method employed in a workshop delivered at a design educators' conference (Graphic Design Educators Network, *Ideas of Revolt*, 2017). In this context, alternative socio-political scenarios (utopia, dictatorship, monarchy, communism) are examined in an action-based workshop on rebellion in the mythical reality of art school – as a concept and place. In the second example, the role of digital technologies such as video, augmented reality, and virtual reality (VR) are analysed and reflected on in a community-university collaboration based in a historically Black neighbourhood in South Los Angeles. Not only are collective, cooperative, or co-design research methods a feature of this project, but fiction plays a key role in giving the local community permission to imagine, and make tangible, their alternative futures in a profoundly eco-social imaginary. Fiction is deployed as a form of agency, helping us move beyond the boundaries of the now, the real, and the everyday to embrace radically new stories about designers as climate citizens, about who we are and what we work and live for.

Graphic Design Educators Network: *Ideas of Revolt*

Established in 2014 by four (U.K.) design educators, primarily in response to poor outputs submitted to the Research Excellence Framework (REF) in the U.K., the Graphic Design Educators Network (GDEN) is described as providing a "space (a lab) to investigate the social, cultural, political and ecological contexts (and requirements) of graphic design education" (GDEN, 2022, para. 2). The REF comprises four funding bodies; the "shared policy aim for research assessment is to secure the continuation of a world-class, dynamic and responsive research base across the full academic spectrum within UK higher education" (REF, 2022, para. 2). Since 2014, the GDEN has organised 12 symposiums, had over 850 attendees and gained 480 members predominantly, but not exclusively, from the U.K.

Figure 1. Members of the 2016-2017 Alternative Art School explore circles of trust and power relations in the institution.

Having attended several GDEN symposia, I was invited to design and lead a workshop event for the GDEN annual conference at Sheffield Institute of the Arts, Sheffield Hallam University, U.K. (7-8 September 2017) working with the title *Ideas of Revolt*. I offered to codesign the workshop with the Alternative Art School (AAS), a student-led collective of level 5 (second year) undergraduate graphic design students from Kingston School of Art (London) (Gale, 2017). The AAS was formed as a rolling collective in which power relations and autonomy were critically discussed as complements to establishing a mutually agreed-upon set of principles and ambitions of the discipline of graphic design in a social context (Figure 1). The AAS co-created the workshop with me (their year leader and tutor at the time) by drawing on the group's own social imaginary and the pedagogic innovations they had collectively devised during the course of previous AAS members' meetings. The five-hour series of "thought experiments and workshops" (Gale, 2017) sought to provoke new visions and configurations of design education in the U.K., unconstrained by the inflexible realities of the contemporary educational, economic, and political landscape. Ranging in age and teaching experience from those in their early 20s to late 50s, the workshop sought to stimulate radical re-imaginings of the art school. The younger participants brought an impassioned ethical conviction that design could and should do more, while the older members drew on a broader range of political and economic histories and experiences.

Figure 2. Breakout groups discuss ideal conditions for art school, GDEN *Ideas of Revolt* conference, Sheffield Hallam (2017). Pictured from left: Emma Teasedale (AAS member), Laura Gordon, Sheena Calvert, Kira Salter, Rathna Ramanathan, and Shoena Turnbull.

Approximately 60 design educators participated in small groups to interrogate the ideal socio-political conditions for an art school and design education in a convivial spirit. Design fiction was introduced to the participants as a critical research thinking tool alongside drawing as a form of shaping concepts, physical construction, and debate as a means of co-constructing alternatives to the general sense of impotent malaise at the contemporary crisis in design education in the U.K. In a functional use of fiction, a range of possible, current, speculative, or near-future socio-political scenarios for art school education were introduced, comprising theocracy, utopia, neoliberal republic, monarchy, capitalist socialism, dictatorship, and other (Figure 3).

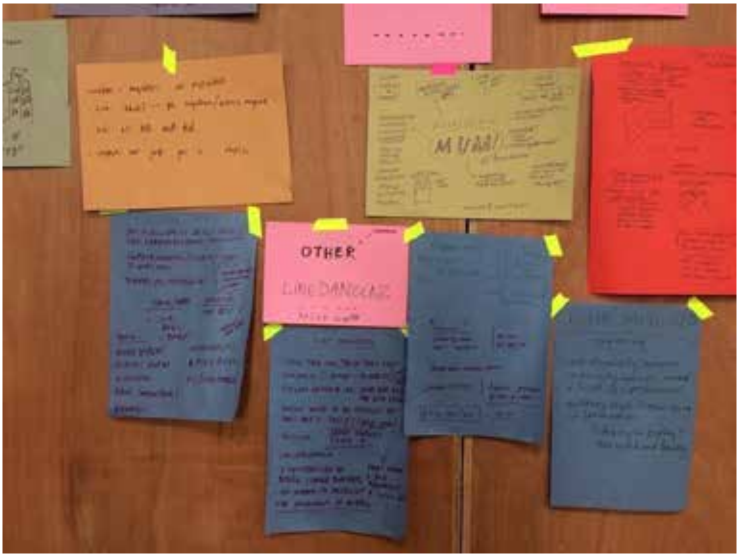

Figure 3. Fictional scenarios for art school and design education.

Each group self-selected through choice of scenario (Figure 2), lending a certain level of investment to the process. The underlying question was: if the current neoliberal conditions of arts-based higher education are unsustainable, as Giroux argues, what alternatives are available to us as critical agents? As participant Hannah Ellis observed, it was made clear at the beginning that each scenario could be constructed within a "sliding scale" from the speculative to the pragmatic because even the most fantastical proposition can be explored as if it were real (Ellis, 2017).

The question of "what if?" was thus inserted alongside the notion of "as if" to move the debate beyond the pre-constituted boundaries of the possible and impossible within concepts of the present by "opening the radically new, embracing or reinvigorating the incoming future" (Shaw & Reeves-Evison, 2017, p. 8). Differentiating "as if" as a present day parallel or alternative fiction from "what if" as a near future speculative proposition infused variable levels of the real into the art school world-building process of each group. "Speculative fabulations" infusing myth, tragedy, and fantasy with the everyday can be defined as: "the making of anthropological fictions sufficiently vivid and intense to open space to the imagination of transformative futures, as to be capable of intervening in and reshaping reality" (Anastassakis, 2021, p. 170).

By giving permission to the participants to determine their own position between the extremes of "reality" and "fantasy," each community of practice collectively formed their own social imaginaries in which the educational institution in each political scenario was conceptually constructed "as if" real, or at least possible. As Shaw and Reeves-Evison (2017) argue, "fictioning can be thought [of] as an invitation that we strategically extend to the radical unknowability of the future" (p. 23). In problematising the art school itself as a design fiction, participants applied real-life working experiences of politics, creative revolt, and social mobility to the range of implausible and/or possible contexts offered.

Autonomy and control, freedom and fun were interposed with themes of celebrity and sainthood (David Bowie as king in a monarchy) as each group co-built a believable prototype of their proposed institution. Frank interrogations of each proposal underpinned a seriously convivial set of presentations from each thematic position that enabled more innovative and radical proposals to be conceived and shared at the end of the workshop. When the groups voted (anonymously) on the best group pitch/proposal, it was the dictatorship of mum (Figure 4) that won: "it was thought she would be tough but fair, would make sure you ate well and would probably keep all of your artistic (symbolic) productions safely stuck to the fridge" (Gale, 2017).

Figure 4. Dictatorship of Mum, GDEN Ideas of Revolt (2017).

In this context, design fiction alleviated what Robert Pfaller (2003) calls "interpassivity" or what Mark Fisher (2009) terms the "reflexive impotence" (p. 21) of a community overwhelmed by the imaginative impossibility of alternatives to the neoliberal conditions of higher education, healthcare, and politics in the U.K. By inviting the participants to imagine an ideal or possible socio-cultural, political scenario in which the art school could not merely survive but thrive, each group embraced the critical agency of the exercise to explore the ideological foundations of art and design education (Mazé, 2008). As Ellis (2017) argues, "As long as you're not carried away into pure fantasy, even the most speculative ideas can be dialled back and implemented somehow" (para. 13). The design educators attending this conference workshop operated as a community of practice in which they mobilised meaning through their own social imaginary, collectively creating new myths and pedagogic narratives in a form of social doing.

Infrastructures of the Imagination: Sankofa City

Employing a "what if?" approach to invoking imaginative freedom in a community-university collaboration between the residents of a South Los Angeles neighbourhood and academics from the University of Southern California, the *Infrastructures of the Imagination* project used fiction and speculative design as a method of "pushing the imagination toward wholly new societal systems" (Baumann et al., 2017, p. 1). Socio-cultural narratives were explored and realised through a strategic deployment of digital technologies such as VR which sought to "empower local community groups by engaging with emerging technologies in their own cultural terms" (Baumann et al., 2017, p. 1). In this community-based context, digital technologies helped participants formulate their own futures by mapping imaginative interventions onto their current neighbourhood as they constructed narrative journeys through the area. The "Sankofa City" project was developed in the context of recent population shifts in urban environments that has often led to economic disparity and a disrupted sense of local identity and belonging. Changes to local infrastructure were anticipated as leading to "significant" ethnic and population shifts. A more participatory approach was employed in which community members were invited to imagine a possible future for the local area and its inhabitants. They used "rapid-prototyping workshops to empower community-student groups to imagine technological interventions in the built environment," giving local community participants the "freedom to imagine" alternatives, investigating "the process and potential of designing speculative futures with local communities, in order to collectively imagine technology that serves a common good and reinforces local identity" (Baumann et al., 2017, p. 1).

As with the GDEN workshop, thematic constraints were employed to help guide participants through the potentially ambiguous or nebulous space of the imaginative landscape. After an initial period of "cross-pollinating" ideas, three groups were established – personas, prototypes, and scenarios – and synthesised with urban technologies to focus on creating an urban "commons." Top-down and bottom-up workshops fostered the creation of "socio-material assemblages ... generated relationships between people and places" and led to a series of "design fiction videos," which brought the participants' ideas to life, with technical support from the team of academics and volunteers (Baumann et al., 2017, p. 4). Public presentations utilised video and visual effects to share a multi-layered experience of a visitor walking or driving through the area, revealing historical moments within the present visible environment. Local residents were "inspired" by the "what if?" process, which mitigated fear of conceptual unknowns by devising a method of "infrastructuring to create shared vocabularies tied to local worldviews" (Baumann et al., 2017, p. 4). The social imaginary in this context was guided towards expanding on the methodological horizons of speculative design to work with and empower the local community directly in imagining "alternative future solutions to 'wicked problems'" (Baumann et al., 2017, p. 4). As the authors observe, speculative design has been criticised as an esoteric and elitist research method, merely fashion editorial (Auger, 2019), or the preserve of the privileged who often appear blind to issues of class, race and gender (Baumann et al., 2017, p. 1).

The Eco-Social Imaginary

Deployment of the social imaginary as a collective mobilisation of meaning has been shown to operate effectively in the re-imagining of art school institutions unconstrained by the imaginative barriers of capitalist realism. It has also been shown to inspire innovative propositions for a local urban community through emerging technologies. In this way, members of the social imaginary have the collective power to instigate change on a small but significant scale and to think in a new way about education, belonging, transport, urbanism, etc. The next stage of this exploration of design fiction and the social imaginary considers two recent cognitive shifts that reimagine a local area or nation in relation to the climate emergency.

In 2007 in Modbury, a small "horsy, farmy town" in the South Devon countryside (U.K.), Rebecca Hosking, a wildlife camerawoman, came up with the idea of banning plastic bags from all shops after discussing the idea with her friends in a local pub one evening (Barkham, 2007). Shortly after filming a documentary for the BBC in which she filmed the "devastating effect of plastic bags on marine life in Hawaii," Hosking "showed the film to the town's traders" (Barkham, 2007). Now "none of the town's 43 traders uses plastic bags" and 60 other towns in the U.K. have contacted her for help in instigating a similar revolution. Small but significant changes are happening all over the world. It is the bottom-up approach to conceptual and social adaptation and change which reveals a new source of collective power as an active manifestation of the social imaginary.

On a national scale, Bangladesh was the first country to ban plastic bags in 2002, while in 2008 in Ecuador, legal recognition was awarded to "mother nature." Although not without criticism and contradiction, the recognition of "mother nature" as a subject of constitutional rights (la Pachamama) represents "a biocentric notion which challenges the modernist vision of nature as resources subject to human use, which could imply a fundamental transition in the human-nature relationship with implications far beyond the legal system" (Laastad, 2020, para. 1). The social imaginary in these contexts suggests that structural as well as conceptual shifts are possible with both local and global implications for addressing the immediate impact and future effects of environmental catastrophe. So, while the social imaginary "incorporates a sense of the normal expectations we have of each other... how we all fit together in carrying out the common practice" (Taylor, 2004, p. 24), design fiction can form a tool for reimagining our common past, present, and future.

Conclusions

Design fiction is framed in this paper as a research method and critical design research tool that seeks to formulate new ways of thinking and designing within the social imaginary of higher education, and with local neighbourhood groups. This paper is motivated by reflections on the need for radical pedagogic practices that I have developed over several years as a lecturer and year leader of graduate design programmes in the U.K. (Kingston School of Art, Glasgow School of Art, London College of Communication, UAL) and more recently as a course leader for a post-graduate graphic design course. The socio-political dimensions of design practice and education are in a state of continuous crisis, determined by the reductive mindset of neoliberal politics and market forces, and delimited by the parameters of the "preconstituted" real. In an effort to sustain an engaged pedagogy in which curiosity, social justice, ethics, values, and power are essential components, I have drawn inspiration from Henry A. Giroux (and bell hooks, of course). The Alternative Art School (Gale, 2017), for instance, was borne out of this sense of critical claustrophobia which emerged in the U.K.'s socio-political landscape as a form of "casino capitalism" (Fisher, 2009). The neoliberal university's transformation into a market-driven, bureaucratic, survey-saturated service transformed students into units of currency and studios into expensive luxuries rather than investments in a holistic education. The observed impact on students caused the most concern: they arrived increasingly anxious about success, about "fitting in" to industry, yet were also impassioned to tackle the urgent ecological issues of our time through design. What new pedagogic methods, tools, and techniques could be employed as a catalyst for more critical discourse, reflexive analysis of design's multidimensional practice, and agency with this community of practice?

Conceived of as an applied approach to research in collaboration, or at least cooperation, with each community (of practice), the intervention of design fiction sought to expand the conceptual horizons of the students while holding a mirror to their inherent but untapped critical agency and autonomy (Gale, 2017). Fiction emerged as a necessary alternative to the conventional set of skills and models that every student was required to consume, and was then developed as a research method for a large group of design educators, gathered at a conference (GDEN, 2017). From a position of anticipating the new and embracing the impossible, participants worked with an adaptable and purposeful structure which afforded each group the permission to step aside from the impasses of the real, if only for a short time. In the process of imagining alternatives, each group adhered to an "as if" and "what if" approach to co-constructing a new vision, identity, and purpose for the art school, and greater space within each educator's everyday practice became more apparent. The conference participants were framed as members of a temporal social imaginary tasked with re-imagining their own institutional future. A new conviviality and resilience emerged from the freedom of imaginative thought exchanged in this network, bringing forth new perceptions and cognition to the idea of art school as a representative institution and to design education as a transformative practice.

In the "Sankofa City" project, design fiction was employed by a university research team in a direct working partnership with local residents of an urban neighborhood experiencing a potential shift in the demographic and the economic cleansing that can result. A new sense of belonging and engagement with the area's musical history and current community was fostered through a structured journey through speculative design and fiction to cement a sense of identity imagined through the use of emerging technologies. An "infrastructure of the imagination" – as the Sankofa project team describes it – was tested in the conventional context of a design educators' conference (GDEN, 2017).

By reconfiguring the audience or user as a discursive partner in a collective "dance" or song, we should seek to make the moving parts of design "sway together and respond accordingly as things change" (Chimero, 2012, p. xiv). In this action, we can collectively create a new shape of design drawn from the images, stories, myths, and symbols of the world. In this paper, I have sought to outline the context in which design students, educators and professionals can be reconfigured as a series of social imaginaries with the power to co-build their own futures. As the research of Dunne and Raby (2016) demonstrates, fiction and speculative design are far from incompatible with a discipline which operates in the realm of function and fantasy, seduction and information. The collective imaginary, which is veiled by the hard materiality of the real, intervenes as a generative tool for social resilience and action. Fiction is posited as a strategic research method (Shaw & Reeves-Evison, 2017) that facilitates a radical adaptation of the social imaginary to contemporary design pedagogy and collaborative practices with local communities. In these contexts, fiction reveals alternative modulations of our local identities and future eco-social formulations in response to exponential climate change and/or disaster. Design fiction is thus deployed in a process of giving clarity and form to the mutability of our times, scaffolded by systems and infrastructures that help us navigate through the nebulous waters of the future.

The practice-based research projects shared in this paper demonstrate how design fiction can be employed as a conceptual and functional tool for reimagining our past, present, and future stories. Creating a new eco-social imaginary fiction offers a mobilisation of meaning within a rapidly changing world, providing conceptual and critical agency not otherwise immediately available in the everyday. This world-building process is intentionally incomplete in order to remain in a state of openness and readiness for new stories, characters, participants, and possibilities to be incorporated in a social action.

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DESIGNING ACCOUNTABLE: COMPREHENSIBLE AND EXPLANATORY DIGITAL SYSTEMS

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Abstract
Arrangements of data structures, algorithms and programs have transformed economies, societies and our most intimate lives. At the same time, exposure of persistent problems in the technology industry's utilization of user data has focused public attention on the detrimental effects of these complex and novel systems on individuals and societies. While digital systems significantly amplify human utility and capacity, when things go wrong, they tend to be characterized, like Frankenstein's monster, as beyond their creator's control. Apologies may be offered and fines levied, but too often the damage is done; few lessons are learned and even fewer applied. If regulation is concerned with how to contain monsters, design may appropriately take on the other side of the coin: how to make more benign ones. Our digital systems can enable action on climate change because they can account for, audit and also influence opinion, sentiment and behavior, thereby supporting collective decision-making and action. Thus, the societal, political and environmental consequences ensuing from lack of attention to design in digital systems is profound. The problem space of climate change is not addressed explicitly in this paper; rather, the design of the systems capable of driving human action on this wicked problem is its subject.

This paper discusses the need for digital systems to be our ally in facing challenges and threats to individuals, societies and environments, including data usage, the proliferation of fake news, open access to cryptographically protected transactions and more. It discusses the material and design basis of digital systems and identifies two interlinked ways the word "account" can be used: to *give an account of* and to have *accountability for.* It then presents a case study of exploitation of user data for comparison with Rittel's properties of a wicked problem. Next, this paper presents socio-technical system as a potential framework for supporting a design understanding of, and engagement with, digital systems and finally discusses the possible role of visualization – specifically mapping – as a cognitive and explanatory support in this vital undertaking.

Author Keywords
Explanation; visualization; mapping; socio-technical system; wicked problem.

Introduction
In recent years, the societal utility of the microcomputer has exploded both in its ubiquity and the variety of contexts for its application. The number, usage of and reliance on computers has risen in parallel with the proliferation of novel contextual uses for it, a growth

echoing the trajectory described by "Moore's Law," a prediction made in 1965 concerning the exponential increase of a computer chip's processing capacity. Microcomputers today are also increasingly barely discernible, embedded into devices and connected to sensors forming transparent (or invisible) and quasi-autonomous digital infrastructures dubbed the internet of things (IoT). Together with machine learning, often dubbed artificial intelligence (AI), computers exchange, parse and utilize data in novel and useful ways in these interdependent, embedded, quasi-autonomous networks. Digital platforms build applications onto networks in a way that, although reminiscent of an IoT dynamic, facilitate human-machine interactions. Examples of platform applications include dating, peer and professional group socialization, market and exchange participation and also services such as accommodation and transportation, transacted within a "sharing economy." Platforms create, maintain and regulate powerful spatial, functional and relational dynamics within societies.

This paper examines the role of design within these new mediations of relational dynamics but touches only incidentally on the specific emergent microcomputing paradigms of IoT, AI and platforms. This paper also does not discuss design as a means of discovering and developing new applications for the microcomputer; this would be an analysis of design innovation which is concerned with how design can make microcomputing ever more useful to humans. Instead, this paper takes the current situation with microcomputers as a given by not posing questions about whether actions (innovations, new arrangements) *can* be taken, but whether they *should* be taken: the ethical questions and further *how* to take action, the design questions. In Herbert Simon's (1968) famous words, it addresses the question of how to design toward "devising courses of action aimed at changing existing situations into preferred ones" in digital systems. Simon's statement on design ostensibly stands in contrast to Facebook/Meta founder Mark Zuckerberg's widely quoted statement on technological innovation. In an interview with Business Insider (2010), Zuckerberg stated his directive to his developers and team to "move fast and break things ... [and that] unless you are breaking stuff, you are not moving fast enough."

The contrasting nature of these statements, one by an acclaimed Nobel Prize winning social scientist and academic and the other by an audacious, successful and wealthy entrepreneur/founder, helps us to understand the paradox of the design undertaking. On one hand, design seeks to create better (or preferred) experiences, services or systems; on the other, it often tends to do this through a relentless develop-iterate-prototype-test cycle, often conducted at rapid pace, with little regard for consequences. Although these imperatives appear contradictory, each shares an epistemology based around 1) embracing action, changing existing situations either incrementally or radically, 2) understanding that design has a central role to play in this change and 3) embodying a "telos" (goal) imbued with a bias toward scientific progress.

This paper briefly sketches out the challenges for designers engaged with a long-term, complex and "wicked" problem; how can the life-and-world changing utility, applications and tools brought about by microcomputers support societies without breaking them? On May 2, 2014, Zuckerberg amended his initial statement, announcing that the company would henceforth be changing its internal motto from "move fast and break things" to "move fast with stable infrastructure" (Baer, 2014), a move designed more to quell alarm about breakage than address underlying problems. The question of the creative and destructive power of digital systems is framed here as a critical task for those who seek to design within the spaces where microcomputers act, and certainly those with the ambition to design according to Simon's "preferred situations." The first section of this paper presents digital systems in a material way that accounts for digital systems as man-made structures, followed by analyzing a case in which microcomputing has presented societies with wicked problems that challenge our ability to account for them. The second section introduces a framework – socio-technical systems (STS) – and the methods of visualization and mapping as cognitive and explanatory supports for design within digital systems. The discussion/conclusion section highlights the significance of the problems described here and their implications for climate change action and discusses avenues for further research and design practice.

Accounts of Digital Systems

For designers, it is important to understand the tangible basis of what has been designed and how it has been designed in order to better understand why, whether and how it might be re-designed. In this section, account means to *offer an account of* what systems operate, while in the second section it means *being accountable for* what digital systems do. This is a subtle distinction but an important one, and these two definitions are linked. This section briefly discusses how material understanding of digital systems makes seemingly invisible operations more tangible, then goes on to acknowledge the "wickedness" of the problem of giving adequate accounts of these systems' impacts and consequences.

The Material Basis of Designing the "Intangible"

Computer scientist and sociologist Paul Dourish (2017) highlights how the most primordial digital material, the zeros and ones or "bits" from which programs and algorithms are built, determine the design logic of the programs that run them. Constraints at the level of bits frequently determine representational and design choices and trade-offs for programmers. Niklaus Wirth (1976), a computer scientist, highlights Dahl et al.'s (1972) argument that many programming errors may be prevented by making programmers aware of their methods and techniques "which they hitherto applied intuitively and often unconsciously" (p. 7). Wirth (1976) argues for the value of programmers developing a meta-understanding of the material, structures and representational relationships brought into alignment by the computer program:

> Programs are concrete formulations of abstract algorithms based on particular representations and structures of data... [and further] decisions about structuring data cannot be made without knowledge of the algorithms applied to the data and that, vice versa, the structure and choice of algorithms often strongly depend on the structure of the underlying data. In short, the subjects of program composition and data structures are inseparably intertwined. (p. 7)

Dourish (2017) explains that Wirth's contribution, focused on the practice of software design in a structured programming tradition, drove standard industry practice "toward mutual design [intertwinement] of algorithmic processes and the 'data structures' over which they would operate" (p. 2). He provides an excellent account of the evolution of interest in algorithms, from part of the specialized "intellectual furniture of computer science into objects of public attention, newspaper articles and coffee shop discussions" and the flourishing of its salience to contemporary culture, especially when activated in relation to very large datasets, or "big data" (p. 2). Dourish (2016) asserts that, besides lines of code, or even within a larger software system, the materiality of algorithms can be understood quite literally

> as a running system, running in a particular place, on a particular computer, connected to a particular network, with a particular hardware configuration. All of these critically shape the effect that the algorithm has... storage speeds, network capacities, instruction pipelines or memory hierarchies can all affect algorithmic performance. (p. 6)

The material basis of "cloud computing" provides a good example of the visibility of the external infrastructure support systems that are essential to cloud performance. Here, centralization of data storage is necessary because physical proximity of equipment such as routers, security devices, storage systems and application delivery controllers enable them to work together more effectively. The cloud metaphor, suggestive of immateriality, refers to its "off-premises" status whereby infrastructure is leased and managed by a third party and data center resources are accessed over the internet. It does not refer to the physical infrastructure that makes the cloud possible. Figure 1 illustrates the physical infrastructure support layer which allows servers to operate together at scale, facilitating smoother, more secure operations of data structure, algorithm and program.

Figure 1. Physical pipelines. An HVAC air handling system for a large data center. Photo: Alf van Beem.

Computer programmers and designers of digital systems more generally must develop a working understanding of their form, content and underlying material infrastructure layers, properties and their relationships. The following case study highlights why this is important.

Prediction as Product: Beta Testing and the Wicked Problem of "Customer Validation"
Originating in the practices around the design of computer technologies, the first use of the term "beta" was at IBM in the 1950s (Day, n.d.). Today, beta-testing is a widely used process in product development across sectors and has entered both the design and business lexicons broadly denoting a "try it out and then reiterate it" approach to the development of products, services, processes and more. According to Babich (2019), writing in the Adobe forum, beta testing is:

> … a type of user acceptance testing where the product team gives a nearly finished product to a group of target users to evaluate product performance in the real world… Beta testing is usually black-box testing, meaning test participants don't know anything about the backend and don't have access to source code. Since beta testing happens most of the time at the end user's side, it cannot be a controlled activity. Beta testing can provide extremely valuable insights – genuine scenarios of interactions with a product.

A nearly-ready product is beta-tested when it is released to a user group and data about how it functioned is obtained and used to inform the design of the next iteration of the product. As designers of products and services well know, the value of beta testing is two-fold: first, it occurs "in the wild" (rather than the laboratory), within user's "native" use contexts and environments and second, the user of the product knows very little about its inner workings and may not even be aware they are the subject of a test at all. The value to the experimenter of this process is obvious; it removes experimenter bias from the test, moving the test into the use environment in which it will be deployed. In doing so, it provides a near-perfect simulation of eventual use conditions and it removes participant bias, as users will have little or no possibility of biasing the test if they are not aware they are being tested.

However powerful beta testing may be, it also raises significant ethical problems, including ones that university academics teaching design and deploying "rapid ethnographies," for example, should note. These include the "big three" paradigms, in academia at least, of informed consent, confidentiality/anonymity and conflict of interest. While a potential ethical minefield, beta testing is not going anywhere; it is far too useful and effective. Arising from the development culture of microcomputing, its applications today are numerous. Here we briefly examine a single case in which an organizational culture of moving fast and breaking things meets the effectiveness of beta testing as applied to data and algorithms which then coincides with a high-level of user adoption.

The most public ethical missteps by a single organization in the age of digital networks are those of Facebook. Currently mired in related controversies, of particular interest is the Facebook (now Meta) Cambridge Analytica scandal of 2010-2018, notable for its breach of the kinds of ethical standards that routinely govern research in social sciences. On March 17, 2018, news broke simultaneously in *The Guardian* and *The New York Times* of a third-party company using Facebook's user data and applying psychometric tools to target voters. Mark Zuckerberg, Facebook's founder and CEO was called to give testimony at a senate hearing on April 11, 2018. The chair of the committee Senator Thune, a Republican and self-described "light-touch person" on business regulation told Zuckerberg that "the fact that 87 million people may have technically consented to making their data available doesn't make those people feel any better" (Pramuk, 2018). In his company's defense, Zuckerberg countered that "for most of our existence, we focused on all of the good that connecting people can do… as Facebook has grown, people everywhere have gotten a powerful new tool for staying connected to the people they love, for making their voices heard and for building communities and businesses" (Bloomberg Government, 2018). The initial news and ensuing two-day hearing inflicted reputational damage on the company, affected public perception and resulted in a short-term financial hit for Facebook/Meta.

As an example of customer validation through beta testing, Cambridge Analytica's 2010-2018 involvement with Facebook was successful beyond the wildest dreams of those who originally designed its analytical tools. In 2007, David Stillwell, then a PhD student in psychology, solved a problem associated with the five-factor – or "big five" – personality model that measures openness, conscientiousness, extroversion, agreeableness and neuroticism (OCEAN). Although widely used by psychologists, when applied to marketing, relationships and politics, the model was limited by insufficient data because people tend to be hesitant about disclosing deeply personal information. Stillwell solved this conundrum by reformatting big five questionnaires into a quiz format and uploading them to Facebook in an app called *myPersonality* which then went viral. Millions of people took the quiz and Stillwell accumulated the resulting data on personality traits and Facebook habits for four million users.

Now working at the University of Cambridge's Psychometrics Centre, he and some follow researchers used these data in a published paper in which they demonstrated, for example, how one could predict an individual's skin color or sexual orientation based on their Facebook "likes," in addition to many other unexpected correlations in this large dataset (Kosinski et al., 2013). The commercial implications of Stillwell's paper on prediction in large datasets were noticed by Christopher Wylie in 2013. At the time, Wylie, the eventual whistle-blower who exposed the company's role in Donald Trump's presidential campaign, Brexit and the company's links to Russia, worked for Cambridge Analytica's parent company, SCL Group, in behavioral research. The seeds of the 2018 scandal were sown at the same moment that Wylie connected with Stillwell's work and found a data scientist willing to work on it for SCL.

At SCL, Wylie initially researched how data online could be used to identify people who would be probable targets of extremist groups to better understand how extreme ideological messages spread through social networks and devise ways of mitigating the effectiveness of these ideologies. Depending on one's interpretation of extreme ideologies, this serves a benign and even a positive purpose for society. However, in 2014, Steve Bannon, a political operative, convinced Robert Mercer – a gifted ex-IBM programmer, conservative donor and billionaire who founded the hedge fund "Renaissance Technologies" which specializes in algorithmic financial trading – to invest in the company. At this point, its focus turned toward influencing the Brexit vote in the UK and the 2016 presidential election in the US (Kroll, 2018).

In the April 11, 2018 senate hearing, design of data-enabled psychometric tools and the use contexts for those tools converged in a way that helped to define the contours of the problem of attempting to apply and monitor standards of ethical conduct in the domain of digital systems. Horst Rittel was a planning scholar who applied ideas from cybernetics and operational research to design in the 1950s at the Ulm School of Design in Germany before moving to University of California, Berkeley in 1963 to help found the Design Methods Group and journal. Rittel (1972) is widely credited with defining the properties of a "wicked problem," a formulation that has been widely taken up by design scholars in describing the contexts in which design now operates. As noted in Table 1, the broad problem of ethics in digital systems, as seen in the Facebook-Cambridge Analytica example, corresponds to all eleven of Rittel's properties of a wicked problem.

Rittel's (1972) properties of a wicked problem	**Ethical examples in digital systems with specific reference to Facebook-Cambridge Analytica**
A wicked problem generates more questions for additional information; each question is unique and dependent on the state of the solution you have already reached. You must anticipate all solutions in order to think of all the questions; this task cannot be delegated.	Although the specific instance of data usage is "unique" to Cambridge Analytica, the larger question of the use value of data to both organizations and users in digital systems generates a very large number of questions in multiple use cases and contexts which cannot be easily anticipated.
Every formulation of a wicked problem corresponds to a statement of the solution. Understanding the problem is identical to solving it.	The difficulty of formulating the problem is evidenced by the April 11 hearing, which failed to do this even after almost ten hours over two days.
A wicked problem has no rule for stopping. You stop for a planning problem because you have run out of time, money or patience, but that has nothing to do with the logic of the problem. You can always try to do better.	In this specific case, and in many others concerning ethics in digital systems, there is no point at which the mission is accomplished. One can always do better, and this is exactly the response Zuckerberg gave in the April 11 hearing.
We cannot categorize a wicked problem as true or false, we can only say that this is good or bad and this only to varying degrees and in different ways for different people.	Senator Thune's statement at the April 11 hearing, that "[it] doesn't make those [87 million] people feel any better," is highly subjective and speculative. How can we know how one individual felt about it relative to another?
There is no exhaustive, enumerable list of permissible operations with a wicked problem.	Though regulators may attempt to enumerate in a finite or exhaustive way what is a "permissible operation," problems are often only problems when they manifest or after their occurrence. Note: this is also the ethos of beta testing.
A wicked problem contains many possible explanations for a discrepancy. Depending on the explanation you choose, the solution will lead in different directions.	With Cambridge Analytica, the nature of status as discrepancy (or problem) can be understood differently. For example, was the key discrepancy unauthorized use of user data, the deceptive way it was gathered, the gleaning of insights about users using psychometric tools or its use in influencing election outcomes in a democratic society?

Every wicked problem can be considered a symptom of another problem. You should not try to cure symptoms since you can never be sure you are attacking the problem.	Cambridge Analytica demonstrated that it was only a symptom of other, deeper problems: monetisation of user data, opacity of terms of use agreements, perhaps the business model of social media platforms?
There is neither an immediate nor an ultimate test for a wicked problem as there is no time limit for potential consequences of a problem and therefore no ultimate test.	Although the Cambridge Analytica case could be declared solved since it came to light, the time limit or extent of consequences of manipulated election outcomes will never be known. Also unknown is how susceptible future elections may be to such interference.
For a wicked problem, we can only anticipate or simulate potential consequences in order to get an idea whether something is a good or not good response because a wicked problem cannot be repeated. Each wicked problem is a one-shot operation; each trial matters and is very consequential.	(See 8)
Every wicked problem is essentially unique. You cannot learn for the next time, only use past successful strategies in the future since the new problem may be different enough from the old problem that the old solution no longer works.	(See 8)
The wicked problem solver is responsible for the consequences of a bad solution and has no right to be wrong.	In a 2021 senate hearing, Zuckerberg again faced allegations that the company's products "harm children, stoke division and weaken our democracy." In response, Frances Haugen, a whistle-blower and former Facebook product manager who worked on civic integrity issues at the company stated, "Mark has built an organization that is very metrics driven… it is intended to be flat, there is no unilateral responsibility. The metrics make the decision. Unfortunately, that itself is a decision. And in the end, if he is the CEO and the chairman of Facebook, he is responsible for those decisions… The buck stops with him" (Transcript, 2021).

Table 1. Compares Rittel's (1972) properties of wicked problems with a discussion of each wicked problem in the context of ethics in digital systems arising from the Facebook-Cambridge Analytica scandal of 2018.

To summarize, the wicked problem properties Rittel identified in the table include: interdependencies of one problem with another; difficulty formulating the problem as a problem; lack of a concrete stop or end to the problem; cause and "symptom" ambiguities; uniqueness of the problem and the lack of replicability of the solution; no test for or time limit to the problem's consequences or the problem solver's responsibility for consequences.

Together, these make any examination of a wicked problem a very complex undertaking. As Rittel (1972) states in his fourth property, "we cannot categorize a wicked problem as true or false, we can only say that this is good or bad and this only to varying degrees and in different ways for different people," a statement absolutely true of the Facebook-Cambridge Analytica scandal under discussion here. One insight from the scandal that can be established unequivocally is just how powerful beta testing is, especially when the "product" being tested is a tool that makes extremely accurate predictions of human decision-making.

Kosinski et al. (2013) describe both the benefits and the perils of this sort of testing, stating that "predicting users' individual attributes and preferences can be used to improve products and services... digital systems and devices (such as online stores or cars) could be designed to adjust their behaviour to best fit each user's inferred profile" (p. 5805). They also highlight potential negative implications, adding that,

> because it can easily be applied to large numbers of people without obtaining their individual consent and without them noticing... commercial companies, governmental institutions, or even one's Facebook friends could use software to infer attributes such as intelligence, sexual orientation, or political views that an individual may not have intended to share. (p. 5805)

While the public may derive a cathartic satisfaction from seeing tech billionaires chastised at senate hearings, the question remains as to whether regulations in the form of hearings leading to policies governing data usage in platforms can achieve more benign results on their own or whether, as Jaron Lanier (2013) contends, digital systems will always present us with a trade-off between privacy on one hand, and convenience and utility on the other. The following section presents some materially oriented ways of understanding how design could engage with an existing situation and account for its consequences on our societies.

Accounting for Digital Systems

About 7000 years ago, Mesopotamians, the inhabitants of modern Syria/Iran/Turkey, began to transition from concrete to abstract counting. Accounting as a practice evolved alongside writing, counting and currency, and is entwined with the technologies of literacy and abstract human reasoning. Because accountants were connected with temples, they oversaw the accumulation and storage of the surplus crop yields that facilitated trade in the ancient world, practices which supported farming, settled communities and gave rise to empires. In this section, the epistemology of accounting, a practice that records, summarizes, analyzes, verifies, reports and explains transactions and interactions within a system, is understood in terms of its design implications.

The April 11, 2018 Facebook hearing created a pageant around the theme of explanation and accountability. Similarly, an inquiry following an air accident is usually convened to establish (1) what happened and (2) who is responsible; as with the Facebook scandal, air accidents are also often the result of systemic rather than singular failures. Politicians in democracies understand that the public expects their leaders to be able to explain events and in the case of the Facebook scandal, at least superficially, the public now understands what happened and who was responsible for it. Returning, however, to digital systems, what happens if the scandals of the future occur in the algorithmic spaces of autonomous and AI-enabled digital systems? How does a society respond when the consequences of future scandals are not only unintended, but may preclude the possibility that they could ever have been anticipated or even be completely comprehended by humans? Kosinski et al.'s (2013) research that validated the effectiveness of psychometric profiling in large data sets optimistically concludes that

> it is our hope that the trust and goodwill among parties interacting in the digital environment can be maintained by providing users with transparency and control over their information, leading to an individually controlled balance between the promises and perils of the Digital Age. (p. 5805)

Hope may not be sufficient, however, as it does nothing to help humans engage actively in the design of better systems. Individual control may appeal to libertarians in the technology community, but it does not rise to the level of informed consent. On the topic of transparency, Jenna Burrell (2016) defines three barriers to transparency in machine learning algorithms, distinguishing between:

> (1) opacity as intentional corporate or institutional self-protection and concealment and, along with it, the possibility for knowing deception; (2) opacity stemming from the current state of affairs where writing (and reading) code is a specialist skill; and (3) opacity that stems from the mismatch between mathematical optimization in high-dimensionality characteristic of machine learning and the demands of human scale reasoning and styles of semantic interpretation. (p. 1-2)

Summarizing Burrell's excellent description of the parameters of algorithmic opacity are problems of malfeasance, comprehension and finally a version of a socio-technical mismatch.

Socio-Technical Systems: Frameworks Within Which to Design

In the post-1945 era, psychologists Eric Trist and Fred Emery and Ken Bamforth, a former miner and research fellow at the Tavistock Institute in London, developed a theory of socio-technical systems. Trist and Bamforth's article "Some social and psychological consequences of the longwall method of coal-getting" (1951) is a seminal work, bridging what happens within a device, often framed as an engineering problem, and what happens within a community, often framed as a social sciences problem. It collapses this internal-external distinction; an STS occurs when technical factors interact with social ones, generating the conditions for organizational performance. The coal-getting case, drawing from Bamforth's firsthand experience in the mines in the north of England, explained the technical and material aspects of the "hand-got" versus mechanized (longwall) methods of mining coal. This explanation supported their argument that hand-got methods developed strong social bonds, trust and mutuality and multi-skilled "agile" engagement as workers performed tasks within small autonomous units. This changed under the longwall method where workers were spread out over long distances and operated in shifts such that no one team or person had visibility of the entire task. Despite its increased efficiency in retrieving coal, the loss of the social bonds produced morale problems, more accidents, conflict and increased worker resistance. Their work launched the scholarship of technologies understood as inseparable from social systems and it also gave a tantalizing glimpse of how the interaction of these factors could be understood in a design context. Their 1951 paper used visual explanation to add richness and context to their explanation of how machinery and new systems altered work dynamics and changed miner behaviors (Figure 2).

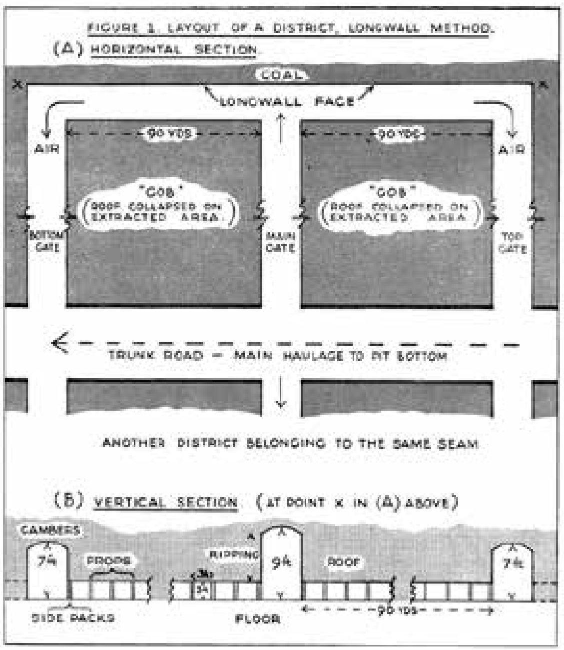


Figure 2. Maps how a longwall coal extraction system works spatially. Map A details the structure of the coalface and access points as a plan drawing, while B shows the “getting” method as a sectioned elevation drawing.

The use of maps and explanatory visuals in their 1951 paper supports a “thick” description of the socio-technical problem of mechanized coal-getting. Thick description is a concept developed by anthropologist Clifford Geertz (1973) to describe his method of ethnography in which culture does not drive human behavior; rather, paying attention to a web of symbols can help us better understand what certain behaviors mean. A thick description explains the behavior and the context in which it occurs, a view that in many ways parallels the task of the designer.

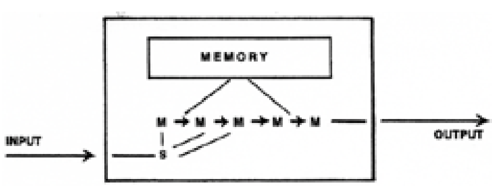
The Map Is Not the Territory, But May Be Preferable to No Map At All: Visualization, Mapping and Design

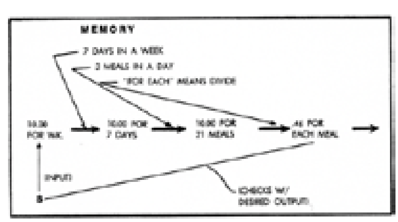
Scientist and philosopher Alfred Korzybski coined the aphorism “the map is not the territory” in a 1931 paper that highlighted the intellectually contested mathematical problem of how to define zero, a sort of wicked problem to which various schools of thought attached themselves, each offering a slightly different account of what zero is. In a second, related problem, Korzybski (1931) discusses the existence of the verb "to be" in Indo-European languages, a verb with four entirely different uses yet the same sound and spelling. This is a deceptively simple yet "very complicated" problem that, he states:

> ... cannot be solved except by a joint study of mathematics, "logic," "psychology," anthropology, psychiatry, linguistics, epistemology, physics and its history, colloidal chemistry, physiology and neurology; this study resulting in a general semantic mechanism underlying human behavior [with] many new interrelations and formulations...

Korzybski uses these two "wicked problems" – defining zero mathematically and explaining the verb "to be" – to illustrate the "map–territory relation": we cannot navigate complex territory using a map or model in the hope that it will substitute for the undertaking "on the ground." He charts hypothetical travel between three cities – Dresden, Paris and Warsaw – to explain how such a map would be "wrong" as this sequence would be misguided, a waste of effort and might even lead to harmful consequences. In contrast, Google Maps is a digital system designed not to misguide or be wasteful; it optimizes time to location in various ways, creating maps and navigational aids using GPS coordinates. However, no map can ever be in possession of complete knowledge of the on-the-ground conditions. In 2020, for example, Google Maps decided to remove from its system the "Road of Bones" in Russia after a driver froze to death when his car broke down on this abandoned road while following Google Maps' route instructions (Stewart, 2020).

Design thinking has its origins in the design methods movement of the post-1945 era (Zwicky, 1948). Early researchers and scholars, including Jones and Thornley (1963), Archer (1965), Jones (1970), Alexander (1971) and others, pursued a systematic method for designers and designing. The first empirical studies in what is known as "design cognition research" come from a methodological basis drawn from a science of design which sought to chart the way that designers think in the act of designing. Lloyd (2021) wrote about the pioneering work of Charles Eastman (1970) who conducted the first published empirical study in design cognition research. Eastman was inspired by Newell and Simon's 1956 work on thinking machines – see Gugerty's (2006) description – based around an input–processing–output model (see Figures 3 and 4).





Figures 3 and 4 (l and r). Figure 3 from Eastman's 1970 study illustrates its underlying model of cognition. Figure 4 shows the processing required to compute how much is available for each meal from $10 available for meals for the week.

Returning to Wirth's description of programming and Dourish's understanding of a program being constrained by bits or zeros and ones, algorithm design has consistently embodied a design bias toward the type of optimization illustrated in Figure 4 as exemplified by Google Maps. As design thinking has moved toward more reflective and recursive processes (Schön, 1983; Schön & Wiggins, 1992; Gero & Kannengiesser, 2008; Visser, 2010), we see its cognitive supports have also begun to evolve toward provisional methods that support generative design and the thinking through and physical manifestation of connections between ideas. Sketching has been discussed extensively in this way by Goldschmidt (1991, 2003), Verstijnen et al. (1998), Suwa & Tversky, (1997, 2002), Suwa, Tversky, et al. (2001) Tversky & Suwa (2003, 2009), Tversky (2002, 2005), Dalsgaard (2014), and others. Fry (2022) briefly discusses the value of Post-It Notes and digital platforms such as Miro which use a variety of mapping conventions and affinity maps, journey maps, mind maps, concept maps etc. to spatialize and sketch, reflect on and reiterate relationships between elements within systems. In his description of a 2019 university student competition to visualize a cryptocurrency exchange platform, Koray Çalışkan (2020), an economic sociologist, describes the winning entry as "a visualization [that] not only captures the modular and multi-functional nature of a cryptocurrency platform that goes beyond being a mere multi-sided market, device or infrastructural geography, but also shows how various parts work with and relate to each other" (p. 135). More work on visualizing digital systems of this kind and analyzing them as a cognitively rich materialization of socio-technical systems will be required of designers in the coming years and decades.

Conclusion

Digital systems are vital to our efforts to tackle climate change; these range from accounting systems such as carbon tracking and emissions management software and globally interlinked satellite-based emissions monitoring systems for companies and auditors to real-time feedback systems through apps to nudge individual consumer behavior to energy usage and control automation optimization systems in car and bus fleets and many more. A 2019 World Economic Forum article (Ekholm & Rockström) claims that these "exponential technologies may contribute to a 15% cut in global emissions." These claims have the inbuilt technological optimization bias that characterizes Schwab's (2016) fourth Industrial Revolution discourse. However, the improved design of accountability writ large, especially on the socio-technical side of digital systems, may also improve the quality of public and political discourse and action on climate change. In a recent talk at Vienna's Institute for Human Sciences, historian Timothy Snyder (2022) stated that, in regard to climate change, "technologically we should be able to crush that problem, but we can't because we are held back." Beyond political narcissism, he attributes human inability to tackle climate change to "our own tech [which] has helped move us to this world where we can't face the future and we can't deal with it." In his estimation, digital systems have made humans more predictable and thus more susceptible to being manipulated and collectively less able to face problems in the three-dimensional world. Here he alludes to fake news, propaganda and unsubstantiated claims that blunt the imperative of immediate climate action or make individual and smaller collective actions appear irrelevant.

As design tasks are concerned, working within the complexities that digital systems present is as challenging as it gets, but the stakes are high and the importance of this work is undeniable. There is much more work to be done by design researchers and practitioners in continuing to evolve the methodologies and methods of design to become fit for this work. This paper proposed one framework – STS – but there are others. It suggests visualization and mapping as useful processes for working in the space of digital systems design but does not elaborate on this topic. There is much more work to be done to understand the power of design in socio-technical systems to address climate change and other wicked problems in our societies.

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DESIGNING FOR A LIVABLE CLIMATE: ADAPTATION AND THE WINDOW OF OPPORTUNITY

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Abstract
As evidence of accelerating climate change grows, the global response is pivoting from a focus on mitigation to an expansion of strategies that prepare us to adapt to the consequences. We recognize that the rate of temperature change outpaces our ability to prevent it in the short term. Therefore humans, societies, and the earth they inhabit with non-humans must be readied for the disruptive and difficult realities we must live with. The Intergovernmental Panel on Climate Change's (IPCC) *Sixth Assessment Report* calls for climate resilient development to protect ecosystem and planetary health (Pörtner et al., 2022). However, this opportunity to put into place adaptation strategies exists for only a limited time – what the IPCC *Report* refers to as a "rapidly narrowing window of opportunity" (Pörtner et al., 2022).

Designers are key participants and drivers in this "get-ready now" strategy while continuing to work towards a future that is climate stable through mitigation. To adapt successfully, quickly, and equitably, designers must be purposed to the task. This paper describes the transformation of product design education by expanding and reinforcing the curriculum with learning that prioritizes driving change through the lens of sustainability and responsible design.

The authors collaborated by first developing design for sustainability courses and content, and most recently, by integrating into the product design program a comprehensive set of design for sustainability principles in a scaffolded approach. The authors incorporated their own scholarship, research, tools, and experiences with that of work done by the United Nations, Cumulus, World Design Summit, and other topic experts. Over an eight-term course of study leading to a Bachelor of Science in Industrial Design, fundamental sustainability concepts will be introduced via each term's core studio course. These required core courses introduce and reinforce a key sustainability theme that is appropriate for the term-level and relevant to the core course instruction. With each term, as the student progresses through the program, the student and faculty build competency in a step-wise, compounding fashion. Specific course learning outcomes, or practices, for each core studio build competency, and by commencement, culminate in expertise and agency to practice. Designers graduate prepared to contribute to implement-

ing sustainable, adaptable, and regenerative systems. Moreover, the capacity to move expeditiously and put into place resilient and near-term solutions is fortified and increased.

Author Keywords
Sustainability; adaptation; design; curriculum; strategies

Introduction

Sustainable development is the model used by design to create systems that support a healthy planet, people, and economy. However, recent climate change data has shifted the possibility of mitigation to a model emphasizing adaptation. The "rapidly narrowing window of opportunity" to mitigate climate change, as noted by the Intergovernmental Panel on Climate Change (IPCC), has caused a rethinking of how to deploy design (Pörtner et al., 2022). Design for adaptation to disruptions and altered conditions, and responsive, resilient systems are not just possibilities but have become necessary outcomes of design. How do we infuse design programs and build onto the design process such that this generation of creative professionals is prepared? How are students introduced to a multiplicity of strategies? How are they inspired to see the possibility of sustainability in all of their work?

In this paper, the authors share recent work responding to these questions. It represents an ongoing collaborative effort with Product Design Department faculty and students to integrate sustainability into the program through curricular transformation and a pedagogical approach, using heuristics to jump-start sustainable solutions.

Q: How do we integrate sustainability learning into design disciplines rather than rely on sustainability electives?
A: Integrate carefully selected sustainability content into all core studios in the Product Design Department. The sustainability content should broaden and enhance the existing curriculum, stimulate further student interest, and raise the quality and scope of outcomes. Prepare graduates to fully engage in adapting to and mitigating climate and resource-related disruptions across environmental, social/cultural, and economic pillars.

Augment program and course curriculum to equip all designers for the task by expanding the Product Department core curriculum to include a Sustainability Program Learning Outcome (S-PLO), and integrate Sustainability Course Learning Outcomes (S-CLOs) into each term's core studio course (see Figure 1, Sustainability Curriculum Ladder with Sustainability Course Learning Outcomes (S-CLOs)). Evaluate educational impact, understanding of sustainability, and new competencies.

Q: How do we build sustainability into the design process?
A: Use heuristics to introduce a range of sustainability strategies for student exploration and experimentation. Familiarity with strategies makes it possible for students to develop concepts around environmental, social/cultural, and economic goals as well as ideate more solutions more quickly.

Train designers in sustainability strategies and multiple and varied approaches to sustainable design. Provide opportunities for students to practice strategy "exercises." Sustainability strategies (as opposed to best practices) can jump-start concept development and put focus on a sustainable outcome.

Program-Wide Sustainability Curriculum / Evolution of an Academic and Studio Course
Sustainability, design, mitigation, and adaptation are staggeringly complex, and teaching them can be difficult and time-consuming. Even the most experienced and engaged instructor can be ineffective in presenting sustainability concepts. Therefore, a program-wide adoption of sustainability learning was seen as an initial step and a Product Department priority. The initiative includes curricular themes for each term, corresponding S-CLOs that are learned and stacked in a cumulative fashion, and relevant sustainability strategies as ideation tools.

The pedagogical and curricular responses described in this paper are largely rooted in a *Design for Sustainability* studio which follows a required *Design for Sustainability* academic course. The academic course is an introduction to sustainability, environmental impacts, and design decision-making, with qualitative life cycle assessment (LCA) as a key learning. The studio course advances these LCA research skills by the application of a quantitative assessment of a benchmark product, which informs a redesign of that product. The heuristics and strategy exercises were developed in this studio and are an important learning outcome. This combination of an academic (knowledge-based) course with a studio course (practice-based) is an aspect of the pedagogy in which research and evidence precedes practice and design decisions. In developing the S-PLO and the S-CLOs, the authors drew upon this experience. The work of known experts and leaders, such as the United Nations' Sustainable Development Goals (UN SDGs), provide research and evidence to accompany the S-CLOs.

The adoption of the integrated sustainability curriculum is also a reflection of the changing perspectives of faculty, students, and the College, who recognize that professional designers and design organizations are increasingly focused on responsible design. Climate targets, circular systems, transparency, and social equity are just a few of the new values that designers bring and that students must learn and experience as part of their design education. Additionally, by integrating a sustainability curriculum throughout the eight terms of studios, the opportunities to learn, apply, and metabolize sustainable design practices are greatly increased.

Previous to this integrated approach and the two academic and studio courses, other ad hoc efforts were evident in the product program. Faculty, at their own discretion and based on their individual lenses and knowledge, would encourage students to consider sustainable solutions. The most common sustainable content in evidence was focused on the choice of materials, reduction in materiality, and in some cases, production methods. In the upper terms, particularly the capstone studio, eco-system thinking would emerge in some projects. Unfortunately, at the culmination of their academic journey, all but a few students had neither the confidence nor commitment to advocate for sustainability as a core tenet of design practice.

Integration of Sustainability into Core Product Courses Over Eight Terms
One sustainability studio taken in term 6 (out of eight) will not equip design graduates to address the consequences of accelerated climate change happening now, nor prepare them to design for longer-term sustainability. Responsible design, with these outcomes in mind, is an emphasis and a skill set that permeates all instruction. In the Product Program, it was decided to integrate sustainability content into all core studio courses: one core studio course each term for eight terms. This provided an equitable approach and spread sustainability learning throughout the Department. It would also be a means of encouraging faculty to collaborate since they would all be responsible for developing their own methods of teaching to the S-CLOs for their studios.

The authors considered term-specific sustainability themes and S-CLOs on several levels to accommodate varied faculty knowledge and experience of design for sustainability, leading them to:

- Select sustainability themes of sufficient breadth and specificity to prompt faculty to select references and other course material particular to the theme.
- Select themes that are clearly understood to be connected to sustainability, relevant to the core course, and which excite and encourage the faculty to actively integrate the theme and corresponding CLOs into course content and goals.
- Provide S-CLOs which faculty can adapt as needed.
- Introduce S-CLOs in an order which builds a cumulative body of knowledge of design for sustainability by starting with foundational concepts and progressing to more complex and innovative ideas.

The themes are introduced and applied term-by-term as the student moves up through eight core studio courses. Sustainability content is added step-by-step over terms 1 through 5, and includes the required academic *Design for Sustainability* course. Once the student arrives at term 6, a comprehensive set of sustainability ideas and skills has been learned, enabling the student to research and evaluate more complex product/service systems. Sustainable systems and models, and analytical and practical tools continue to the final term 8 when the ability to communicate and advocate prepares the student for graduation and professional practice.

Sustainability Curriculum Structure and Intent
Developing a design for sustainability curriculum is demanding, and even more challenging to incorporate into a program's existing learning structures. Design and engineering, both purposeful, practical fields, rely on strict and codified processes associated with them. These processes ensure rigor, maintain high standards and quality, and produce viable outcomes, but also make it difficult to change. The authors present an approach in which new sustainability learning is integrated without sacrificing design rigor and quality.

Referring to their *Design for Sustainability* curriculum, the authors identified key sustainability principles and their intersection with the undergraduate Product Program learning structure. These intersections became a node for integration of sustainability learning.

The nodes, or “themes,” name and describe sustainability learning broadly (see Figure 1: Sustainability Curriculum Ladder with Sustainability Course Learning Outcomes (S-CLOs)) and are supported by new S-CLOs written for each core studio and term and described below.

The themes described in this paper do not represent all sustainability principles, therefore related UN SDGs are listed. This link to the SDGs, which are recognized globally, can lead the faculty and students to relevant research, measures, and targets. Importantly, it connects the sustainability themes to UN language for sustainability accepted across all organizations.

Moving Fast: Create a Strong and Flexible Scaffold
Having identified the nodes, it was possible to refine the sustainability themes to integrate horizontally with core course learning outcomes. It was also possible to relate the sustainability themes vertically, enabling students to build upon prior learning throughout the eight terms. This provided the basic ladder structure integrating core courses with sustainability.

Specific sustainability learnings linked to each term’s core course theme were written as S-CLOs (see “Term-by-Term Sustainability Course Learning Outcomes” below). The sustainability themes and corresponding S-CLOs establish a scaffold for sustainability learning as the student moves through the Product Design Program. The S-CLOs reflect transformative ideas, thinking, and ethos for design and practice, with the goal of responsible, just outcomes. They ensure a level of sustainability literacy and contribute to a new design skill set.

The sustainability scaffold is based on S-CLOs that increase in complexity as the student moves up through the terms, supported by the previous steps. In this, their first iteration, the S-CLOs are intentionally succinct while broad in scope. The S-CLOs provide guidance and direction for faculty when planning and carrying out their curriculum.

Reviews to Maintain Standards and Competency
To keep the scaffold from “spreading” or flattening altogether as S-CLOs undergo changes, it is necessary to look to sustainability leaders and knowledge experts and hold to global standards. International (UN SDGs), national, and industry-specific standards are ways in which faculty and their departments can adhere to best and better practices. A regular review of S-CLOs as they relate to standards is itself a best practice, as is a review of the effectiveness of the learning outcomes.

In addition, integrating sustainability content into other, non-core courses reinforces and expands the scaffold. One-off classes and studios with unique content can bring novel ideas and new applications for sustainability and design, further strengthening the sustainability curriculum. For example, lab, shop, and materials classes that incorporate S-CLOs contribute to a holistic approach to sustainability and design. Sponsored studios and transdisciplinary studios that introduce new stakeholders and design disciplines broaden and strengthen the matrix, adding nodes or points of intersection.

Evidence of Impact on Student Skills and Understanding of Sustainability
Evidence of a "better" sustainable design outcome requires comparison and measurement, but evaluating the success of a sustainability curriculum calls for other measures. The authors reviewed 15 years, or 37 terms, of *Design for Sustainability* (now called *Design Lab 2*) studio projects and grouped them according to topic areas and final project concepts. As seen in Figure 5 (Design for sustainability student projects mapped to design categories), the sustainable design projects covered a wide range of topics, everything from consumer goods to space exploration. Some terms had a predetermined topic, selected either by the faculty or a sponsor/partner. Other terms allowed students to select their own topics of interest with guidance from faculty. Consumer goods, home appliances, and electronics dominate, in large part because these categories contribute measurably, often negatively, to key sustainability indicators. In all cases, students learned advanced life cycle assessment skills, used sustainability goals and strategies for concept development, developed an understanding of systems and their dynamic nature, and furthered their ability for research. The outcomes from this studio reflect the power of a dual-pronged approach to design for sustainability, using both LCA based research and design and heuristic strategies for concept development. See Figure 4 (Design for sustainability – student projects designing for adaptation and resilience) for examples of student projects.

The authors are exploring the use of additional indicators as a means of tracking the efficacy of curriculum integration as well as sustainability learning outcomes. In a preliminary test of this method, the authors used evidence of "recognition" and "leadership" as a measure of the impact of sustainability learning. Projects were marked accordingly on Figure 5.

Projects Marked for Recognition

- Project won a competition or prize
- Project was exhibited
- Project was published
- Project was given an opportunity for further development by a project sponsor or partner

Projects and Student Designers Marked for Leadership

- Student was a member of the college's sustainability club
- Student was selected to participate in sustainability research or internship
- Student was a sustainability leader or speaker
- Graduate went on to receive a Master's or PhD in a sustainability-related field
- Graduate worked/is working in a sustainability-focused design field
- Graduate started their own business with an emphasis on design for sustainability
- Graduate became an educator with an advocacy for sustainability

The Product Department reviews individual student work and learning outcomes assessed based on the PLOs. Reviews occur at terms 2, 4, 6, and 8 and are conducted by faculty and the department chair. Reviews at terms 4, 6, and 8 will be opportunities to collect and assess S-PLO related evidence. Reviews at terms 2, 4 and 6 have a two-fold purpose in that students are given appropriate developmental guidance and the department tracks the PLO scores as an indicator of how well the department is teaching to those desired outcomes. The eighth term review is evaluative only since the students do not participate.

Sustainability Curriculum Content / Product Design Department

The Product Design Department engaged its faculty in a two-year assessment and revision of its undergraduate curriculum. A significant result was the first department-wide Program Learning Outcome for Sustainability (S-PLO), to be implemented in tandem with new Sustainability Course Learning Outcomes (S-CLO) tied to sustainability themes for each term's required core studio.

The new curriculum reflects a multi-tiered approach to the student journey through the program. The design of the new curriculum focused on increasing the clarity and transparency of what the students were learning in all terms and was achieved through workshops where faculty worked collaboratively. Retention of learnings, expectation by faculty of what students should know versus what they need to be taught in each term, and alignment of content within specific studios were the overarching goals.

Sustainability Program Learning Outcome / S-PLO

The Product Department's first S-PLO, written in bold below, was cooperatively written and supported by the Program Chair, faculty, and Faculty Director, and has been added to six other Product PLOs (PLO titles: Design Process; Written and Visual Communication; Oral Communication; Research and Development; Professionalism; and Technical Aptitude). The addition of the S-PLO to the department PLOs ensures that this outcome and the subsequent S-CLOs will be required and evaluated.

Sustainability Program Learning Outcome

Evaluate, design, and advocate for sustainable solutions, processes, and behaviors across environmental, social/cultural, and economic pillars.

The S-PLO emphasizes comprehensive design solutions across four pillars. It calls out three critical learnings: the ability to evaluate and assess relevant sustainability measures, the design of sustainable solutions, and the ability to speak to and for responsible approaches through design as outcomes of the Product Design Program. The S-PLO was informed by the United Nations' definition of sustainability, later incorporated into the UN SDGs (2015).

Term-by-Term Sustainability Course Learning Outcomes (S-CLOs)

Key sustainable design principles, or "themes," for each term's core studio course were established to define the broad learning outcome. The themes represent nodes which connect sustainability learning with the CLOs of the core studio. The sustainability principles and learning outcomes represent essential knowledge and skills to enable the graduate designer to contribute to creating product/service systems that are resilient and able to adapt to near-term threats affecting the planet and the humans and non-humans that inhabit it. In the longer term, the outcomes provide the designer with the ability to contribute to sustainable development through mitigation of climate change and its related environmental, social, and economic consequences.

The term-by-term, sequential integration of S-CLOs is outlined below and described as follows:

Term number theme: Name
Core product course: *Title*
S-CLO
Supporting S-CLOs
UN SDGs that correspond to the course, theme, and S-CLOs are noted to provide guidance and sustainability-related content for course development. In addition, **sustainability strategies** are listed that may be learned and applied in the course. For more detail about the sustainability strategies and their content, see Section 4.1 below.

See Figure 1 (Sustainability Curriculum Ladder with Sustainability Course Learning Outcomes (S-CLOs)) for a comprehensive listing of themes, S-CLO, and supporting S-CLOs. See Figure 2 (Sustainability Curriculum Ladder with Sustainable Design Strategies mapped to S-CLOs per term) for a comprehensive overview of how sustainable design strategies are used to support scaffolding of the S-CLOs.

Themes and CLOs: Lower Term Product Studios
Term 1 theme: Minimization
Core product 1: *Introduction to Product Design*
S-CLO: Awareness of materials and material choices as they pertain to sustainable design and familiarity with strategies for minimizing material use and reducing harm.
1a Familiar with the UN SDGs and general understanding in a design context
1b Able to use minimization strategies in concept development and prototyping
UN SDGs: 3, 9, 11, 12, 13
Minimization strategies:

- De-materialization
- Re-materialization
- Longevity

Term 2 theme: Whole systems thinking
Core product 2: *Function and Form*
S-CLO: Understand system components, characteristics, and relationships, and create and evaluate a regenerative product/service system.
2a Familiar with the UN SDGs and their system relationships
2b Familiar with principles of natural and human-made systems
2c Able to apply systems thinking strategies to address sustainability
UN-SDGs: 9, 11, 12
Whole systems thinking strategies:

- Footprints
- Biophilic design
- Systematize

2nd Term Student Review

Term 3 theme: Cradle-to-cradle
Core product 3: *Human Centered Design*

> **S-CLO:** Apply cradle-to-cradle principles to reduce the environmental impact of product design and/or supporting ecosystem compared to a reference product.
>
> > **3a** Able to speak about and refer to pertinent UN SDGs
> > **3b** Familiar with sustainable materials and cradle-to-cradle characteristics
> > **3c** Use of behavioral strategies to align with sustainable consumption

UN-SDGs: 3, 8, 9, 11, 12, 13
Cradle-to-cradle strategies:

- Re-materialization
- Biophilic design
- Systematize

Term 4 theme: Re-invention
Core product 4: *Design Innovation*

> **S-CLO:** Apply design strategies that support responsible development and reduce negative impact, and effectively communicate the product/service system value proposition.
>
> > **4a** Use of design to reduce the environmental impact of product/service and system
> > **4b** Able to compare sustainable design solutions with reference designs
> > **4c** Able to use sustainable design strategies to explore and propose innovative product/service system solutions

UN SDGs: 9, 11, 12, 13
Re-invention strategies:

- Biophilic design
- Systematize
- Re-packaging

4th Term Student Review

Themes and CLOs: Upper Term Product DesignLabs
Term 5 theme: Sustainable enterprise
DesignLab 1: Branding Strategies

> **S-CLO:** Transparently communicate a brand's sustainability across economic, social, and environmental spectrums.
>
> > **5a** Communicate sustainability using metrics and visualization
> > **5b** Visualize and narrate the product/service ecosystem
> > **5c** Apply systems thinking to UX/UI

UN SDGs: 8, 9, 10, 11, 12, 13
Sustainable enterprise strategies:

- Systematize
- Re-packaging

Term 6 theme: Life cycle thinking
DesignLab 2: Sustainable Design

S-CLO: Conduct research, analysis, critically compare life cycles and use sustainability strategies to innovate product/service systems, and demonstrate principles of responsible design throughout their career.

6a Able to analyze the life cycle (LCA) and create LCA-based design goals
6b Able to apply sustainability strategies to create innovative design concepts
6c Able to compare life cycle impacts of product/service systems concepts
6d Able to effectively communicate design concepts and their sustainable outcomes

UN SDGs: 6, 7, 8, 9, 11, 12, 13
Life cycle thinking strategies:

- De-materialization
- Re-materialization
- Longevity
- Footprints
- Biophilic design
- Systematize
- Re-packaging

6th Student Term Review

Term 7 theme: Circularity
DesignLab 3: Design for Production

S-CLO: Apply sustainable design strategies and best practices, communicate the value of sustainability and costing throughout the design and manufacturing processes, and strive to model a circular system.

7a Transparency in communicating brand values
7b Familiar with best practices of brands that include sustainability as part of stated values and mission

UN SDGs: 8, 9, 11, 12, 13
Circularity strategies:

- De-materialization
- Re-materialization
- Longevity
- Footprints
- Biophilic design
- Systematize
- Re-packaging

Term 8 theme: Leadership
Product Capstone Project

S-CLO: Demonstrate systems thinking and high-level competency in sustainable design strategies and best practices, and effectively communicate the imperative to design for sustainability.

8a Integrate and demonstrate ability to use all learned sustainable design skills:
product/service system thinking, materials knowledge, life cycle assessment and related design goals and strategies
8b Visualize and effectively present project concepts and communicate environmental, social/cultural, and economic values to stakeholders

UN SDGs: Able to refer to appropriate guidance SDGs
Leadership strategies:

- De-materialization
- Re-materialization
- Longevity
- Footprints
- Biophilic design
- Systematize
- Re-packaging
- Values based design* (*strategy under development)

Graduating Term Evaluation

Curriculum Highlights

Three pedagogical approaches: sustainable design strategies, LCA modeling, and experiential education – developed, revised, and modified over multiple terms by the authors – are detailed below. Experience in the classroom and course outcomes suggest that they expedite sustainability learning and streamline design decision-making, both of which are components of a timely response to adapting to climate change and its consequences.

Keep It Simple: Sustainable Design Strategies

Sustainable design strategies were developed as a response to the challenge of teaching the complexities of a life cycle analysis (LCA) methodology for researching product/service systems and establishing sustainable design goals that drive and inspire concept development. The LCA-based approach is a widely accepted best practice in design for sustainability, but can be quite daunting for students in a program that is oriented towards traditional applied design teaching methods. Using heuristics for idea generation in the field of design has been a well-used technique for decades (Yilmaz et al., 2016), and is familiar to most students, who have encountered the practice in previous studio courses. By introducing heuristics, students are given a set of tools for the rapid and gratifying generation of sustainable design concepts. The overarching goal is for students to integrate a deep understanding of the complexities of LCA-based sustainable design with the ability to rapidly generate design concepts using heuristics that drive toward their sustainability goals.

Like the scaffolding of the Sustainability Course Learning Outcomes (S-CLOs), the sustainable design strategies progress from foundational and straightforward to advanced and abstract. There are eight categories of strategies, introduced by term, and in combinations which reinforce the term's S-CLOs (see Figure 2 (Sustainability Curriculum Ladder with Sustainable Design Strategies mapped to Sustainability Course Learning Outcomes (S-CLOs) per term)). Each strategy category has several sub-strategies or specific heuristic approaches for idea generation. The sub-strategies are intentionally written to challenge the assumptions and expectations of the students, to encourage thinking outside their normal patterns of idea generation, and to inspire new and creative solutions. The strategies are meant to be adapted and expanded along with the S-CLOs as knowledge, goals, and practices change over time.

The current collection of sustainable design strategies – with sub-strategies – is as follows:

- **Dematerialization –** using less material and reducing negative impact
    - Single material
    - Dematerialized makeover
    - Ultra-minimalist challenge
- **Rematerialization –** material matters
    - Power of 10
    - Repurposed
    - Me-cycled
- **Longevity –** make it last
    - Change product lifespan
    - User customization / personalization
    - Multifunction – convertible
    - Componentize
    - Add-on
- **Footprints –** take up less space
    - Expand / collapse
    - 2D to 3D
    - User assembly
    - Ship & store
- **Biophilic –** what would nature do?
    - Technical / biological
    - Biomimicry
    - Natural features
- **Systematize –** product / service / system solution
    - Producer take back
    - Design for behavior change
    - Build community
- **Repackaging –** reconsider everything you learned about packaging
    - Repurpose
    - Incorporate
    - Rethink
- **Values-based** (Currently being developed, this set of strategies will support the eighth term S-CLO oriented toward cultivating a strong sense of advocacy and leadership in the student's professional practice.)

In their current implementation, strategies are introduced as weekly exercises in the term 6 core studio. By using sustainable design strategies as rapid, weekly exercises, students are oriented toward quick creative solutions to the challenges presented (see Figure 3 (Sustainable Design Strategy Exercises – Student Examples (2019-2022))). By extending this approach across the Product Design Program, students are given more opportunities to practice and adapt these skills.

Manage Complexity: Life Cycle Modeling
Life cycle assessment was developed to model and assess the environmental consequences of systems of production. It is based on a simplified system of sequential processes organized according to stages in the product's life and afterlife. It can be used to uncover opportunities for new and better solutions, becoming a key tool in climate change innovation and design that is feasible in the near-term.

The ability to conduct LCA research is a key outcome in the *Design for Sustainability* courses: students learn and use LCA assessment models and tools to research, evaluate, develop design goals, and evaluate "best" concepts that meet environmental criteria. With the integration of S-CLOs across the Product program, the understanding of the life cycle as a model of a product/service system and the use of life cycle methods will provide additional research and communication tools, and contribute to the student's sustainability literacy.

Make It Real: Experiential Education – Personal Waste Exercise
Sustainable design strategies and life cycle assessment represent ideas for how to think about sustainability. This knowledge provides the basis for a design solution. The personal waste exercise is about the student experiencing these ideas. In the *Design for Sustainability* studio (*DesignLab 2*), students are given a direction: keep all of your waste, document your waste, and over time reduce your waste. This is a research assignment that studies and tracks personal consumption, reveals waste management infrastructure, examines sustainability of product/service systems, and unveils the failure of single use packaging and recycling. It challenges students to measure and represent their waste, understand the behaviors associated with waste, and present their findings.

This exercise is best introduced early in the course because it brings to light many of the concepts further explored in the course: the role of behavior, the inadequacies of infrastructure, and the failure of design. The complexity and rigidity of systems that contribute to the problem ultimately become the ground for design solutions. Further, it underscores the reality of a planetary scale crisis.

There are other approaches to "making it real," including the use of case studies, field trips, interviews, and community partnerships. The purpose overall is to engage the student with sustainability, not as an abstraction, but as an ongoing opportunity to work towards a "better," more resilient, and livable Earth.

Continuous Improvement: Track, Monitor, Recognize
Reviews are presently conducted at three stages in a student's career to monitor progress and provide feedback to students, and are being considered as a means of tracking the S-PLO and S-CLOs. Other means being proposed include visiting the course finals of every Product class, every term, to get an overview of the course work and evident sustainability learning outcomes.

Recognition of faculty and students doing notable work that addresses sustainability supports continuous improvement and can be a means of inspiring innovation. A number of means are being considered, such as a *Sustainability Distinction* credential.

In addition, the work of graduates who have gone through the Product Design Program, especially those who will have graduated after having gone through the entire eight term program that includes the S-CLOs, represents an opportunity to more closely assess the success of the learning. Other areas of interest include companies and organizations that hire designers, particularly those with a stated sustainability mission, as to their particular expectations and needs for designers that can support or help build their mission.

Conclusion

Designing for adaptation challenges designers to face the realities of our current trajectory as a civilization and to respond with a sober and informed vision of what is possible (see Figure 4 (Design for Sustainability – Student Projects Designing for Adaptation and Resilience)). An understanding of the complex global systems involved and an ability to use strategic tools to evaluate, compare, and innovate creative design solutions are an elemental part of their education and their future careers.

The authors describe new sustainability course learning outcomes that align with core Product Design courses, and which connect to one another via a novel Product program scaffold to build sustainability literacy and skills. The scaffold is sturdy yet flexible; new learnings and priorities can be readily introduced. Heuristics (sustainable design strategies), system research and evaluation (life cycle models), and experiential education (personal waste exercise) are described as necessary components of this learning and add skills particular to design for adaptation.

The success of this approach is not immediately forthcoming, and it will be necessary to monitor and change as needed. The “rapidly narrowing window of opportunity” identified by the IPCC does not portend a soft landing (Pörtner et al., 2022). Rather, it provides designers with a design brief that must be taken seriously and which requires timely, responsible outcomes.

Implementation, Opportunities, and Next Steps

The approach described in this paper will require additional research, evaluation, and communication and sharing of results. Items of interest include:

- Monitoring student outcomes to assess learning; visiting all finals to discover the extent of S-CLO integration.
- Developing faculty knowledge of design for sustainability; providing tools and opportunities to learn relevant sustainability information.
- Learning from alumni in sustainability-related fields; inviting them as guests, mentors, and advisors.
- Seeking input from professional partners to remain abreast of their needs; actively networking with colleagues and sustainability experts.
- Collecting data related to student/faculty achievement; tracking awards, speaking, leadership, etc. as a means of calibrating successful learning outcomes.
- Recognizing outstanding work of students/faculty through exhibits, certificates, fellowships, and scholarship.
- Developing heuristic sustainable design strategy exercises around justice, equity, diversity, and inclusion topics for all term levels.

Ongoing Research
The authors are recipients of a grant from the American Society of Engineering Education (ASEE) to implement the approach discussed in this paper and share outcomes. The grant is sponsored by the Engineering for One Planet (EoP) initiative of the Lemelson Foundation. How to monitor, track, and evaluate the success of the curriculum integration effort as well as when to change the approach to maximize effectiveness is a key interest of this research.

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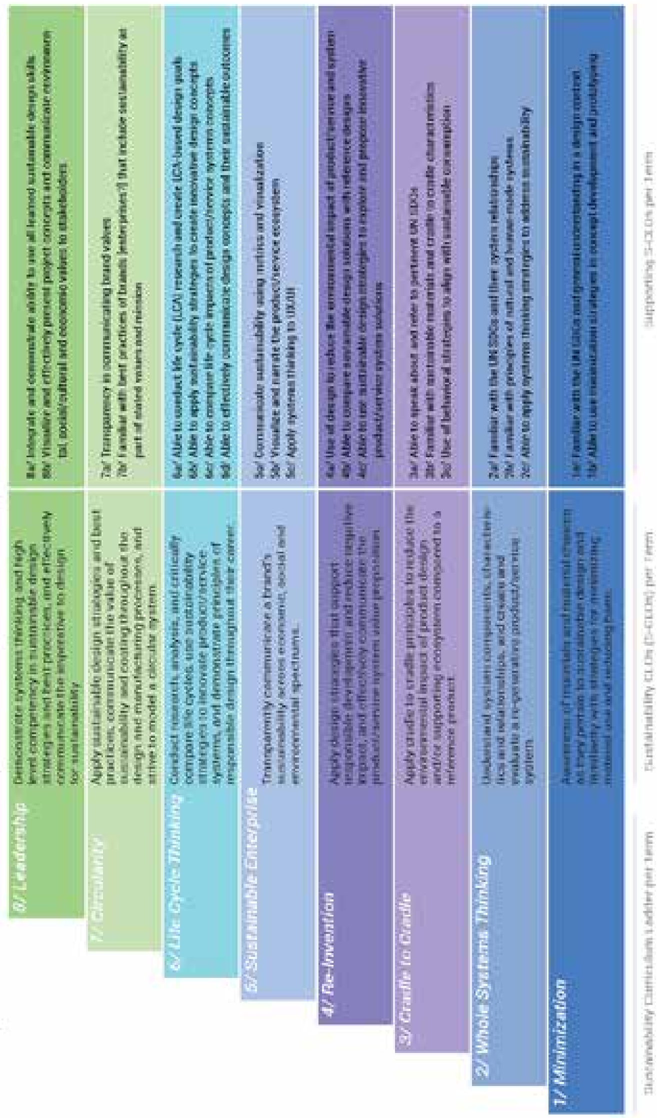
Figure 1

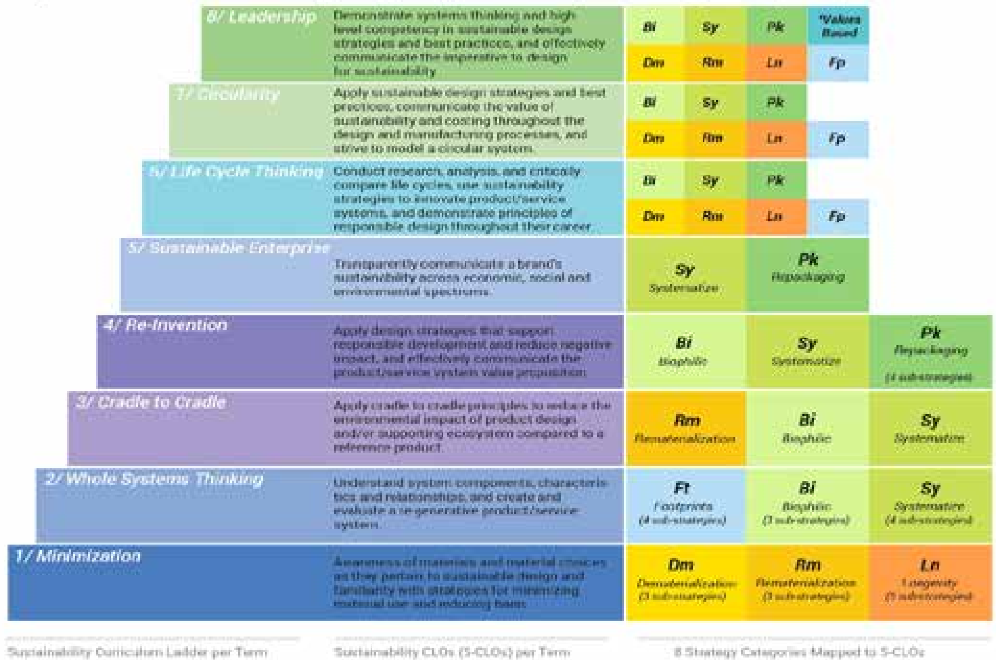
Sustainability Curriculum Ladder with Sustainability Course Learning Outcomes (S-CLOs)



Note. Each term (1-8) has a theme supported by a main Sustainability Course Learning Outcome, which is bolstered by supporting S-CLOs which set more specific educational goals and facilitate evaluation.

Figure 2

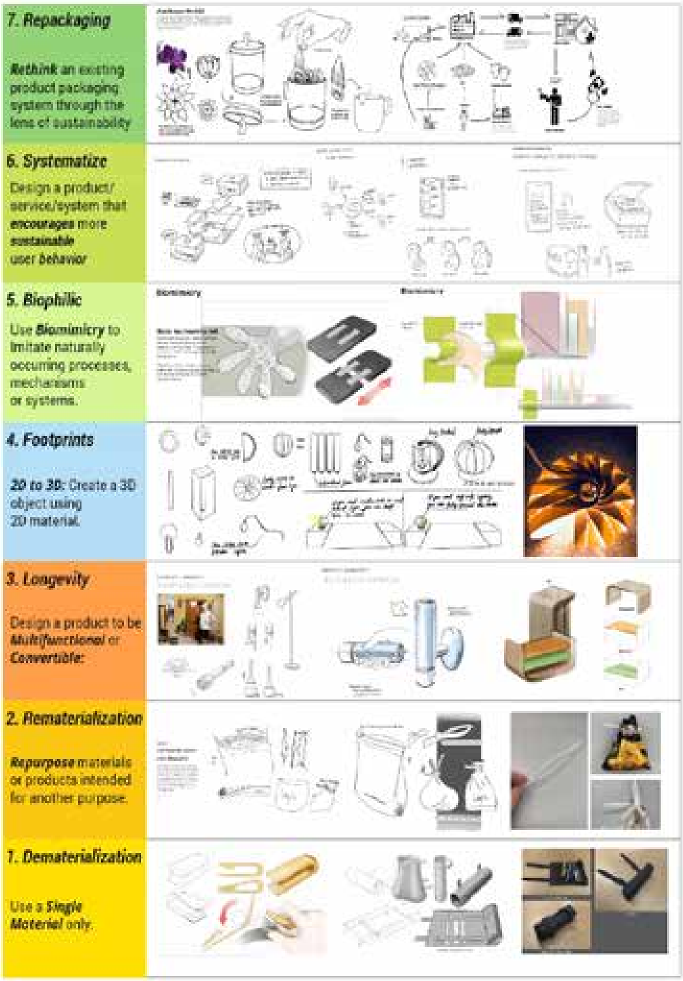
Sustainability Curriculum Ladder with Sustainable Design Strategies mapped to Sustainability Course Learning Outcomes (S-CLOs) per term



Note. Each Sustainable Design Strategy Category has multiple sub-strategies which are introduced in the curriculum in an order relevant to achieving the S-CLOs.
* Values-Based Strategies for Leadership are currently in development

Figure 3

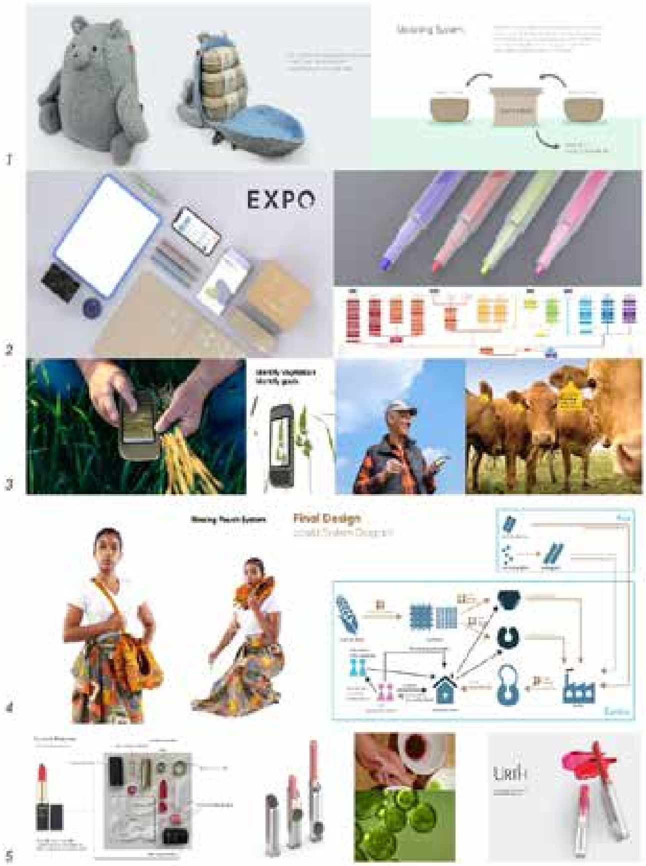
Sustainable Design Strategy Exercises - Student Examples (2019 - 2022)



Note. Each numbered section represents a sustainable design strategy with examples of student work addressing a single sub-strategy. 1. All Wood Paper Stapler, Felt Pen Case. A. Ding. 2. Repurposed Zip-Closure. J. Yang. 3. Multifunctional Lighting and Furniture. S. Wilson, A. Ding. 4. 2D to 3D Lighting. L. Liu. 5. Bio-Inspired Bookshelf Mounting System. A. Ding. 6. Subscription Service Emergency/Disaster Kit for Infants. S. Wilson. 7. Local, Sustainable Tea Brand for Kenya. S. Lambrecht, B. Axness, H. Ji

Figure 4

Design for Sustainability - Student Projects Designing for Adaptation and Resilience



Note. 1. Survi-Bear, S. Wilson, 2019. Disaster preparedness product service system focusing on children's health and safety 2. Reimagine Expo, V. Chen, Y. Tan, C. Zhou, M. Zhu, 2020. Reducing use of plastic, mitigating toxicity and reframing a well established brand using product service system design and sustainable design strategies. 3. VAST Rangeland Management System, M. Kesterson and S. Wu, 2020. Product Service System for rangeland managers to monitor and preserve ecosystem health, mange CO2 output and adapt to a changing climate. 4. Care - Postpartum Care Kit for Women in Rural Zambia, R. Qian, 2019. Using sustainable product service system design for social outreach and global health. 5. Urth by L'Oreal - Sustainable Lipstick for Gen Alpha, A. Li, E. Kim, O. Alvarez, 2020. Reducing environmental impact of plastic and toxicity by leveraging algae-based biomaterials from renewable resources. (with guidance from L. Bonanomi, Center for Renewable Materials at UCSD)

Figure 5

Design for Sustainability Student Projects Mapped to Design Categories - a flexible, scalable and powerful framework for adaptable, resilient, sustainable design.

Note:

- = Project Recognition in Design Competitions, Publications, Exhibits
- = Student Leadership in Sustainability through School Organizations, Research, Entrepreneurship, Teaching, Professional Practice

DESIGNING FROM THE CORE: FACILITATING CORE THINKING FOR SUSTAINABLE DEVELOPMENT IN DESIGN EDUCATION

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Abstract
How might graphic designers identify and clarify their personal values and identity so that they might develop a responsibility mindset in their design process? This has been a central question in the research of the authors Napier and Lettis, two design educators who have been collaborating across the world from the United States and Ireland, through Master's thesis and Ph.D. work, from first-year graphic design students to senior visual communication design students, and from in-person to online teaching. Our research is driven by a deeply vested interest in personal or core values and how they relate to making sustainable or responsible design decisions. We believe that design students must be able to develop a personal awareness of their individual values and goals to not only benefit their design process and practice, but also to benefit sustainable development.

"Value thinking" is a central mode of thinking encouraged in education for sustainable development, which "develops and strengthens the capacity of individuals, groups, communities, organizations and countries to make judgments and choices in favor of sustainable development" (UNECE, 2009, p. 15). Within our research, we acknowledge that value thinking also involves thinking of oneself, and the direct correlation between the "personal" and sustainability. We termed this *personal value thinking* or, as Lettis has termed it since, *core thinking.* Ann Thorpe (2007), an educator of sustainable design and author of *The Designer's Atlas of Sustainability,* states:

> Many of the issues confronting us in the landscape of sustainability are those that feel more personal than professional, for example, your connection to nature, your politics as a citizen, or your willingness to put your personal resources toward ecological sustainability.

We have found that in the context of sustainability in graphic design education (GDE) and design education generally, many programs are exclusively available to postgraduate students. Additionally, while some undergraduate education does aim to foster the development of personal values, it is unclear which processes are used to help students clarify and integrate those values into their identity and practice. This paper will describe the processes, methods, and tools that Napier and Lettis have developed to facilitate core

thinking for sustainable development in different courses, at varying levels of graphic and visual communication design education. It will discuss the theoretical background of value thinking and include a high-level look at the ongoing efforts of evolving materials aimed at supporting design educators to foster sustainability-minded design students. Additionally, this paper will discuss both students' and educators' reflections on this ongoing work. It is the hope of the authors that a more inclusive approach to fostering sustainability-minded students and graduates will impact the role that designers can play as responsible citizens.

Author Keywords
Values; graphic design education; value education; sustainability; responsibility; process.

Introduction
In the past decade, there have been many materials aimed at supporting design educators to help foster sustainable development-minded students. Examples include The Designers Accord's (2009) *Integrating Sustainability into Design Education: The Toolkit,* Ico-D's (2011) *Icograda Design Education Manifesto,* and publications such as *The Designer's Atlas of Sustainability* (Thorpe, 2007) and *Design to Renourish* (Benson & Perullo, 2017), to name a few

Additionally, various programs and degrees in higher education around the world are being devoted to teaching sustainable design. These programs (Table 1) are evidence of the growing importance of sustainability in design education; however, many are aimed at postgraduate students and are an additional step for students coming out of typical graphic design (GD) programs. Students must seek out sustainable design programs, rather than having sustainability or responsibility integrated in their curriculum. Of course, approaches to advocate sustainability may be integrated into graphic design education (GDE), but little is known about what these approaches are and how they might be working. Accomplished design educator Thomas Ockerse (2012), Professor Emeritus at the Rhode Island School of Design, United States, supports this point. He argues that there is a lack of published research relating to the processes that foster "design from the core" in design education (Ockerse, 2012). (This term leads to Lettis's use of "core" in her research rather than "personal.") Napier and Lettis, the authors of this paper, believe that use of and understanding of impact around these kinds of processes could develop a profound sense of knowing in graphic design practice, bringing about a new and impactful perspective on sustainability in graphic design.

Type of course	Title
Undergraduate Programs	Visual Communication + Change (Linneaus University 2019); Communications (Carnegie Mellon University 2020a)
Postgraduate Programs	M.A. in Design for Sustainability (Savannah College of Art and Design 2019); MA Biodesign (Central Saint Martins 2020); MA Design for Social Innovation & Sustainable Futures (London College of Communication 2020); Masters of Design (Sustainable Design) (University of South Australia 2020); MFA Transdisciplinary Design (Parsons New School 2020); Sustainable Design MA (University of Brighton 2020); Sustainable Design MA (Kingston University London 2020); Sustainable Design MA (Minneapolis College of Art and Design 2020); Environmental Communication PhD (University of Brighton); PhD in Transition Design (Carnegie Mellon University 2020b)

Table 1. Sample sustainability and/or responsibility design courses – graphic design education and design education (Lettis, 2022).

Amy Dritz (2014), sustainable design advocate, suggests that often professional designers attribute sustainable activity to themselves, not their education. In *The Designer's Atlas of Sustainability,* author Ann Thorpe (2007) describes the connection between personal values and sustainability:

> Many of the issues confronting us in the landscape of sustainability are those that feel more personal than professional, for example, your connection to nature, your politics as a citizen, or your willingness to put your personal resources toward ecological sustainability. (p. 195)

Accessing core values – as inspired by Ockerse (2012) – and connecting those to the wider world allows an opportunity for the connection to be emotional and therefore strong (Eilam & Trop, 2010; Garrison et al., 2015). Verganti (2017) thinks that a robust drive of individuals from the inside-out drives creative innovation. These points combine to suggest that the explicit use of core values in GDE could be important. This leads to the following questions:

- Can a facilitation of students' deep understanding of their personal values earlier in their education lead to a more inclusive approach to fostering sustainability-minded graduates?
- What might the best process be to allow students to identify and clarify their core values and identity, so that they might develop a sustainability mindset in their design process?

These questions and others have been at the center of Napier and Lettis's research. Since meeting over five years ago, the two design educators/researchers have been developing and trialing processes for integrating core values into the design process of undergraduate

GD students. From Napier's Master's thesis *Process of Integration* (Schiff-Napier, 2009), to Lettis's PhD work in *Croí – The development and evaluation of a process to encourage core and responsible design in Graphic Communication Design Education* (Lettis, 2022), the two have been conducting action research, collaborating on course project development, and trialing multiple cycles of their processes at their respective universities nearly 4,000 miles apart across the world. Their research recognizes the need for students and graduates to develop a strong personal awareness through core thinking so that they can contribute to the betterment of individual design practice with sustainable development in mind.

It is worth noting that while sustainability (or sustainable development) and adaptation are increasingly seen as interrelated, the authors recognize that these are different concepts. Within this research, Lettis and Napier propose that sustainability and sustainable development are frameworks that address aspects of complex systems or streams such as society, culture, economy, and environment (AIGA, 2009). Adaptation is thus characterized as an incremental change that allows a system to retain its core functions and characteristics (Johnson et al., 2018, p. 3-25). The authors' work aims to enable students to develop a core mindset and approach to graphic design, impacting their ability to develop processes that support sustainability and sustainable development in their work.

Theoretical Background – Values

Value Thinking and Core Thinking

Education for Sustainable Development can be defined as follows: "(Education for Sustainable Development)...develops and strengthens the capacity of individuals, groups, communities, organizations, and countries to make judgments and choices in favor of sustainable development" (UNECE, 2009, p.15). This area of education is advocated in international educational policy work that contributes to sustainability initiatives (UNESCO, 2012, 2014, 2015, 2019). A central mode of thinking in Education for Sustainable Development is value thinking. The central role of value thinking in advocating sustainability performance is pointed out in Figure 1.

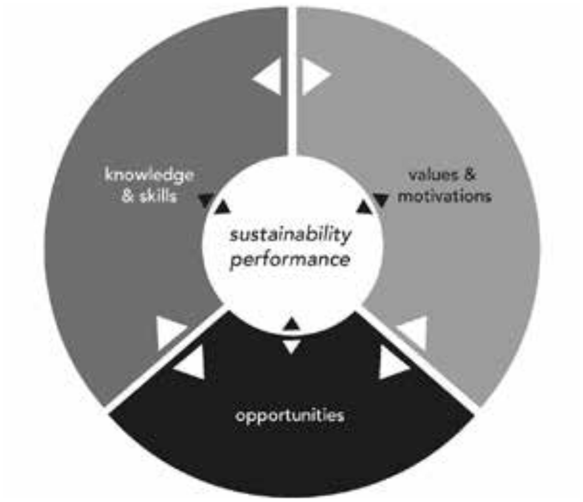

Figure 1. Key competencies and performance of sustainability citizens from Rieckman (2018, p. 46).

Although there are a number of ways that value thinking is defined in the literature, it can be described as "the ability to collectively map, specify, apply, reconcile and negotiate sustainability values, principles, and goals, and targets" (Wiek et al., 2011). However, the authors have found that those definitions suggest thinking outside of oneself, "general value thinking" (Lettis et al., 2020, p. 185), "responsible value thinking," or "responsible thinking" (Lettis, 2022).

A connection to values can be nurtured through facilitation of general value thinking or, as Lettis (2022) terms it in her PhD study, responsible thinking, but it is the authors' belief that core thinking deserves more focus due its potential (explained in the introduction above). In a design education context, understanding how values impact design process and practice is becoming a critical component in what educators are required to teach.

Core Values Matter

AIGA – the largest and oldest professional design organization in the U.S. – periodically assesses the changing context for design practice and the implications it has for both college design education and the continuing education of professionals. After studying trends in a number of fields, a summary draft report titled *AIGA Designer 2025* was published in 2017 (AIGA Design Educators Community). This report summarized seven trends that were evident in their influences on graphic design, and included corresponding topical areas needed for education. Following this publication, in 2018 AIGA established *Design Futures,* a series of briefing papers that outlined and described trends shaping the context of design in the coming decade.

AIGA encourages college faculty to use these briefing papers in conversations supporting curriculum within their institutions. In its affiliation with the National Association of Schools of Art and Design (NASAD), the disciplinary accrediting body for higher education, AIGA developed competency standards for undergraduate and graduate design education. Connected to each trend are competencies that every design student should have upon graduating.

The defined skillsets are wide-ranging, which can not only be challenging for students, but also for design educators trying to include necessary skills for contemporary design practice in the curriculum. Looking at the trends and accompanying skillsets, specifically within the trend "Core Values Matter," it is suggested that college students should be able to:

- Identify the social and ethical responsibilities of designers and clients in addressing design challenges; and
- Evaluate design solutions in terms of their social, cultural, technological, economic, and environmental impact.

With the importance of values being highlighted in terms of social and ethical responsibility and an obligation to learn how to evaluate design decisions for sustainable impact, it is paramount to understand how to teach processes and methods to harness such skills.

Research in other areas of design education, such as human computer interaction and technology design education, is recognizing that there are few educational materials available that relate to values in design education about sustainable and ethical development (Nilsson et al., 2020; Eriksson et al., 2021; Eriksson et al., 2022). It also recognizes that value-based approaches are mainly theoretical presently (Barendregt et al., 2020; Kok et al., 2021; Nilsson & Hansen, 2021). More broadly, it is also recognized that educators need to learn how to implement value education (Meyer, 2018) and that support is needed for educators to implement it (Türkkahraman, 2014). This research does not suggest that undergraduate GDE is not nurturing the development of core values. As explained initially, what Napier and Lettis have found is that it is unclear what processes are used to help students clarify and integrate these values into practice, and how to connect those values to sustainable development.

In addition, GDE is under pressure to accommodate education for a broadening field. Instead of meeting the challenge in impactful ways, GDE is renaming courses and programs or adding more to an already crowded curriculum (Davis, 2007; Ockerse, 2012; Littlejohn, 2017). It is recognized that educators will need support if the area is going to change (Cezzar, 2020). Educators will need to facilitate students being able to practice new design processes but have not yet been effectively educated in how to do so (Norman, 2010; Napier & Wada, 2017).

The last point suggests that integration of a core approach might be favorable if it is to succeed. It is the authors' belief that enabling design students to clarify core values and connecting those to sustainable development earlier and throughout their curricular trajectory might help them to develop a strong sense of identity, with the eventual goal of contributing to the profession as sustainability-minded citizens. These points lead to the question in Napier and Lettis's research:

- What might be the best process to allow students to develop a strong identity through the use of core values in GDE?

This inquiry is constructed as follows in Lettis's research, alongside a number of other related questions:

- What might a process of core thinking and doing in GDE be, and how should it be implemented?

Building on Napier's initial research in the United States – focused on the process of integration (Schiff-Napier, 2009) – Lettis developed and evaluated a process of core thinking and doing for GDE over five years. The study resulted in a process called *"Croí"* (pronounced Cree – Irish for heart) (Lettis, 2022). The aim of the process is to facilitate educators supporting students in clarifying and using core values and goals in design process and practice. This is done in an effort to encourage not only core thinking but also core doing, i.e. action as well as thought. The study demonstrated that *Croí* is shown to encourage personal value or core thinking and doing. It is also shown to directly lead to general or responsible thinking. It is less clear whether it leads to responsible doing directly, but indications are that it can, the main signifier being core design itself. Napier then amended and trialed Lettis's updated process within the context of an American undergraduate visual communication design course.

Research Methodology and Methods

Participants in Lettis's (2022) research were students and educators from three institutions – Cork Institute of Technology, Ireland; University of Illinois Urbana Champaign, United States; and Technological University Dublin, Ireland. Lettis conducted an action research (AR) study over five years. AR is a methodology for researchers (often teachers) to understand and generate knowledge about educational practices (Creswell, 2012; Kagan et al., 2017; Cohen et al., 2018). Figure 2 presents an overview of the research methodology (AR), and the design and methods used in Lettis (2022). It also presents the cycles of research that happened over that time. Riel's (2019) model of AR provided a basis for the design of the study.

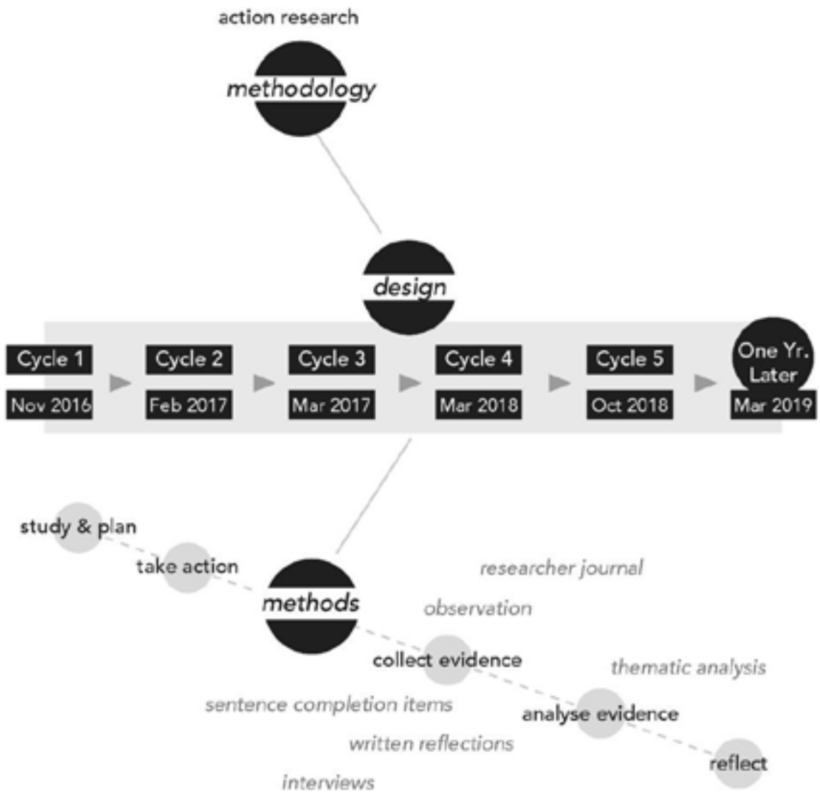

Figure 2. Research methodology, design, and methods (Lettis, 2022).

This design led to cycles of AR that involved trialing *The Process of Integration* (Schiff-Napier, 2009), developing *Croí* and conducting "The One Year Later Study" to evaluate the longer term impact of *Croí.* Each cycle involved using particular phases based on Riel's (2019) *study and plan; take action; collect and analyze evidence; reflect;* and *share* (when deemed necessary). In each phase, appropriate methods were identified for use, such as observation, use of a researcher journal, sentence completion items, written reflections, and interviews (more detail can be found in Lettis, 2022). Thematic analysis, which can be described as a method for determining, analyzing, and describing patterns or themes within data (Braun & Clarke, 2006), was used to analyze the data, since Lettis was trying to determine themes that would lead to the development of the process.

In the frame of the particular study this paper describes, Napier also used an AR approach since the methodology is suitable for investigating educational practice (Creswell, 2012; Kagan et al., 2017; Cohen et al., 2018). A main characteristic of AR is that it is collaborative (Creswell, 2012; Kagan et al., 2017) . An argument can be made that as a stand-alone study (which this paper mainly describes), this is not AR since it is not cyclical. But Lettis and Napier are involved in an ongoing, collaborative AR process. In this context, this particular study represents a cycle of AR, since both Lettis and Napier will reflect on and continue research based on this study. As such, Napier also employed AR-led research methods – observation, use of a researcher journal, sentence completion items, and written reflections. Interviews were not held in this study due to time constraints. Napier also used thematic analysis to analyze information.

The following sections describe the course structure and methods used in Napier's study to facilitate students through a process of core value and goal clarification and integration, with the aim of developing more sustainability-minded students.

Course Structure and Process

Curricular Context

At Herron School of Art and Design, a NASAD-accredited school, the BFA in Visual Communication Design (VCD) is a professional undergraduate degree for students desiring theoretical and studio experience with an emphasis in design. Upon entering year three of the program, students enroll in rotating topic "Design Labs." Based on the collaborative research of Napier and Lettis, Napier developed a seven-week lab, *Designing from the Core,* which focused on core value and goal clarification and integration. Due to the global Covid-19 pandemic, in the spring of 2021, all VCD courses were taught online; this particular course was taught asynchronously with a variety of third- and fourth-year VCD majors. The course was broken down into modules with class activities scheduled twice a week through the online platform Canvas. Weekly activities included a mix of readings, reflection, assignments, and discussion.

Designing from the Core was developed based on Lettis's (2022) process. While the original version of the process, *Croí,* contained twelve steps, due to the nature of the short lab, process steps were condensed and/or combined.

The focus for each weekly module was as follows:

Week 1: Contextual Background
Week 2: Value & Goal Statements
Week 3: Moodboard & Exploring Impact
Week 4: Visualization
Week 5: Reflection
Week 6: Process & Professional Practice
Week 7: Final Reflection

Weekly Modules

Week 1: Contextual Background (Tools: Readings, Discussion Board)

At the start of the course, students introduced themselves via the discussion board tool on Canvas and completed four different readings. The readings introduced fundamental concepts and current trends shaping the context of the current practice of design:

1. Learn from the Core, Design from the Core (Ockerse, 2012)
2. Design Futures (AIGA, 2018)
3. The Living Principles of Design (AIGA Center for Sustainable Design, 2009)

4. Personal Value Thinking in Graphic Communication Design Education – The Introduction of a Clarification Tool for Students (Lettis et al., 2020)

Students responded in the discussion board, describing their impressions and takeaways. One student shared:

> There are so many points from these readings that made a whole lot of sense to me and helped clarify what it is to be a sustainable designer in today's world. First, from the title of this course, I think it is obvious one of the main points are how important it is for student and graduate designers to understand their values and their core modes of thinking in order to make clear decisions in their design practice (2021).

Week 2: Value and Goal Statements (Tools: Lecture Videos, The Value Thesaurus, The Digital Schwartz PVQ, The Eulogy Exercise, The Core to Professional Worksheet)
In the second week, students began the value clarification process by identifying values and goals, creating Value and Goal Statements, and preparing for visualizing.

They first completed *The Digital Schwartz PVQ* (Lettis, 2022), a spreadsheet that Lettis used to assist students in identifying high-ranking values for themselves. Lettis used the original PVQ-RR provided in an email (Lettis, 2017) by its designer, Shalom Schwartz. The questionnaire had the students rank statements in order of importance on a scale from 1-5 (1 being the lowest and 5 being the highest); statements included "It is important to me that the weak and vulnerable in society be protected," and "It is important to me never to violate rules or regulations." Lettis had adapted it for Excel, so that students could evaluate their own value ranking easily.

Students then reviewed their three to five highest ranking values next to *The Value Thesaurus* document, based on theory developed around how values motivate behavior (Schwartz & Butenko, 2014). This document contained 19 categories that the questionnaire statements could fall under, with definitions and descriptive adjectives. For example, the category of self-direction (subcategory: thought) was described as "Freedom to cultivate one's own ideas and abilities; Freedom of thought." The adjectives included: *Creative, free, curious, independent, autonomous, self-determined, self-directed...in my thoughts.*

The aim of providing *The Value Thesaurus* was to enable the students to turn their questionnaire results into simple value adjectives, which they would then use in a later stage of the process. They were to read their high-ranking areas and choose an adjective that resonated with them.

Next, students completed *The Eulogy Exercise*, an exercise founded again in psychology theory (Hayes et al., 2009). The aim of the exercise is to identify personal and professional goals. Students were prompted to imagine they were at their own funeral where friends and family had gathered. They were provided with *The Eulogy Exercise Worksheet* developed by Lettis (2022) which prompts students to expand on ideas in three categories: 1) what you did; 2) how you made the world a better place; and 3) words people use to describe you. They made lists first, and then selected three to five items in each category that resonated with them.

Using goals highlighted in *The Eulogy Exercise* (Hayes et al., 2009), students chose the most important ones and decided which category they might belong to – personal versus design goals – with the understanding that sometimes they could be both.

The next step was to generate *Value and Goal Statements* by identifying a personal value and a design goal that complement each other. Students developed statements beginning with "As a designer, I will..." They were prompted to think of their personal goal as "what you hope to achieve," and the design goal as "the way you go about it."

For example:
"I will influence culture (personal goal) by being original and unconventional (design goal)." *Value and Goal Statement:* "As a designer, I will influence culture by being original and unconventional," or, "I will work in a successful design agency (personal and/or design goal) by being creative (personal and/or design goal)."

After generating three to five *Value and Goal Statements*, students selected one. They uploaded their statements and answered the prompts in a discussion board, with participants sharing: "After doing these assignments, I feel more connected with myself and that I have a more clear understanding on how I want to represent myself as a person as well as through my design work" (2021). Another student stated, "I feel like this was one of the first times in my design career where I've been genuinely asked what was important to ME and how I wanted design to play a role in that" (2021).

Week 3: Moodboard & Exploring Impact (Tools: Various Visual Methods; Google Jamboard)
In week three, students focused on visualizing their *Value and Goal Statement* as well as exploring the impact of their goal in relation to the four streams of sustainability. As stated in the *Living Principles of Design* (AIGA Center for Sustainable Design, 2009), these are society, culture, economy, and the environment. Students developed moodboards as a way to figure out desired elements such as imagery, type, texture, etc. They were shown examples and directed to do visual research with the constraint that it had to contain their *Value and Goal Statement.*

In the *Exploring Impact* portion of the week, students responded to the following prompt: "How does (design goal) by being (value adjective) benefit — society, culture, economy, and the environment?" In Lettis's (2022) process, she had termed this section of her process "Linking values and goals to a Sustainability Framework." Napier changed this intuitively, and both authors agree Napier's term seemed more appealing to students.

In an attempt to virtually replicate working on whiteboards, the students used Google Jamboard to record their responses. First, they wrote their *Value and Goal Statement* on a virtual sticky note. Then, they would answer the prompt on each slide per stream. Some responses included: (in the environment stream): "Teaching viewers through design that being kind also means being kind to the environment - Inspiring people to take initiative in taking care of the world."

Another response was (in the society stream): "Help others and myself better understand how we all participate in a wider society; how everyone's contribution is important."

Week 4: Visualizing (Tools: Various Visual Methods; Discussion Board)
In the fourth week, students first reflected on the *Exploring Impact* activity via a discussion board post. One student shared:

> I enjoyed doing this Jamboard exercise because I think it helped me further understand my goal and how it can impact others and my work! I feel like while doing this Jamboard activity, I had to really dive into the real meaning of what I want, where it stems from and how it will realistically create change (2021).

The students' second task of the week was to make a visual (i.e. digital poster) of their selected *Value and Goal Statement.* They were encouraged to explore different methods of making (i.e. handmade elements, textures, etc.), and they were required to upload reflective comments with their submission (Figure 3).

Figure 3. Student digital poster work (N. Asbell & K. Bundren, 2021).

Week 5: Reflection (Tools: Discussion Board)
Students used this week to post their completed visuals in the discussion board where they could view/comment on each other's posters. They were also encouraged to spend time reflecting on their design process and how they go about solving problems and creating work. They were given multiple process models to reference, including Herron's design process model, Min Basadur's Simplexity Thinking Process (2018), and the design thinking process diagram from Stanford's d.School.

Week 6: Process & Professional Practice (Tools: Readings, Process/Practice/Skills & Commitments Worksheets)

The sixth week focused on the design process and practice and exploring how to enact values to reach goals in and through design. This phase was broken into three distinct steps.

Step 1: Lettis (2022) had constructed slides to explain key ideas from AIGA's *Design Futures* (2018), as well as a design process and a professional practice model. Students were prompted to engage with these and a series of worksheets developed by Lettis. The worksheets helped them think through actions that they would take in both their process and practice that will help them develop personal commitments in their design career. These worksheets were called *The Process and Professional Practice Worksheets, The Actions and Skills Worksheets,* and *The Impacts, Commitments and Skills Worksheets* (Lettis, 2022).

Step 2: Students were directed to move through a series of prompts:

1. *Value and Goal Statement*: (example) As a designer, I will stand for truth through my design by being honest.
2. List actions that relate most to your goal and add your value:
   Process: (example) I will gather research by being people-centered, or I will gather visual research by being honest.
   Practice: (example) I will act legally in business by being honest with my clients.
3. What results might this have?

(example) I will gain an honest reputation and earn clients.
(example) I will get accurate research that will lead to truthful design.

1. Evaluate which actions are the most valuable in you making progress to your key goal (i.e. your *Value and Goal Statement*). Select/highlight the actions you have listed that most relate to your *Value and Goal Statement.* They can be all related to process, all related to practice, or a mix of both.
2. Create approximately ten commitments to your design career. Start by writing "I will…" and then fill in the rest of the sentence. You might pull from your actions list, looking for the ones that relate most to your *Value and Goal Statement,* or you might create new ones.
3. What skills do you need to fulfill these commitments? List the skills you might need to have or acquire in order to fulfill your stated commitments. You may also identify any skills you can think of that aren't listed here, as long as they're relevant to your commitments.

Step 3: Once students completed the worksheets and wrote out their actions, commitments, and corresponding skills, they were to visualize their own process & practice. They were given prompts such as, "What might the phases of your process be? What sorts of actions would you complete in those phases? What sorts of skills would you need/use?" (Figure 4).

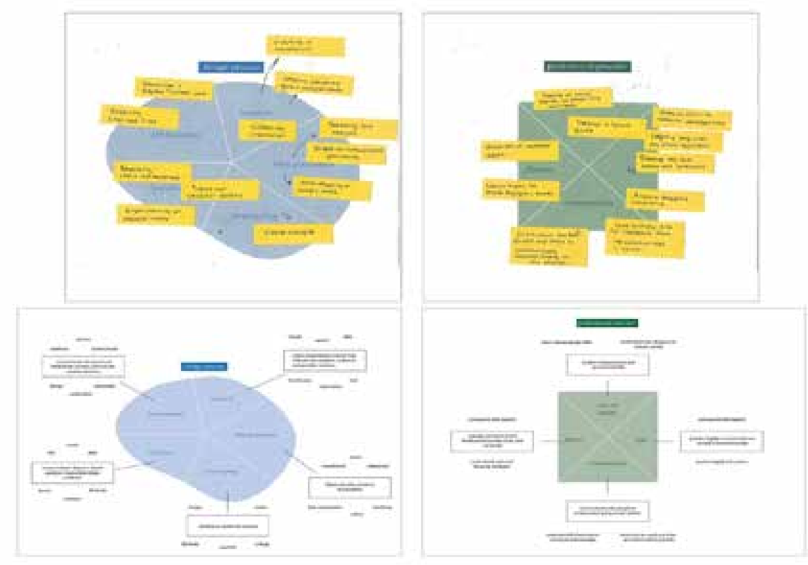

Figure 4. Student process and practice work (S. Pacis & T. Cunningham, 2021).

Week 7: Final Reflection (Tools: Discussion Board, Written Reflection)
In the final week, students uploaded their process and practice visuals and reflected on the activities via the discussion board in Canvas. They also completed a brief written reflection on their overall experience in the course. Students shared:

> I appreciate the thoughtfulness of this class and I definitely think it would be beneficial to introduce the concept earlier in our education. Possibly even towards the second semester of our sophomore year. I don't think it should be an elective honestly, I feel like it should be a required full semester long class (2021).

> This course has helped me remember to center my values at the forefront of all of my work. This course was a great way to end my undergraduate career, centering myself and my values before entering the world (2021).

> I was able to dive deeper into understanding myself and goals as a designer. I think this is extremely important and wish that more courses helped designers reflect and see exactly what they want to do (2021).

Conclusions

This research explores how to facilitate design students in identifying and clarifying their core values and identity so that they might develop a sustainability mindset in their design process. The processes and methods used in the course described above represent a cycle that is part of a continuing process of research for Napier and Lettis. Trialing these methods and encouraging reflection throughout has now been explored in two different countries, and in four different graphic and visual communication design programs, through varying modes of teaching and levels of curriculum.

While the results represent a small sampling, emphasizing qualitative research and a deeper understanding of in-depth experiences, it is acknowledged that what has been found is not generalizable. What has been gathered is still within initial stages of development in a specific educational context.

However, the feedback from students has been encouraging, and the continued emergence of tools, methods, and educational opportunities for burgeoning designers to become climate citizens through core and responsible development is exciting.

The findings from this trial point to three themes:

1. Desire to explore values early in educational experience
As referenced in the statements above, students shared repeatedly through discussion and reflections that they desired the opportunity to explore core values earlier in their education. In Lettis's (2022) PhD work, her research has shown that "complex contexts such as responsibility can frame Year One Graphic Communication Design Education (GCDE). This happens by use of a structured process, supporting earlier year students to deal with complexity – learning, which has positive implications for GCDE praxis, GCDE, and GCD" (p. 370).

2. Personal awareness
Students repeatedly demonstrated through the use of this process their ability to develop a stronger connection to themselves. As they moved through the activities, they reflected on being able to explore their values in a way that they had never been asked to do before during their education. This was evident in both Napier's MFA as well as Lettis's PhD work. Lettis's (2022) research is shown to provide educators in GDE with an authentic way for their students to "clarify, discuss and use their values and goals in their praxis" (p. 369).

3. Defining Goals
Goal setting is not something that is typically explored in GDE outside of the context of professional project brief work. Students expressed that they have not had to explore the relationship between their personal and design goals before and that doing so enabled them to have a greater sense of purpose in their design work. This echoes results of Lettis's (2022) extensive PhD work, where she asserts that with *Croí*, "students begin to see that core design is possible because of translating core goals to professional goals, by integrating values into their process and professional practice and by linking impacts, skills, and commitments" (p. 370).

After her extensive PhD study, Lettis (2022) found that *Croí* was beneficial in supporting students in developing a core approach to graphic design. She will continue to look at ways of integrating value work across the years of a program with the aim of further embedding a core mindset in graphic design students. She also plans to explore the latest developments in education for values in other design areas such as *Teaching for Values in Design* by Value Sensitive Design in Higher Education (VASE) (2021) to investigate how value education can be expanded upon in graphic design curriculum. Napier will continue to trial the process either through course format or curriculum development, also taking from the latest research, with the eventual intent of sharing materials with the broader design education community. Both authors hope to work together to advance the use of core values in GDE, and to disseminate the results of their work with the intention of contributing to a more universal treatise going forward.

As designers and educators, we are often encouraged to put aside our personal values in professional contexts. Within the areas of design facilitation and people-centered design specifically, it is important to remain objective. However, as young designers navigate their educational path, their ability to connect personal values to the design process and outcomes might help them make more sustainable-development minded decisions, thereby fostering a spirit of adaptation.

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DO DEMOCRACIES AFFORD? DESIGN AS EXPERIENTIAL CHANGE

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Abstract
In the New Climatic Regime, climate change establishes the contemporary character of the geopolitical setting. Such a planetary crisis challenges current modes of existence, calling for the need to conceive new cultures and lifestyles through the lenses of ecological thinking, from bees to plastic agglomerates in the oceans. The profile of the more-than-human expands our understanding of the multiple, hybrid entanglements that make up our world. In this sense, the New Climatic Regime forces political obsolescence, challenging the sensible layer of everyday life with more-than-human agencies affecting each other in the sensible layer of reality, namely the political space where actions and the embodiment of those actions merge and make manifest. Such a scenario exacerbates the systemic asymmetry between institutional agency and socio-technical change, casting a shadow of posteriority over contemporary democracies. Here, world-making practices like design are expressing their poietic ability while also contributing to transitioning towards more sustainable futures.

In fact, public space is becoming the experimental theater of a pragmatic turmoil, where design is challenging theoretical and practical stances of collective life through its devices of reference – prototypes – and processes – prototyping. Such devices and processes nurture the political discourse, launching a wave of diffused prototyping, blurring disciplinary boundaries throughout the planet: since both design and politics concern culture and identity while negotiating technology and materiality, it seems that prototypes and prototyping are turning into a meeting point to spark possibilities of transformation and adaptation.

Thus, this paper aims to discuss how design-focused ways of knowing linked to making, crafting, and doing are engaging the political ways of acting traditionally linked to negotiating, managing, and planning. Focusing on design's experiential nature, this paper explores some case studies set in the sensible layer of reality, where ethics and aesthetics intertwine: here, a call-to-the-senses, aimed at nurturing the establishment of more-than-human communities, reaches citizens. By f(r)ictioning traditional narratives, design contributes to combining plural ways of knowing at a proximity scale of practice, linking bottom-up practices to top-down guidelines. This seems to produce hybrid ways of knowing, triggering alternative approaches inspired by care, relationality, and communal future sense-making. In this sense, it seems that design is playing a catalyzing role in accelerating the generation of knowledge, challenging the politically unthinkable with the experientially desirable. In such a framework, democracy itself can be understood as

something more than a mode of governance, opening new paths to experimentation as a process of never-ending becoming.

Author Keywords
Design and democracy; prototyping; experiential knowledge; more-than-human perspectives.

The Planetarium

The Anthropocene has unveiled the ecological crises underlying human development paths. Here, *humanity* and *nature* have endured troubled relationships over centuries until planet Earth found itself enveloped by the establishment of "a global episteme and aesthetics, driven by the necessity of acceleration" (Hui, 2020, p. 114). In fact, the mobilization and channeling of materials, goods, and energy above and beneath the earth exposed the inherent fragility of the planet, pushing humans to cope with the vulnerability of their artificial, somewhat accidental, planetary systems. Paradoxically, the digital infrastructure crossing international boundaries contributed to broadening human awareness on a global scale. Digital media elaborates data for humans to perceive the planet from different perspectives, showing the more-than-human complexity of metabolic processes that essentially make the Earth (Bennett, 2010; Haraway, 2016). The possibility of tracking events out of human perception makes global phenomena like climate change manifest in the abstractions coming from "studies of seismic activity, the health of forests, maps of contaminant flow, and the tracking of organisms from dragonflies and turtles to seals and elephants" (Gabrys, 2016, p. 30). New geographies reveal how climate change crosses political boundaries, overshadowing human prosperity. In this sense, the climate – the most obviously natural phenomenon – becomes the most clearly political object – the state of the climate. In the New Climatic Regime (Latour, 2018), climate change is not exclusively a scientific phenomenon; it is our contemporary geopolitical setting. As a result, today "we don't defend nature. We are nature defending itself" (Fremeaux & Jordan, 2021).

Ranging from bees to plastic agglomerates in the oceans, the profile of the more-than-human expands our understanding of the multiple entanglements that make up our world. Here, concepts stemming from feminist, decolonial, and pluralistic approaches signal a turning point, creating space for "cultures that are open enough, adaptable enough, and pleasant enough, where the first thought is not 'more' but 'sufficient for all'" (Light, 2022). In this sense, environmental conflicts are ontological: they are conflicts over life itself, as they essentially challenge modes of existence (Tassinari et al., 2020). Since the act of designing is deeply connected to designing ways of being (Papanek, 1971), design practice turns out to be forcing political obsolescence, challenging the sensible layer of everyday life through a pragmatist turn (Rancière, 2010; Dixon, 2020). Such a layer is fundamental to the contribution, as it can be understood as the political place bridging actions and the embodiment of those actions: in other words, it is the place where world-making practices like art and design play a critical, f(r)ictional role (Mallol, 2011). Here, they are expressing their *poietic* ability to support the shape of democracies in times of planetary challenges (Costanza-Chock, 2020; DiSalvo, 2022; Manzini, 2015; Manzini & Margolin, 2017; Rezai & Erlhoff, 2021), fueling processes of transformation to transition towards more sustainable futures (Irwin et al., 2022).

Such practices are turning public space into an experimental setting, where everyday life becomes the theater of a pragmatic turmoil (Dixon, 2020): design is, in fact, challenging theoretical and practical stances of collective life, spreading its devices of reference – *prototypes* – and related processes – *prototyping.* Such devices and processes are meaningful in handling the tension emerging from the urgency of tackling climate change in short-term horizons and the need to plan transitions within longer timescales. This tension unveils the systemic asymmetry between institutional agency and socio-technical change, casting a shadow of posteriority over contemporary democracies. In fact, the pathways towards change in lifestyles, productive means, consumption models, and political systems are highly contested and intrinsically interdependent (Escobar, 2018; Light, 2022). Thus, adaptation and transformation require not only integrative approaches to build modes of being together on the planet but, most importantly, creating the conditions to generate alternative ways of knowing to enact that transformative integration.

For such reasons, creative disciplines are gaining institutional momentum as drivers to fuel change in a mission-oriented Green Deal (Bason et al., 2020). As a result, a wave of diffused prototyping is blurring disciplinary boundaries throughout the planet: since both design and politics concern culture and identity while negotiating technology and materiality, it seems that prototypes and prototyping are turning into a meeting point to spark possibilities of change for bigger-picture challenges, focusing on a joint commitment to public purpose and value.

Thus, by framing prototypes and prototyping (Schrage, 2013; Corsín Jiménez, 2014) as devices and processes triggering hybrid ways of knowing in the New Climatic Regime, this paper aims to discuss how designer-focused ways of knowing linked to making, crafting, and doing are merging with the political ways of acting traditionally linked to advocating, negotiating, and managing. As the ontological turn wraps together world-making disciplines like design and politics, this paper focuses on design's embodying and experiential features. Here, a descriptive case study methodology is applied to explore some examples stemming from the experimental turmoil happening in the public space. The main goal of the contribution is emphasizing how the commonplace is becoming the preferred sensible layer of reality to bridge top-down and bottom-up efforts through the entanglement of ethics and aesthetics. Therefore, this paper will ultimately present a preliminary research framework to be further developed in the research project, aimed at interrogating the experiential knowledge generated, nurtured, and challenged by *prototypes* and *provotypes.* These are interpreted here as the common grounds of experimentation and knowledge generation in interdisciplinary contexts of transformation and adaptation.

Prototyping Democracies

A major chicken producer trying to improve the lives of its chickens; the Te Awa Tupua River in New Zealand, so fundamental to its community that it gained legal rights; the Estonian Artificial Intelligence (AI) Task Force proposing that Kratt laws grant AI algorithms a legal status: it seems that the non-human is going to play a growing role in social, cultural, and economic dimensions, thus gaining political relevance. More-than-human perspectives contribute to questioning the notions of both "citizenship" and "community," competing agonistically with conventional concepts of politics and the political (Mouffe, 2011).

By setting political life in hybrid ecologies, the concept of more-than-human citizenship is gaining vital relevance. For this reason, experimenting with(in) the civics level gains a special resonance today, since it addresses the foundational layer of socio-political practice where beings and things gather in public spaces to experience the "distribution of the sensible" (Rancière, 2010). As Carl DiSalvo (2022) puts it, in the New Climatic Regime there is a multifaceted value in "staying with the trouble" with civics (Haraway, 2016): planetary issues call for planetary awareness, inviting planetary citizens to take the stage. Thus, climate change calls for climate care (Light, 2022): a planetary, interdisciplinary commitment crossing different scales and stemming from a relational value, since it is about how communal life will be structured and experienced.

"Care" is relevant here since it invites overcoming the problem-solving framework (de La Bellacasa, 2017; Tronto, 2013). In fact, "to care" is to have concerns, pay attention, and get involved: it is an intimate, long-term entanglement with something or someone. Therefore, "climate care is not an issue we need to 'address' but rather something we need to be engaged in" (Light, 2022). From a political studies perspective, this recalls a strand of research inquiring into the capacity of democracies to respond to climate change through concepts of "eco-democracy" and "eco-citizenship" (Pickering et al., 2020). As such, democratic values like representation, inclusion, participation, accountability, and transparency are questioned in light of non-human agencies influencing human prosperity, paired with the strengthening of caring activism (Fine, 2018) to address environmental, social, and economic inequalities. With care embodying a source of meaning and purpose, eco-citizens cope with ideological and material changes built around the virtue of (climate) justice.

The emergence of themes of care and justice (Björgvinsson et al., 2012; Costanza-Chock, 2020) signal the need to tackle inequalities through interventions with real people in real places (Julier, 2013; Manzini, 2015). As a result, co-design practices spread to stakeholders in open environments of mutual, interdisciplinary learning. Then, with designing stances diffused throughout the sensible layer of communal life, civics turned into a laboratory where unprecedented social modes, conversations, and meanings are collectively prototyped (Manzini, 2015). In such a practice, designing is, at the same time, the catalyst of collective social dreaming (Dunne & Raby, 2013) and a means to explore the possible conditions that might make those visions experienceable: thus, designing becomes a way to care for collective futures.

In this sense, as DiSalvo (2022) discusses, design experiments not only challenge conventional civics, but they embody "a staging ground that help[s] visions of society take form by activating the civic imagination through making and the use of made things" (p. 30). In times of imaginative crisis about plural futures to transition to, it seems that a growing wave of political pragmatism is bridging the gap between design and democracy (Bason et al., 2020; Dixon, 2020; Rezai & Erlhoff, 2021). This is strongly linked to the act of "prototyping," one of the foundational, most pragmatic processes of design: producing experienceable artifacts contextualized within everyday life in order to simultaneously start discussions, derive theoretical and practical insights, and shape the directions of possible futures (Schrage, 2012; Corsín Jiménez, 2014). Thanks to these features, prototypes are being broadly recognized as productive and processual aspects of experimentation: places like medialabs, hacklabs, and social art collectives, or events like workshops, are hosting a growing variety of actors, all interested in prototyping and experimentation "as both modes of knowledge-production and cultural and sociological styles of exchange and interaction" (Corsín Jiménez, 2014). This mirrors the need to tackle uncertainty and ambiguity in the New Climatic Regime; prototyping is the common ground to operate in the acknowledged complexity of our unstable world (Manzini, 2015).

By expressing and representing the nexus where traditional views of innovation, collaboration, and authorship are destabilized, prototypes invite both designers and other stakeholders to engage with "how shared decisions about shared futures are made, how we use public space to understand public purpose, how we contest and co-create" (Bason et al., 2020). Thus, design and politics intertwine in prototyping processes and practices, with "the languages of openness and open-endedness, of provisionality and experimentation, inspiring each other as models for cultural practice... the prototype works as a descriptor for both an epistemic object and an epistemic culture" (Corsín Jiménez, 2014). Consequently, on the one hand, prototypes provide a language for political pragmatism to manifest; on the other hand, it is a reference for design's inherently political nature. Thus, the qualities of prototyping establish features of new modes of interaction, perception, and the experience of democracy as essential.

With pragmatism infusing the experimental turn in public space and actors, caring activism enters the sensible layer of everyday life through prototypes embodying transformational stances through agonistic and pluralistic approaches. For such reasons, this paper will discuss three case studies in which *pragmatism through prototyping* occurs, bridging top-down guidelines and bottom-up approaches through designerly means. Selection criteria adopted for case studies draws from the theoretical approaches discussed so far: climate change-related challenges, civic context, more-than-human perspectives and ecological thinking, crossing-boundary strategies, and the prototype/prototyping feature as a mode of cultural engagement with a specific, embodied, real-life situated, open-ended, and temporary experience – here understood as their unique prototype feature.

Climavore

Climavore (https://www.climavore.org/), a long-term research project initiated in 2015 by Cooking Sections, explores via site-specific and site-responsive iterations how to eat as the climate changes.

The "climavore" is a form of devouring that proposes adaptive forms of food production and consumption, acknowledging the intrusive and extractive features behind intensive agriculture and aquaculture techniques and the effects of related climatic phenomena such as subsidence, flash floods, or drought. In this sense, the project uses ingredients as infrastructural devices to react to human-induced climatic events. Here, the more-than-human perspective informs every stage of the project, intercepting the sensible layer of reality through several initiatives which are either self-motivated or commissioned by cultural institutions. Each of them is an ongoing prototype where several different contributions are invited to spark transversal transformation in the economy and ecology of food cultures.

On Tidal Zones (2015-ongoing) is one of Climavore's prototypes dedicated to the dead zones caused by salmon farms on the Isle of Skye, Scotland. The prototype's main question explores ways to shift from a polluting salmon farming economy to one based on the filter feeders and seaweeds which are crucial to maintaining robust and healthy intertidal ecosystems.

For its experienceable feature, the prototype takes the shape of an oyster table placed in the main tidal zone. The structure hosts both humans and non-humans, each benefitting from the other: at high tide, it is home for oysters filtering seawater; at low tide, it functions as a dining table for humans. According to the tides, performative meals feature a series of Climavore ingredients, where workshops with fishermen, politicians, residents, and scientists have been held to discuss another cultural imaginary for the island. A network of restaurants was also established, each replacing farmed salmon with a Climavore dish. Currently, the prototype is growing into a permanent installation to provide technical and legal advice on alternative and situated food production techniques, facilitate research on aquacultures, train young cooks on the island, and introduce a new coastal horizon for Skye altogether. As such, Climavore's prototypes produce experiential knowledge in a highly situated practice, nurturing and nurtured by the authenticity of local beings, their conditions for wellbeing, and their strategies to be together.

Zoöp
Klaas Kuitenbrouwer initiated the Zoöp project (https://zoop.hetnieuweinstituut.nl/) at Het Nieuwe Instituut with other ecologists, philosophers, artists, entrepreneurs, and lawyers. It is the result of a series of speculative workshops – "zoönomic futures" – beginning in 2018 aimed at challenging human-centric governance to "strengthen the position of non-humans within human societies, stimulate quality of life for multispecies communities and counter extractivist dynamics." The project takes the shape of a more-than-human governance model that acknowledges mutual reliance. In 2020, the legal structure of the model was developed in close collaboration with the law firm De Brauw Blackstone Westbroek, which provided a solid legal basis drawn from existing elements of Dutch law. This prototype intertwines imaginative experiments and practical outcomes, disrupting organizational models and policies with a wave of ecological caring. The resulting model invites creative publics and land stewards to afford ways to add more-than-humans into the value proposition processes, recognizing their rights to life.

The Zoöp model consists mainly of three bodies: the Zoönomic Institute, the Zoönomic Foundation, and Zoöps. Zoöps are organizations that want to contribute to ecological regeneration by including the voices and interests of non-human life in their board. An organization receives the Zoöp license by assigning a Board Observer Seat to the Zoönomic Foundation. Here, independent experts translate the interests of non-human life into the decision-making processes of their Zoöp. Through this mechanism, more-than-humans are represented in the management of the land.

The protocol is currently being tested and refined in several test sites called "Proto-Zoöps." In 2022, they include a farm, a hotel, a university, and a cultural institution. Almost twenty organizations in the Netherlands, Belgium, Germany, Italy, and Slovenia already engage the Zoöp model in a prototyping state, whereas from 22 April 2022 (Earth Day) onwards, Het Nieuwe Instituut in Rotterdam is the first Zoöp in the world.

This prototype is open to any organization willing to discover their inner, hidden ecology and draft strategies to support its growth. The situated knowledge here hinges on the peculiarities of Zoöps; however, the whole model can be understood as a rhizomatic structure of hybrid knowledge generation and sharing.

The Gigatonne Challenge
In October 2020, Complexity University launched the Gigatonne Challenge (https://gigatonne.co/) as a "ground-breaking at-scale, at-pace strategic response to the climate crisis." It can be framed as a long-term program aimed at building capabilities to reduce global emissions by one gigaton of CO2 per year while engaging and benefiting those most affected by the climate crisis. Even though the more-than-human perspective is not predominant, this project provides a clear example of a highly pragmatic approach to the complexity of climate change and how prototypes have a say as experienceable, unlearning-learning devices. In fact, the Gigatonne Challenge starts from a strongly quantitative stance intended to provide citizens around the world with the conditions to make a difference in the sensible layer of reality, leveraging a form of caring activism.

As their manifesto states,

> if we imagine the challenge of reducing a billion tons of emissions a year as climbing Mt. Everest, how do we learn to climb such a daunting peak? – Hint, it isn't by simply listening to a lecture on climbing – The Gigatonne Challenge offers participants from around the world an opportunity to practice "climbing" as part of a team.

Putting it in numbers, the Gigatonne Challenge has already completed three two-week sprints, with thirty-one teams starting the challenge from forty-six different countries, supported by fifty-three coaches whose efforts were embodied in twenty-two prototypes producing twenty-three and a half tons of CO2 abatement.

The Gigatonne Challenge triggers prototyping at a planetary scale, benefitting from the experiential character of this same process. Teams design their own prototype, combining their knowledge to pragmatically engage with the aesthetic-sensible layer of their (activist) ethics. The program welcomes citizens with any background expertise and develops through two main stages: the first is the unlearn and rewire phase, where participants are supported in building broad, bottom-up capabilities to "scale Mt. Everest" and work together to reduce one billion tons of CO2 per year. The second stage focuses on prototypes in which teams co-design situated strategies based on the team's resources while setting abatement targets focused on reducing emissions in four domains plus one – food waste, general waste, transport, energy efficiency, and equity.

Affording Democracies
"Climavore," "Zoöp," and "the Gigatonne Challenge" engage prototypes and prototyping in different ways, providing alternative paths towards public value generation in The New Climatic Regime. This study understands prototypes' function primarily as a means to learn, discover, generate, and refine in osmotic manners (Valentine, 2013). This occurs thanks to prototypes' primary quality: their incompleteness makes it possible to examine an idea's quality outside of the problem-solving framework and thus without needing to

engage with finalized artifacts. This specific feature helps knowledge and practices from other domains to hack their own traditional infrastructures and engage with embodied, experiential approaches. By understanding prototypes not just as crafting-related artifacts but most importantly as media for crafting knowledge interaction, Schrage (2013) discusses how prototypes are "platforms for collaborative creativity" since they "enable different ecologies and economics of innovation insight. They are [a] means to interpersonal – not just technical – ends." In other words, dealing with unfinished artifacts – whether material or immaterial – creates an intimate and safe space for different perspectives to take the stage and make a difference: the prototype will only be benefitting from diverse contributions, especially if they are in agonistic friction with each other (Mallol, 2011; Dunne & Raby, 2013). As a result, if prototypes embody manifestations of an unknown range of possibilities, then the cultural shift from defined solutions to open possibilities in disciplines other than design is afforded by prototypes' incompleteness.

Such a feature suggests the multipotential shapes the prototype might be molded into. In this sense, prototyping thrives on imagination about possibilities. Moreover, imaginative thinking invites discourses in future tenses – prototypes have a peculiar relation with temporality. To some extent, all design practices are future-oriented, implying that, essentially, what designers make becomes the future we inhabit. Times of crisis strengthen this stance, turning designers into visionaries "in service of society" (Nelson & Stolterman, 2000), inventors of "scenarios and strategies [who] must play in the territories of the imagination to create new stories, new fictions, which will add to the thickness of the real" (Branzi, 1999). Thus, it seems that design catalyzes knowledge production by acting as a multi-temporal force: design explores futures through its prototypes, then comes back into the present to fuel transition informing those prototypes (Irwin et al., 2022). In this sense, the second quality we are addressing is temporal ubiquity, as these devices dwell in two complementary timelines: on the one hand, radical futures in which prototypes engage with deeper levels of culture, mental models, and structures; on the other, the progressive present in which prototypes invite working on contingent phenomena and their ecology of patterns. Yet again, both futures and present are not destinations or something to channel defining efforts into, but media to fuel imaginative thinking through their embodied vessels. In this sense, prototypes are the "quintessential future-facing object" (Glenn, 2013, p. xiv) as they are not meant to define futures, but generate and, through iterative processes, inform, update, and revise them.

Thus, temporal ubiquity is another quality afforded by prototypes blooming in the public space. The prototypes of the case studies discussed here inhabit those two dimensions, which are always connected, to trigger different responses and fulfill different purposes. This aligns with a research strand in design which distinguishes *provotypes* from *prototypes:* according to the temporal ubiquity feature, the first dwells in *radical futures*, serving as contingent spaces for collaborative analysis and exploration while driving dialectic processes of change (Mogensen, 1992; Boer, 2011). The latter populates the *progressive present*, inviting stakeholders to become bricoleurs (Manzini, 2015), using whatever is at hand to approximate and reassemble pre-existing artifacts and reshape their meaning. Following this model, provotypes embody *tensions* stemming from differences in the shared nexus of knowledge: their main goal is to provoke reactions and insights from the stakeholders to co-find and co-frame relevant questions. Consequently, prototypes embody those *questions* to have stakeholders experience them and explore their triggered possibilities throughout the prototyping process, testing, and practice. The Gigatonne Challenge seems perfectly aligned with this approach, as its global teams act as bricoleurs discovering a sense of their actions and agency.

Notwithstanding the temporal-related distinction, both provotypes and prototypes create the conditions for experts with different backgrounds – designers, ethicists, political scientists, economists, philosophers, chefs, lawyers, and so on – to work together on *futures.*

Thus, prototyping occurs in a highly interdisciplinary context: just as designers are well known mediators of knowledge (Celaschi in Germak, 2008), prototypes are the devices enabling that same cultural mediation through embodying processes (Schrage, 2013). However, this aspect is turning out to be enriched by more-than-human perspectives, since – as Climavore and Zoöp make clear – non-humans are going to be increasingly involved in prototyping practices and thus knowledge production. This proves a challenge for both designers and other agencies to design prototypes open enough to allow more-than-human contributions to inform them. This can also be framed as the third quality of prototypes blooming at the intersection of design and democracy: *intimacy.* Prototypes traditionally have the capability to creatively engage with stakeholders so that they can make such devices their own: experiencing them through a personal connection with the artifacts and what they stand for.

Climavore and Zoöp offer a solid example of how non-humans might also participate in the prototyping process, triggering interspecies reflection. As such, prototypes are devices of embodied knowledge which might also be understood as the interplay between two types of knowledge. In fact, recalling the distinction between provotypes and prototypes, engagement with those devices encourages the production of actionable knowledge and reflective knowledge. The first might be easily linked to prototypes living in the progressive present that translate f(r)iction into decisions, actions, and impacts; the latter seems to resonate with provotypes inhabiting radical futures which stimulate openness, and even unlearning, through embodied conversations. All the case studies have a trace of such an interplay in their prototyping phases. However, if this is valid from a human perspective, as may be experienced in the Gigatonne Challenge, from a more-than-human perspective, we witness the rise of more-than-human ways of knowing. Here, creative practices like design are believed to play a catalyzing role, since they might contribute to translating the experiential knowledge traditionally enabled through prototypes into embodied, somewhat codified knowledge, even when it comes from more-than-human sources. This might be a promising step to better inform the new shapes of democracies from more-than-human ontological and epistemological perspectives.

A Never-Ending Journey

The New Climatic Regime is not only a climate crisis: it is a cultural crisis and thus an imaginative one. The theoretical approaches in this paper help highlight how essential notions of public life such as citizenship and community are soon going to change. Today, the New Climatic Regime is enriching those concepts, so that communal flourishing will result from a multispecies response-ability, where citizenship – or, rather, *kinship* – comes before any other role, even the “stakeholder” ones. This is possible if we frame civics and civic engagement as being in service of more-than-human communities. Within this interpretation, the focus point shifts on a relational perspective which seems to perfectly hold design and democracy together. In fact, they can be understood as a set of practices and capabilities whose mission aligns with being in service: they are naturally inclined to engage with others and otherness. As such, both design and democracy cannot be autoreferential practices, since they thrive on *bridging, mediating, and becoming.*

Here, relationality helps in articulating care in design and democracy as an experiential value, represented by a direct engagement in maintaining, repairing, and sustaining more-than-human ecologies for collective thriving. This concept of care relies on prioritizing shared purposes and commitments. Thus, more-than-human attunement entails sustaining togetherness which both design and democracy understand as the ultimate outcome of their agency. As such, care is essential to future democracies since it entails taking and enabling response-abilities both for humans and other entities that cannot represent themselves within the contemporary political infrastructure but prove to be highly influential on collective life. This aligns not only with the relationality of both design and democracy, but also with how this relationality is delivered: they are always producing sensible experiences towards at least one interlocutor. Discourse, then, is engaged with incomplete, temporally ubiquitous, and intimate devices: in fact, prototypes enable democratic experiences through design, producing nurturing cycles of mutual learning, shaping, and positioning. Here, this endeavor of participating and endlessly negotiating plural imaginaries and practices is essentially inherent to the nature of democracy.

Pragmatist and agonistic shapes of democracy suggest the foundational need to unceasingly reiterate, contest, and renew democratic conditions. In this sense, just as “climate care is a journey to remake cultures, find justices and regenerate habitats” (Light, 2022, p. 34), so is democracy through design: an ongoing endeavor of inquiry and experiment. Just like prototyping, the effort of keeping democratic possibilities vibrant is never complete. The pragmatist turns towards futures tightened by the interplay between design and democracy: here, democracy speaks to the experiential nature of design as something we are involved in making, feeling, and doing. By f(r)ictioning traditional identity and future sense-making, design contributes to combining more-than-human ways of knowing at the proximity scale of the practice of civics, linking bottom-up practices to top-down guidelines. As a result, the *politically unthinkable* is challenged and informed by the *experientially desirable* in experimental practices. Here, democracy emerges from a process-oriented stance: with provotypes and prototypes acting as situated-utopias facilitated – not determined – by design. There is no definite destination since the interplay between design and democracy is traced in the journey.

Thanks to prototypes and prototyping, this paper has built a preliminary framework – a research prototype – from which it seems possible to gain insights of the affordances of democracies as both modes of communal life and perpetual becoming. The case studies presented here are believed to belong to a broader range of experimentations that developed situated, experiential approaches to keep the state-of-becoming kindled. Paradoxically, the main driver of such approaches resides in creative processes, which, by definition, draw their life force from uncodified stances to knowledge production. However, the embodied stage of prototypes might help unpack the same intimate, situated, and bottom-up ways of knowing that eventually imprint the socio-materiality of everyday life.

Prototypes, thus, become proxies through which it is possible to approach prototyping as the intimate, hybrid process for design and democracy to embed adaptation and transformation in everyday life. Both designers and democratic institutions – as well as other agencies that might be interested in working on the civic layer of society – might benefit from this approach, as it invites them to stay with the trouble, namely tackling possibilities in more-than-human ecologies. Here, locality, temporariness, and partiality are both strengths and weaknesses of civic efforts. This tension might benefit from designing dynamic and inclusive representations of worlds aimed at releasing conventional boundaries on behalf of open-ended relationalities: according to the discussion built so far, prototypes and prototyping embody the affordances of a never-ending journey which might be addressed as both "democracy" or, rather, "*democracying*." From a research perspective, the focus on "-ing" seems to call for alternative strategies to track experiential knowledge resulting from prototyping in more-than-human civics to preserve its transient yet influencing agency over the sensible layer of reality. Here, diverse strands for future development open for research. Notwithstanding the need to further develop a more nuanced understanding of similar practices through the qualities resulting from the present study, the hope is to have contributed to outlining research coordinates to further notice the proxies of transformation and adaptation in times of planetary entanglement.

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“DOWN TO EARTH”: FROM ANTHROPOCENTRIC TO DE-ANTHROPOCENTRIC DESIGN PARADIGM

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Abstract
Throughout the history of design, designers have always shouldered the responsibility of creating ideas and actions for the ideal life of human beings (Zhang, 2021). Design has always been an important medium for human beings to build and communicate an ideal world. The anthropocentric paradigm regards humankind (including designers) as the primary actor and the most central element of the world’s existence; however, this has led the world into total disorder and anomie (instability). Human activities have greatly impacted the Earth’s ecosystem which has caused climate change, leading to fundamental dilemmas such as global warming, hunger, wars, and most recently the COVID-19 pandemic that has (by March 2022) infected over 470 million people (WHO, 2022). The Earth is gradually becoming unable to provide healthy and sustainable habitats for human beings (Kupers & ARTEM, 2017). In the face of an anthropocentric dilemma, design has the responsibility and obligation to stand up and provide actionable guidance for human ideals and the future. Therefore, it is urgent to change the existing way of life and adjust the usual “people-centred” way of thinking and values. The Anthropocene offers us an opportunity to recognise human material dependence and vulnerability and rethink the relationship between human beings, the world, and the Earth. Because we are currently living in a time defined by environmental, geopolitical, and socio-economic crises, based on the “down-to-earth” approach proposed by Bruno Latour (2018), this paper presents arguments and design cases that echo the “de-anthropocentric” design position. We look at design approaches that try to understand how nature interacts with human beings rather than how humans exist within an ecosystem. We primarily aim to break the positioning of humans at the centre and their needs as the scale and value judgment standard, and bring non-human existence, such as the natural environment and other species, into the new design framework. Through the idea of “de-anthropocentric” as the basic consensus, we highlight the need to revise the relationship between people and things, reconstruct the relationship between people and things, people and the world, and people and the Earth, and provide new ideas for realising the design ideal of passing through and adapting to the Anthropocene.

Author Keywords
Paradigm shift; de-anthropocentric design; sustainability; adaptation design; Anthropocene.

Introduction

The term Anthropocene refers to a geological epoch proposed by Nobel Laureate Paul Crutzen and his collaborator Eugene Stoermer in 2000 (Pearce, 2007, p. 21). Before the Anthropocene, the Earth had a stable internal structure as a planetary system with living activity. Despite a number of large-scale disruptions like deadly mass extinction catastrophes, the planet was able to adapt, recover, or rebuild through the intricate feedback loop of evolution, preserving relative internal stability. In 1982, Crutzen revealed the "hole in the ozone layer" and pointed out that human activities were affecting the Earth's natural ecosystem in the form of ocean acidification, habitat destruction, erosion, sedimentation, extinction of biodiversity, and the destructive impacts of urbanisation (Crutzen & Birks, 2016).

Although some scientists have questioned whether the word *Anthropocene* can be used to name a geological era (Wright, 2014), it can be discerned from the spate of scientific and humanistic articles and books that human beings do have an impact on the environment which, while beneficial to some species, has been disastrous for others. For example, Gerardo Ceballos et al. (2015) listed the extinction of mammals and birds caused by human activities in *The Annihilation of Nature: Human Extinction of Birds and Mammals* and expressed the pessimistic belief that the Anthropocene is the beginning of the eradication of nature by humans. Global climate anomalies (including global warming) and the COVID-19 pandemic, which has been spreading and mutating around the world since the beginning of 2019, have prompted more and more scientists, natural philosophers, and designers to think about human consciousness and the human race's self-appointed centrality on the planet, leading to a re-exploration of the relationship between humans and nature in the second decade of the twenty-first century.

Many believe that human beings' negative impact on the environment and Earth in the Anthropocene crisis is far-reaching and beyond a controllable range. However, from an etymological viewpoint, the term *crisis* – in ancient Greek, *krisis* – is not only a decisive moment but also an excellent opportunity for change. As a problem-solving strategy, the concept of design is "involved with how things ought to be, with devising artefacts to achieve goals" (Simon, 1996, p. 114). Design also shoulders the responsibility of ensuring a better future life for human beings and is a medium for the human development of an ideal world (Zhang, 2021). Throughout the history of design, the ideals and values of designers have always been closely related to the context of the times and the social problems that need to be solved. For example, the design ideal of the Arts and Crafts movement was to try to explore an aesthetic paradigm and a design logic that matched the mechanised production mode; the design ideal of the Bauhaus period was to investigate the unification of technology and art to achieve a more democratic design value; and so on.

Faced with the dilemma of the Anthropocene, designers should rethink new inclusive and sustainable ways of life and integrate the potential of design into their understanding of nature and human beings to deal with new problems during the crisis. Through literature research, this paper re-deconstructs "nature" and finds that the continuous change of people's understanding of nature affects the change of the relationship between people and nature. After that, through the discussion of the dilemma of the “Anthropocene,” it is believed that the relationship between human beings and nature should be transformed. This paper holds that the design ideal of the Anthropocene is to learn to re-understand “human beings,” re-understand the world, and recognise that human beings are part of the natural system (including biology, land, ocean, etc.), and all elements in the system interact and interrelate with each other. Designers need to rethink their role and responsibility in the dilemma of the Anthropocene. They must shift from a human-centred to a de-anthropocentric focus to re-understand and re-create the interaction between humans and the world to rebuild the link between humans and nature. Through the discussion and exploration of “beyond human-centred design” and “non-human-centred design approach,” ten cases were selected for analysis, and finally the 4RE (rediscover, reconnect, reimagine, and reconstruct) design principles were proposed. This may help generate new, inclusive, sustainability-oriented design options to meet the new needs and demands expressed by people during and after the crisis to enhance the sustainable quality of future living places.

Literature Review: Re-Recognising the Anthropocene

Human Beings’ Understanding of Nature Is Constantly Changing

“Nature is a very nebulous concept...it is possible to say that my main focus is the transition from nature to territory. Ecological challenges are for our survival, not the survival of nature” (FU, 2017).

To revisit the relationship between humans and nature, we first must deconstruct and define *nature* as a term. Nature is a Western cosmological concept derived from a history of mixed influences, which is both particular and universal. Figure 1 describes the historical development of Western naturalism from the four main periods of antiquity, Christianity, the Renaissance, and the Scientific Revolution. In Greek philosophy (around 350 B.C.E.), Aristotle categorised animals in a standard table according to their bodies, wings, legs, and fins. He thought that nature was made up of a collection of creatures that created order and followed natural law in accordance with their structure (Aristotle, ca. 350 B.C.E./1991). According to Christianity (from the first century C.E.), human beings are the divine genesis of the supernatural and are superior creatures to plants and animals. Human beings are entrusted by God with administrating and regulating the planet (Crow, 2022). The European Renaissance established a barrier between humans, nature, and the world through a pictorial perspective, allowing humans to conceive of nature and things as separate objects. In the seventeenth century, the Scientific Revolution introduced the concept of mechanical properties, regarding them as a unified system, and the belief that the behaviour of each element might be explained by natural law.

Figure 1. Western naturalism: An historical process (redrawn from source: Pesses, 2016).
Descola believed that nature was a world order created by “moderns” (Pesses, 2016). He proposed a naturalistic dualism based on truth and value, arguing that the difference between the humanities and technology lies in their dualistic perception of nature. Henri Lewis Morgan, an adherent of Descola’s theory, took the lead by investigating the relationship between technology and various forms of social structure, arguing that the purpose of the humanities is to examine and explain values by exploring chaos, purpose, organisation, and order. The structuralism proposed by Claude Lévi-Strauss (Pesses, 2016) presents a conceptual model of human society to explain how humans comprehend the world.

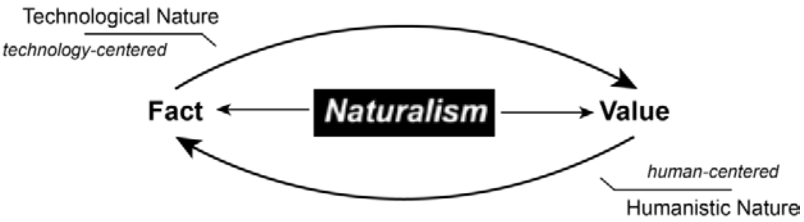

Figure 2. The relationship between technology and nature (drawn by the author).

Descola (2013) believes that naturalism is based on fact and value and divides nature into two independent fields: culture and nature (Figure 2). According to Descola’s description, technical nature leads from fact to value, while humanistic nature leads from value to fact. Technological nature emphasises humans’ ability to control nature through technology and ideology, expressing the ideal of human life through information collection and technological transformation. Humanistic nature – while it does not deny that human life and systems are affected by the surrounding environment – regards humans as supernatural beings who control and dominate nature. Hans Jonas’s natural philosophy presented a new description of nature (what he called *physis*). He regarded nature as an organic whole and argued that the responsibility of human beings to nature is not based on human will but founded on the reality that humans are part of the natural whole and are essentially the same as other beings in nature (Donnelley, 1989). Kant viewed it as arrogant for humans to imagine that how we perceive the world is the only possible way to connect with the things in it; he viewed our ignoring of how non-human objects interact with the world as “dogmatic anthropomorphism” which he tried to avoid, suggesting that what human beings perceive is not the thing-in-itself but our relationship with it – with nature and the world (Wu, 2020).

Qian Mu, a famous Chinese philosopher, mentioned in his article “The Possible Contribution of Chinese Culture to the Future of Mankind” (1991) that starting from “heaven and man are united as one (Tian Ren He Yi, 天人合一)” (Heaven and man, n.d.), ancient sages put forward many philosophical views on the harmonious coexistence of man and nature, especially Confucianism, Buddhism, and Taoism. Benevolence (Ren, 仁), advocated by Confucianism, proposes that human beings and all things in the world should be in a state of harmony and unity, and emphasises that human beings are a part of nature (Ren (Benevolence), n.d.). Equality for all sentient beings (there is no difference between living things, Zhong Sheng Ping Den, 眾生平等) (Equality, n.d.), advocated by Zen Buddhism, affirms the right of all living things to exist. *Tao,* the truth (veritas), imitates nature (Dao FA Zi Ran, 道法自然) (Lin, 2022), calm and content self of nature (Zi Ran Wu Wei, 自然無為) (Termonline, 2003) put forward by Taoism emphasises that people should understand nature, conform to nature, and coexist with nature. Although the ancient Chinese view of nature recognised humanity’s transformation, regulation, control, and guidance of nature, the more mainstream idea was to reach a consensus of non-duality of humanity and nature, which placed humankind in an equal or even obedient position with nature, and believed that humanity was a part of nature and should obey the universal laws of nature.

The Anthropocene Dilemma

The relationship between humans and nature has been changing with human activities and technological progress. Part of the Anthropocene’s predicament lies in the fact that technological breakthroughs and even some technological “creations” put nature in jeopardy. Humans, for example, take fossil fuels, phosphate rock, and other raw materials from the Earth’s crust more quickly than natural processes can replenish them, while dumping waste (in the form of solids, liquids, and gases, some of them poisonous) into the land, atmosphere, and ocean at will (Lenton & Latour, 2018). Another example is humans’ irresponsible handling of water as a shared and vulnerable resource for all living forms (Mukherjee, 2020), as well as fishing and the cultivation of crops and animals as a source of food and fodder (Haalboom, 2020).

The most notable aspect of humans’ interaction with nature is that it stems from the technological creations made by human beings to “protect” nature yet still depends on the result-oriented technological and scientific practice that initially led to the problem. It is time that humankind re-examined the relationship between nature and technology, an issue that increasing numbers of individuals are thinking about in light of the present ecological catastrophe. There is concern that new technology may substantially harm nature, and people are becoming increasingly reliant on long-term monitoring and recording of the planet to point to the most suitable and essential remedies. In comparison to the system mentioned in the Gaia hypothesis, these inventions and creations are poorly linked and unsustainable (Lenton & Latour, 2018). In this dilemma, the conflict between humans and nature seems to become more acute.

Design-Driven: Adapting to the Anthropocene, Embracing Gaia

Design Initiatives for the Anthropocene Dilemma

“If designers want to realise the full potential of design ideas, [in addition to analysing and studying the design object itself], they also need to examine how the ‘situation’ on which these design practices rely is self-constructed” (Margolin, 1995, p. 355).

The Anthropocene reveals a crisis of human sustainability. An important reason for the emergence of this crisis is that humans have long adhered to arrogant anthropocentrism (Zhang, 2021), which places humans in opposition to nature and makes the conflict between humans and nature more serious.

As can be seen in Figure 3, Lou Yongqi uses the image of Chinese Tai Chi to express the contradictory and unified relationship between nature, human, artificial, and cyber systems. He stated that "any contradiction in a both positive and harmonious way, opposing and connecting with each other, checking and balancing one other" (Jing, 2020, p. 33). Contradiction is conducive to promoting cognitive reconstruction and transforming it into innovative behaviour. Viewing the contradiction correctly is conducive to the development of design innovation itself, and is also conducive to the transformation of relationships. From the ecosystem perspective, it suggests the need to establish a new ecological relationship of harmonious coexistence between humans and nature.

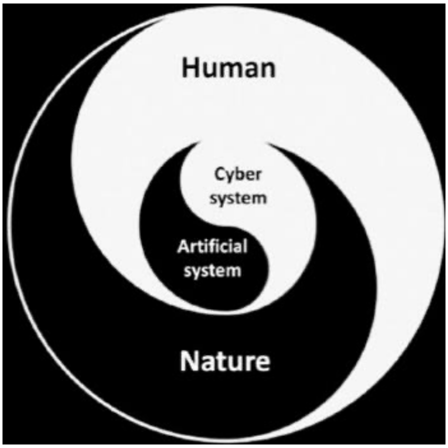

Figure 3. Four systems: nature, human, artificial, and cyber systems (image source: Lou, 2019, p. 27).

In *Prosperity Without Growth: Foundations for the Economy of Tomorrow,* Tim Jackson (2016) explored the relationship between humans and economic growth, proposing that we should rid ourselves of the obsession with economic growth and focus on the interaction between humans and nature, and that we should take nature and other elements of the ecosystem into consideration for the future to reconcile "our aspirations for the good life with the limitations and constraints of a finite planet" (p. 3). Latour, in his book *Facing Gaia: Eight Lectures on the New Climatic Regime* (2017), proposed the phrase "new climatic regime" to describe the Anthropocene, in which the relationship between human beings and the Earth is the determinant of humanity's future. In *Down to Earth: Politics in the New Climatic Regime,* Latour (2018) advocated rethinking the relationship between human beings and nature across the dichotomy of local and global, encouraging a synergistic coexistence with nature. Latour (2018) suggested that Gaia's discovery should drive humans to return to the Earth and that "the place of the action is here below and right now" (p. 81). Latour proposed a way of rethinking and re-enacting the dilemma of the Anthropocene that challenges anthropocentrism from a different angle, urging human beings to form a new understanding of the Gaia principle to reposition our relationship with the Earth.

In 2019, Ezio Manzini proposed a new design challenge, advocating for social innovation for the planet and urging Design for Social Innovation and Sustainability (DESIS) laboratories worldwide to prioritise climate and environmental sustainability in their research (Franqueira, 2019). Don Norman also stated in his talk *The Future of Design Education and the World: An Initiative and a Book* at the 2021 International Association of Societies of Design Research (IASDR) (2021) conference that climate change is a symptom of the world’s issues, not the cause, and that design creates chaos. As early as 1971, Papanek (1971) mentioned in his book *Design for the Real World* that the Earth’s resources are limited, and that future design practice and education should focus on the majority of the world’s growing population. Furthermore, Papanek emphasised the designer’s social and ethical values and living in harmony with nature.

Today, increasing numbers of designers are beginning to think about the relationship between humans and nature and are beginning to discover that the Anthropocene dilemma is largely a consequence of human-centred design practices (Tassinari et al., 2020). The production and consumption that dominate the design paradigm of the human-centred way of life have led designers to ignore the fundamental interrelationships inherent in human and non-human natural subjects, as if humankind’s interests were separate from those of other natural participants, leading to design processes and results that lack inclusiveness. When humans only pursue their aspirations, demands, and interests (even the interests of a small group of privileged classes), they often harm the interests of the whole planet and, thus, their own interests as well. Tony Fry (1999) referred to this design consequence as “the defuturing aspects of design” (p. 237). He urged designers to share responsibility in the process, and also to take new actions to address the issue. These approaches urge us to change our current way of life and our habitual thinking and ideals.

To put it another way, humans urgently require a new epistemology and alternative scheme based on non-anthropocentrism, as well as a cross-species cooperative logic and action framework to realise the link between humans and things, between nature and technology. Design will play a significant role as a medium. When humans’ connection with things changes, humans’ relationship with nature and the world will be altered as well. Faced with the Anthropocene’s design shift, we must rethink and re-negotiate the connection between humans and the planet, nature, and things.

The Decentralisation Design Paradigm

The Anthropocene arose mostly out of anthropocentrism as the dominating worldview for a long period (Zhang, 2021). Bruno Latour (2017) argued in *Facing Gaia* that humans have lived above and separated from the planet for far too long since entering the human realm. He called for and offered a roadmap to return to the Earth’s surface – or more specifically, to generate the human desire to return to the Earth’s surface, to be “with the world.” Faced with the Anthropocene dilemma, many people are questioning the supernatural status of human beings, and are even coming to believe that “human-centred design is fundamentally misleading” in its practice (Lindley et al., 2020). This is evidenced by the emergence of Actor-Network Theory (ANT) – a theoretical orientation based on the ontology of relational practice and a view of individual behaviour as constrained by such networks (Wellman, 1988) – non-anthropocentrism, and posthumanism. The Anthropocene has given rise to a new design paradigm that is forcing designers to question and reflect on the old human-centred paradigm.

Questioning the "human-centred" design paradigm, designers began to think beyond human-centred design and the non-human-centred design approach (Liu et al., 2022), and proposed concepts such as green design (p. 33), ecological design (p. 35), product-service system design (p. 37), life cycle design (p. 46), recycle design (p. 63), reduce design (p. 123), system design (p. 219), and interspecies design (Kaiser, 2021). These design methods are design for the planet, or design for sustainability and adaptation. It is a dramatic shift in perspective which needs to move from egoism to ecosystems. The concept of this perspective positions non-human participants as equal to humans, and designers should consider design options for products and services that do not harm the planet.

Confronting the Anthropocene's challenges is more of an invitation, an opportunity for designers. When confronted with the challenges of today's society, designers should be inspired to consider an adaptive design expression and paradigm to resolve the place and function of human beings and to understand that humans no longer have the hegemonic role of conquering, using, and exploiting nature, but should instead regard their connection with other species as one of equality and symbiosis. Designers must reframe human interests in relationships and consider what they care about when designing products that contribute positively to nature (Tassinari, 2019).

This paper proposes that de-anthropocentrism is primarily about breaking the traditional mode of thinking that uses human needs and scales as the sole criteria for value judgments, expanding the ethical communal consciousness of coexistence, and correcting human beings' position in the world. However, it must be admitted that anthropocentrism cannot be eradicated. That is, the intention to create designs relevant to people and for people cannot be avoided (Zhang, 2021). As a result, de-anthropocentrism is a complement to, rather than a replacement for, the idea of human-centred design.

Design Actions for De-Anthropocentrism

The idea of a design pattern was proposed by Ezio Manzini (2015) in his book *Design, When Everybody Designs: An Introduction to Design for Social Innovation.* It is considered a new form of collaborative design process across organisations, stakeholders, producers, and users corresponding to the traditional model. The concept that "everyone is a designer," advocated by Manzini, embodies the idea that everyone should be engaged in the design process and can contribute their own knowledge, abilities, and resources to form close cooperation around a common design ideal and vision. The concept is in opposition to the traditional, technical, expert-style design mode, and instead encourages people to actively cooperate – with human and nonhuman entities – to seek solutions when faced with difficulties. Design patterns not only exist as a new form of design value and innovation, but also provide new insights into the designer-centred and human-centred design paradigm. In the process of case selection and analysis, this paper selects ten social innovation practice cases with reference to the principle of service innovation design of desirability, viability, feasibility, responsibility, systematic and transparent (Manzini, 2015). The specific selection criteria are to focus on non-human roles, quality (reliability, intensity, trust, freedom, etc.), long term, and planet fit. Through the analysis of some social innovation practice cases, this paper finds that the design paradigm of de-anthropocentrism has expanded to a variety of connotations in different practical contexts and exists in different forms.

Project Name	Design Pattern	Construction	Role of Designers
Martí Guixé's Solar Kitchen Restaurant (Lee, 2011) Combining nature and surroundings to produce a completely different taste experience	Meaning construction: Rethinking the kitchen, cooking, food, drink, and the relationship of all of these to nature	Business model	Rediscover Reconnect Reimagine Reconstruct
The Permaculture Movement (Tortorello, 2011) Focusing on microclimates and native ecosystems with system design; simulate and use the patterns and elastic features from the natural ecosystem	Meaning construction: A simple system for designing sustainable human settlements, restoring soil, planting year-round food landscapes, conserving water, redirecting the waste stream, and forming more companionable communities	Knowledge alliance	Reconnect Reimagine Reconstruct
Lettuce House (Sustainable Lifestyle Lab, 2015) New thinking on people's daily living and lifestyle, applying green, healthy, low-carbon, and sustainable living concepts to real-life scenarios	Meaning construction: Modular housing design scheme, adopting an ecological cycle system design to form a comprehensive solution	Complex network	Rediscover Reconnect Reimagine Reconstruct
For the Love of Bees (2019) Bee-centric design project and collaboration platform invites people to come together to imagine their city as the safest city for bees in the world	Meaning construction: Building a safe city for bees	Knowledge alliance	Reconnect Reconstruct
Future Life Prototype Street (Jing, 2020) Seeking new technologies, products, services, and even value norms and economic models to meet social functions	Meaning construction: Community with innovation, entrepreneurship, and creativity	Value network	Reconnect Reimagine
Low-Carbon City Project (Jing, 2020) Macro planning of the national innovation system due to urban climate change	Meaning construction: Striving for social democracy and environmental rights, and regarding the urban system as the critical field of social transformation	Complex network	Rediscover Reconnect Reimagine
Wadden Sea Landscape Reconstruction Project (Döring et al., 2021) Balancing the conflict between rising sea levels from climate change and the daily lives of residents	Problem-solving: While protecting the fragile coastline ecological environment, ensure the daily life and cultural and recreational activities of coastal residents	Complex network	Rediscover Reimagine Reconstruct
GreenThumb (2022) A response to the issue of public and private land abandonment brought about by the financial crisis	Problem-solving: Converting abandoned urban land into community parks managed by residents to improve air quality, biodiversity, residents' well-being, and enrich community resources	Platform	Reconnect Reconstruct

A Flax Project (Meindertsma, 2022) Presenting the different senses of flax producers, processors, and users	Meaning construction: Make an affordable, scalable, environmentally friendly, locally made product whilst exploring new production processes	Value network	Rediscover Reconnect Reconstruct
India Ground Water Resources Participatory Management (Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation Government of India, 2022) Sustainable development and management of India's groundwater resources	Problem-solving: Treat groundwater as a public resource, develop and disseminate technologies, and monitor and implement national policies for management by communities and stakeholders	Knowledge alliance	Reconnect Reconstruct

Table 1. De-anthropocentric design projects (collected by the author).

Discussion

The socio-environmental challenges of the Anthropocene have become apparent, with impacts at different scales exacerbating cultural, social, political, and environmental problems. These issues have brought new challenges to designers. The previous discussion on the relationship between humans and nature and the analysis of social innovation practice cases reveal that designers need to re-examine the relationship between humans and nature and between humans and non-human natural subjects. It is necessary to connect people with more non-human natural subjects to address issues from a comprehensive and systematic perspective. We must listen to the voices of non-human natural subjects and develop a sharing platform that spans different scales and levels. The platform should have the ability to reshape the surrounding world by collectively designing actions within and across scales, addressing real cultural and socio-environmental issues in specific locations, and combining social, political, and environmental issues with higher and more complex requirements for the roles and abilities required of designers. The following will discuss the specific roles and responsibilities of designers from four dimensions, and try to put forward the 4RE principles (that is, re-discover, re-connect, re-image, and re-construct) based on the previous literature review and case study to more clearly define the capabilities required by designers.

Rediscovering the Relationship Between Humans and Nature

The Anthropocene challenges our understanding of sustainable development. If human beings want to survive in the new era of the Anthropocene, a fundamental shift in the relationship between humanity and the planet is required (Steffen et al., 2007). This is the central issue that increasing numbers of designers are considering in their design practice. Ron Wakkary (2021) mentioned in *Things We Could Design: For More than Human-Centred Worlds* that although human-centred design aims to improve human life, it only focuses on the human group itself, but ignores other non-human unique ways of existing, which are also closely related to human survival and development. Humans are not autonomous in making sense of the existing world and designing future life, they are “bound together materially, ethically, and existentially” with non-humans and nature. Therefore, designers must rethink the relationship between humans and the planet with more humility and generosity to make it less complex and more regenerative. To re-recognise and discover the relationship between humans and nature, humans and the world, and humans and non-human natural subjects, it is necessary to change our existing way of life, adjust our habitual ways of thinking and our values, and re-examine the perceptions, thinking, and behaviour of individuals, society, and nature. Participating in the design process, observing and tracing the culture of daily life, and engaging as many stakeholders as possible from multiple perspectives in the context of contemporary unsustainability (Willis, 2006) to understand how human and non-human natural agents exist in the world are critical approaches to rethinking the relationship between humans and the planet.

Reconnecting the Relationship Between Humans and Nature

Designers must explore opportunities for people, collectives, and organisations to connect within and across scales around their concerns and the things they care about (reconnect) after learning how human and non-human natural subjects exist in today’s world (rediscover) (Escobar, 2018). In the process of reconnecting, designers can act as connectors, creating opportunities for individual and collective concerns to be addressed and harnessing the capabilities and resources of various stakeholders to allow potential platform partners to connect; to engage as many stakeholders, organisations, and institutions as possible on the shared platform; and to consider the possibility of potential (re) connections between platform partners of different organisational forms.

Reimagining How Diverse Groups Co-Create and Act Together

After engaging as many stakeholders as possible to connect (or reconnect), it will be necessary to facilitate and stimulate the potential of these many actors and stakeholders to collaboratively reimagine systems, organisations, and platforms. Reimagining is a way to inspire different stakeholders and collectively envision a shared platform through co-collaboration and co-creation, as multi-role, multi-participatory various design is “an essential tool for reimagining and reconstructing local worlds” (Escobar, 2018, p. 4). Designers must first reimagine the design ideal and core values to determine how to lead other stakeholders to carry out design actions collectively. Designers must consider how to reimagine the ideas and aspirations of humans, non-human natural subjects, and the environment on shared platforms through collective design actions, and how to help designers in different roles express and assert themselves after this has been decided. Designers might use storytelling, digital environments, performances, prototypes, scenarios, photography, science fiction, and other design tools and methodologies to encourage participants’ creativity and imagination in this process. Therefore, as they envision how diverse groups might co-create and act together, designers should be able to satisfy future or marginalised needs and demands.

Reconstructing the Design Ideal of De-Anthropocentrism

The de-anthropocentrism design ideal proposes a new human-centred possibility. It should be admitted that the de-anthropocentrism mentioned in this article does not replace human-centred design ontology but only provides a supplement to it. When human-centred design is not feasible or faces complex challenges that cannot be met by the existing local and singular technological culture systems (such as the novel coronavirus, global warming, etc.), designers must build a multi-species, cross-regional vision, action frameworks, and cooperative platforms based on the idea of de-anthropocentrism.

Conclusion

Faced with the dilemma of the Anthropocene, it is clear that human-centred design thinking and values need to shift. The Anthropocene offers us an opportunity to rethink the relationship between human beings and the planet, while at the same time offering an invitation to apply initiative to existing design concepts and values. This paper first discusses the relationship between humans and nature in detail. Then, based on Bruno Latour’s idea of “down to earth,” it puts forward non-anthropocentrism as a supplement to the human-centred design paradigm. Through the induction, collation, and analysis of some innovative design practices, it suggests the 4RE principles (rediscover, reconnect, reimagine, and reconstruct) to help designers to address the dilemma of the Anthropocene adeptly, and discusses how designers should understand the relationship between humans and nature, as well as the roles and skills that will be required of them in future design practice. This paper argues that it is necessary to abandon the view that human needs and demands are measures of scale and value; we must incorporate non-human natural subjects into a new design framework, and within it, strengthen the autonomy and coexistence of human and non-human natural subjects. As critic Anne-Marie Willis (2006) put it, “Design designs: we design our world, while our world acts back on us and designs us” (p. 70).

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IF IT'S BROKEN, DON'T JUST FIX IT: EXPLORING REPAIR AS DESIGN THROUGH A TWO-WEEK DESIGN CHARRETTE

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Abstract
Repairing products has a long history but is not a commonplace practice today. Many products end up in landfills without even being considered repairable, and this is one of the reasons for our unsustainable, linear production system. This paper explores repair's potential as an act of design by exploring the results of a two-week design charrette conducted with forty-seven industrial design students at The Ohio State University in Spring 2022. Fourteen teams of students received broken, donated, or unwanted products to repair and were challenged to learn more about how design could inform repair activities.

The results encouraged instructors to conclude that design-led repair has a valuable role to play in design education – especially as a lesson that supports design's contribution to the creation of a sustainable, circular future. Making unwanted, broken, or dysfunctional items useful demonstrated repair's potential to expand knowledge of materials, techniques, and tools, along with reconsidering users' needs. It also emphasized the benefits of making repairability central to the design of manufactured objects.

Author Keywords
Repair; design-led repair; visible repair; circular design; design charrette.

Introduction
The rise of modern industry shifted the production of goods from handmade processes to machine-made systems in a linear way. Automated production processes increased the demand for resource extraction and mass-production during the centuries that followed. Globalization and technological advancements diminished the consideration that objects and environments could have an "afterlife." Whereas mending was a relatively common activity until the middle of the twentieth century, replacing worn things with more affordable/upgraded versions has become the habit of most consumers today (Goldmark, 2020).

Manufacturers familiarized themselves with sustainability frameworks such as life cycle design by the end of the twentieth century. Life cycle design (LCD), also known as eco design or design for the environment, is the combined practice of design and environmentally conscious manufacturing (Vezzoli, 2007). Thackara (2005) acknowledges advances in LCD but also criticizes the method for calculating the materials, energy, and toxicity influences of a product during its lifecycle by noting that

> One counterintuitive outcome of this method’s application is the finding that although natural materials are commonly believed to be more environmentally friendly than artificial or [hu]man-made ones, the picture is more complicated than that. (p. 14)

Cradle-to-cradle (C2C) is another popular framework that presents nature’s life cycle of birth to death as a metaphor for basic strategies for industries to adopt as a way to enhance the sustainability of their production (Braungart & McDonough, 2001). Braungart and McDonough, authors of *Cradle to Cradle: Remaking the Way We Make Things*, note that while eco-efficiency is a reasonable framework for designing for sustainability, the four Rs (reducing, reusing, recycling, and regulating) usually require more energy, reducing their effectiveness as a strategy.

Because most goods purchased globally are discarded within three months of their acquisition (Chapman, 2006; 2021), designing products that are emotionally engaging is another critical factor for enhancing sustainability. Norman (2004) explains that the “emotional side of design may be more critical to a product’s success than its practical elements,” suggesting that increasing users’ attachment to objects might extend the longevity of their usefulness.

Design for sustainability approaches have been evolving for the purpose of reversing environmental damage while also encouraging economic growth and social justice within corporate structures, but criticisms abound. Strategies such as design for disassembly are seen as short-sighted because they continue to support the existing industrial system and offer only incremental change. Others, like cradle-to-cradle, call attention to important considerations about the energy embedded in manufactured goods, but trade-offs are often accepted as compromises for not challenging the status quo of manufacturing in more radical ways.

Recent developments that question systems at a larger scale, such as circular design and the circular economy, propose novel approaches to creating a more sustainable world based on “old” ways of structuring people’s economic and emotional connections with their goods. Circular design aims to transform the entire life cycle of products by extending their use beyond their initial phase. A circular economy revolves around eliminating and repurposing waste and pollution and respecting nature (Ellen MacArthur Foundation, 2017). Unlike cradle-to-cradle, which accepts the transformation of goods into raw materials, one of the goals of circularity is to extend the use of products by “enabling maintenance, repair, and reuse, rather than recycling” (Terzioğlu, 2020, p. 1). In recent years, corporations such as Nike, Ikea, and H&M are starting to embrace a circular economy concept. The circular economy is on the agendas of companies, non-governmental organizations, and governments as a pressing issue, and repair is one strategy to transition to circularity (Ellen MacArthur Foundation, 2017).

A lifetime of acquisition also equates to a lot of discarding if no care is paid to how to extend the life of our goods. The lack of sustainability in this cycle has been called out and examined for fifty years, especially since Victor Papanek (1971) highlighted design and designers' role in its creation. Chapman (2020) says, "norms also influence our perception of product life spans" (p. 3). Comparing a car with a flat tire and a smartphone with a cracked screen, Chapman (2020) challenges the norms about repairing, saying, "both are equally repairable, yet one a quite common practice, the other unthinkable" (p. 3). According to Lee Vinsel and Andrew Russel (2018), adoption of the maintenance mindset is the alternative to innovation-oriented consequences. According to them, "it starts with an awareness of the importance of maintenance, a commitment to keeping things in good working order, and attention to the investment of time, energy, and resources required" (Vinsel & Russel, 2018, p. 141).

With this in mind, we set out to question the relationship between design and repair and to understand how we as design educators can inspire our students to use a different approach in their future designs. We created an opportunity for them to experience the challenges and the opportunities that damaged manufactured goods embody in a two-week long charrette.

The State of Repair

Repair is the process of mending or restoring broken goods to a serviceable state if they become worn or damaged (Merriam-Webster, 2022). Replacing worn or broken objects with new belongings has become the habit of most consumers today (Chapman, 2021). Mattern (2018) claims, "Yet the lifespan of an object also depends on context. While in the West a cracked screen can mean death, elsewhere it opens up possibilities for reuse." Change is in the wind though, as renewed interest in repair is gaining momentum today (Postma, 2020). In his book *Meaningful Stuff,* Chapman (2021) notes that "an important aspect of keeping... things is maintenance" (p. 38). He proposes that in economically developed parts of the world, "repair" activities are not performed anymore. He mentions that there are various barriers such as "end[ing] in failure, further damage, or a sense of having wasted time" that prevent people from caring for their possessions (Chapman, 2021, p. 39). Terzioğlu's (2020) repair motivations and barriers model shows that reasons for not fixing broken things include "design-related problems, accessibility of materials and methods, required skills and knowledge, lack of confidence, and the negative stigma attached to repair..." (p. 2).

Currently, repair shops offer traditional techniques for maintenance of everyday items around the world, but their presence is diminishing. On the contrary, Repair Cafés, hackerspaces, Fixit clinics, and community-based fixer organizations in the Netherlands, the United Kingdom, and North America are growing in number (Wackman & Knight, 2020). Moreover, these places offer a variety of diverse capabilities and options for the consumer who either does not believe that they can fix things or is part of the consumption cycle in which most goods are only a few clicks away. Additionally, repair cafes and hackerspaces around the world are places to find the right tools, like-minded people, and the courage to fix things (Charter & Keiller, 2014). There is also a robust connection between the Right to Repair movement and Repair Cafés (Wackman & Knight, 2020, p. 14), elevating repair as a political issue.

Apart from the grassroots organizations mentioned above, there are for-profit organizations that support repairs and repairers. One such organization is IFixit which provides manuals of most electronics and electric devices on their database. They also sell fixing kits for electronic/electric devices (IFixit, 2022). Another company, Sugru, sells a silicone-based adhesive to be used in a plethora of types of repairs (Sugru, 2022). Menddie is a service company that brings repair shops and people together via their website for clothes repair (Menddie, 2022). Companies such as Patagonia also offer repair services for their products and provide do-it-yourself online repair tutorials for a wider audience.

Repair as Design

Design-led or visible repair is another highlight in these recent repair initiatives. Crosby and Stein (2020) claim that, "...it [design] must [engage with an ethics of mutual care] by acknowledging repair as a design practice that is diverse enough to redirect, and by including repair as a criterion for making decisions about what and how we design" (p. 183).

Hackerspaces, Repair Cafés, and Fixit clinics are emerging as places where "design-led" or "visible" repair approaches offer new life to damaged or unwanted items, establishing new connections with objects in the process. Visible mending of clothes, garments, and furniture has over 146,000 posts on Instagram at the time of this writing. People are sharing t-shirts darned with bright colors, toys fixed with Sugru, or socks patched with cartoon-like graphics.

In her book *Fixation: How to Have Stuff Without Breaking the Planet,* Goldmark (2020) echoes Douglas Harper, noting that "fixing and making are but different points along a continuum" (p. 117). According to her, the two sides of this equilibrium "require creativity and patience" (Goldmark, 2020, p. 117). Crosby and Stein (2020) also claim that repair activities are another version of designing. Chapman (2021) asserts that "repair need not always be a regressive process of restoring something to a former state. Oftentimes, repair is a progressive process, pushing something forward into a coproduced and expanded form" (p. 21). Kintsugi, the Japanese art of fixing ceramics with gold lacquer, is a good example of this type of "transformative repair." Kuelemans (2018) explains transformative repair as:

> ...more specific and less energy-intensive treatments for broken objects that do not supply or perpetuate harmful, existing systems of production. The artistic scope of transformative repair facilitates experimentation, fostering innovative means for reducing waste and... this potentialises resale through distribution channels beyond the home. (p. 4)

A Design Charrette for Repair

The industrial design program at The Ohio State University began hosting design charrettes to engage second, third, and fourth-year students with each other during the pandemic in 2021. The first design charrette was organized to reconnect our students and reinvigorate their learning experience after a year and a half behind computer screens and give them a chance to learn from professional designers and producers (Gümüs-

Ciftci et al., 2021). The 2022 topic focused on design's relationship with repair. Based on the limited literature on repair as design, we sought to explore the extent to which repairing and designing are intertwined; Maestri and Wakkary's (2011) assert that repair contributes "a higher level of creativity," especially when everyday design happens for broken household objects (p. 88). While many students have experimented with making and modeling, few had experience disassembling, diagnosing, and correcting or recreating workable products before engaging in this activity.

Charrette organizers first collected broken, dysfunctional, and unwanted products. These included donated items from faculty members and acquaintances and products from donation stations, secondhand shops, and on curbsides. These articles were stored on site before being distributed to student teams through a random lottery.

Figure 1. Abandoned furniture in front of a garage in an apartment complex.

Organizers determined that products that required electronic/electrical interventions would not be included among the goods circulated to students for the charrette. Instead, mundane everyday products, furniture pieces, and personal garments provided the challenge. In the end, the inventory of broken products included two table lamps, two office chairs, two dining chairs, two leather bags, two pairs of shoes, a baseball bat, a set of ping pong paddles, a pair of tongs, and a folding chair.

The event kicked off with presentations from a design scholar currently examining motivations and barriers for repair-through-design and a technical expert from one of Ohio State's innovation-based collaboration initiatives. In these talks, students learned how repair and design are related, along with potential technologies they could use at the innovation-based initiative's premises. At the end of the first day, fourteen student teams drew numbers from a bowl to determine which items they would work with, and one group drew a bonus item.

In the days that followed, the groups gathered to research, ideate, and iterate on possible repair scenarios. The student teams received mentorship from design faculty and staff and had access to a range of analog and digital tools.

Mon 24 Jan	**Tue 25 Jan** Kick-off: Presentation 1 & presentation 2	**Wed 26 Jan** Research/ repair	**Thu 27 Jan** Research/ repair	**Fri 28 Jan** Research/ repair	Sat 29 Jan	Sun 30 Jan
Mon 31 Jan Repair	**Tue 1 Feb** Repair	**Wed 2 Feb** Repair	**Thu 3 Feb** Final submissions	Fri 4 Feb	Sat 5 Feb	Sun 6 Feb

Table 1. Timeline of design charrette.

Toward the end of the second week, the students submitted their repaired products, along with a poster to accompany the fixed item, a repair process logbook, and a two-minute video explaining their takeaways from the charrette.

Outcomes

Forty-seven second through fourth-year industrial design students spent two weeks mending through design. Diagnosis and negotiating with material limitations provided the basic framework for determining the projects' outcomes. Ten out of fourteen student groups restored products to their original function using designed repairs, and the others repurposed them by imagining new uses (Figure 2).

This charrette revealed some critical lessons for student designers and instructors alike. For students, learning to diagnose their object involved assessing future value if repaired to its original function. In some cases, broken objects had to be deemed "unrepairable," thereby triggering experiments in reinvention. In the case of an "expired" bike helmet, for instance, restoration was not viable. In the case of a pair of traditional Indian shoes, the limited availability of repairable material required students to create a different product (a small handbag) through the process of repair. While riskier and less likely to yield desirable results, these projects reveal some interesting possibilities and perhaps even unintended consequences. Take the broken plates, for instance, and the introduction of resin to them. This experiment may not have yielded an appealing plate, but it raises the possibility of transforming broken pottery into translucent surfaces that could become privacy panels.

In some cases, students struggled to make the best out of the materials their original objects provided. Navigating scale and merging new materials with "old" challenged students to compromise on their desired vision, thereby also raising questions about how specific materials affect the future potential of manufactured objects in the process.

Figure 2. Repaired products (left to right: a pair of tongs, a lamp, and an office chair).

Students largely ignored the aesthetic challenges presented by the traditional forms of lamps and chairs, using design elements and principles to identify where opportunities for aesthetic change could restore or even augment functions that required students to design their objects.

Figure 3. View of the exhibition

The exercise culminated in a weeklong exhibition that displayed each project (Figure 3). Daily opportunities for visitors to sit down and learn to fix their clothes and garments augmented the displays. After visiting the exhibition, visitors seemed inspired and more willing to try repair (Figure 4).

Figure 4. A selection of repairs conducted during the exhibition

What Students Said They Learned

After the design charrette, organizers used a survey to allow students to evaluate the quality of their collaboration with other industrial design students at different levels of their program and the challenge the chosen charrette topic presented. Students also shared the highs and lows of their two-week experience with designing and executing repairs. Two key points emerged in the information collected through the survey and through an analysis of the teams’ two-minute videos, along with instructors’ observations. First, students really valued learning by doing through the manipulation of an existing product. Secondly, students recognized that design could/should be accountable to consumers who want the right to repair their belongings.

Learning by Doing: Industrial design students who need to have a wide range of skills across the board have concluded that the design charrette about repair gave them a plethora of different making/prototyping opportunities and it allowed them to showcase their learning with a result that was closer to a finished product than a prototype often provides. At the end of two weeks, our students understood repair similarly to Bridget Harvey (2015), who mused of her own practice-based doctoral study:

> Although broken objects often come negatively to our attention, removing them from the position of dirty or garbage by repairing unsettles the one-way relationship of practitioner to thing or material and begins to teach the practitioner about its material self. (p. 4)

We asked students at the end of the charrette how they would think about the repairability of their own future creations. All forty-seven students replied that they will consider how the design of future products allows for ease of repair, and the majority also reflected on the need to repair their own belongings. With this project, students were given a task that required making and they all achieved successful results.

Design's Accountability: One of the questions we posed in the survey was "How did the original designer's intentions influence your understanding of repair strategies/modalities?" One student said, "I think repair always goes back to the beginning of a new design. Is what you are designing able to be easily repaired? Are the materials safe to be broken down and used for something new?" Another student reflected on the responsibility of designers and how a designer needs to think about the whole life cycle of a product. Another group that was given a leather purse pondered their choice to turn the bag into a container to keep memories instead of another fashion item that will become obsolete in a brief time. In another example, the decision to turn a bike helmet into a different kind of product came from the realization that all helmets expire about five years after their manufacture. Overall, students agreed that the intentions of the original designers were significant in making repair decisions and designers need to take responsibility in generating products that are easier to fix and that last longer.

What the Design Educators Learned

The annual multi-year design charrette reinvigorated our students and connected them with each other during the pandemic in a short, fast-paced project in 2021 (Gümüs-Ciftci et al., 2021). This year, we wanted to investigate the relationship between design and repair to find ways to inspire our students and the public to consider fixing products instead of discarding them. Following this design charrette, we realized the project revealed a pair of somewhat unanticipated questions: What is the line between repairing and upcycling when "remodeling" products? How can problem diagnosis be leveraged to support a designerly approach to repair? And what are effective ways to inspire collaboration and community building in our program?

Meaningful Repair and Upcycling: Because processes of repair also support repurposing goods and reusing materials in new ways, we encouraged students to understand this as another take on circular design. Upcycling is considered a way to keep materials in use instead of dumping them in landfill; sometimes products really do become less useful, if not extinct. This seems to be the case for sporting equipment that often fails to meet current standards of safety or performance. On a more aesthetic level, fashion, too, can slip out of the range of what is "acceptable" by current standards. Chapman (2021) says, "meaningful possessions create constancy in a world of relentless change" (p. 23). In the case of our students, one team's motivation was challenging the idea of fast fashion, which they achieved by keeping the essence of a container and giving it an emotional value. Another created kitchen utensils out of ping pong paddles and a baseball bat. The extent to which the former product was reflected in the new product (and the extent to which that mattered) became an interesting issue of debate.

The Importance of Diagnosis and Ideation: Considering the above examples of upcycling, we realized the importance of initial diagnosis when repairing. The bike helmet presented many different problems for its team, starting with the expiry date. Then its production methods did not allow a clean disassembly. The team took a different approach in the end by using only the semi-translucent material of the outer shell to form a lamp shade, although it required a careful investigation of the materials and production and also of the original form and its affordances. Contrastingly, another group took liberties by creating a different version of the folding camp chair by transforming it into a camper's table. One of the students explained their motive:

> The original designer of the camping chair intended for it to be something for people to sit in, for it to be durable in outdoor conditions, and for it to transport easily. Our transformation of the chair into a table retained several of these intentions. People may not be able to sit on it anymore, but instead are able to place objects on it as a work surface. It still remains durable in outdoor conditions and still collapses for easy transport. Our table is still very much a piece of portable outdoor furniture, now with a slightly altered purpose.

This group changed the purpose of the initial product, without a doubt, but their diagnosis and ideation helped them deliver a meaningful transformation.

The Need to Build Community: The annual design charrettes encourage students to have more interactions between different cohorts of industrial design students. With the understanding of how repair activities can also build community and provide positive effects on society, we concluded that this charrette and its topic were timely and that our students benefited from working together after almost two years of pandemic-related isolation. We agree with the philosophy stated by Repair Society (2013), cited in Oropallo's (2019) article on fixing:

> Repair is not just about fixing things. The act of repair has cultural, social, economic effects (sic) and benefits. Repairing is about the constant struggle to make things work, from language, to things, to relations between people, to systems in society. In fact, repairing is a way to go forward; it bridges old and new, past and future, and could therefore be seen as a sensitive way of thinking about future forms of society. (p. 163)

Therefore, we would like to integrate repair and the establishment of a repair mindset into our design studio classes and create more opportunities such as the design charrette for our future students. We believe that coming together to repair will create a sense of belonging, an adaptation to the contemporary needs of society, and an alternative pathway to the ever-evolving design profession.

Conclusion

Design-led repair and repair in general can be considered a valuable strategy for a sustainable, circular future and designers have a key role to play! This charrette provided an opportunity to experiment with both the limits and capabilities of design to make unwanted, broken, or dysfunctional items useful, and it demonstrated repair's potential to expand design knowledge of materials, techniques, tools, and users' needs and experiences at a one-to-one scale. It also highlighted the benefits of placing potential repair at the center of the process of designing manufactured objects moving forward. Future repair workshops are planned to increase design students' capacity and confidence to repair and keep undervalued goods out of our landfills.

The design charrette was also an efficient vehicle to introduce repair concepts to students who used their maker skills to fix or reinvent. Most importantly, when presented with the challenges that broken manufactured products provide, students considered the importance of designing for repair in the future.

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IMPROVING COMMUNITY-BASED ADAPTATION TO CLIMATE CHANGE THROUGH PARTICIPATORY GAMIFICATION DESIGN

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Abstract
This paper discusses community-based adaptation to climate change and its relationship to the practice of participatory gamification design. Since Chinese cities have been suffering from the negative effects of climate change in urban infrastructure, economy, and social environment in recent years, there are increasing issues due to the lack of preparation and response. Effectively preparing for and responding to climate risks requires residents' active participation and design action. This paper provides a participatory gamification design approach to improving community-based adaptation to climate change, including a participatory process to activate community residents' innovations and an open-ended gamification design to match the ongoing climate change. Zhengzhou city is taken as the case study to test our theoretical design in this paper since it experienced a flooding disaster with more than 300 deaths in 2021 and the city is undergoing urban reconstruction and governance for climate change. Participatory design workshops were organized to expose the opinions of Zhengzhou residents about climate risks and response in a digital and online medium. At the same time, gamification elements were used to increase residents' motivation, participation, and learning efficiency. All suggestions were found to indicate that well-prepared, self-rescuing behavior is key to improving survival against extreme weather, and a digitally participatory game prototype helps increase residents' participation. In addition, governments and other stakeholders should identify and develop potential community-based adaptation measures from top-down interventions to reduce urban vulnerability to projected climate change.

Author Keywords
Community-based adaptation; climate change; gamification design; participatory design; China.

Introduction
With China's rapid urbanization, urban development has gradually shown the regional agglomeration. The agglomeration of population and industry increases the regional energy consumption, leading to climate problems such as "hot island," "rain island," and "dry

island." Meanwhile, a lack of training for disaster management, emergency communication, and residents' preparedness responses could cause huge economic and social loss. Thus, how we can effectively build capacity to adapt to climate change at the community level is key to alleviating urban climate vulnerability.

Existing research on community-based adaptation mainly introduces multi-stakeholder participation to realize bottom-up evaluation (Ford et al., 2018), decision-making (Jamero et al., 2018), and response. However, in the actual implementation, these studies mainly adopt traditional participatory methods such as questionnaires, interviews, and offline workshops. The form and content are dogmatic and unattractive, and the effective and universal guiding principle has also not been established (Kirkby et al., 2017). Specifically, the following problems exist: first, the participatory process is relatively tedious, primarily based on user research and knowledge dissemination, and it is difficult to fully activate the motivation for participation and thus cannot promote spontaneous change of risk awareness and behavior. Second, the association between different activities is weak, and there is no unified model that supports content iteration and update. Third, most of the implementation methods are offline; even if some of them are online, they are still in the form of interviews or lectures. Less consideration is given to the forms and paths for online participation.

To improve the climate risk awareness of community residents, this paper presents an open-ended gamification design method based on participatory design. It includes three parts: event collection and regularization based on multi-stakeholder experience, gameplay determination combined with instructional objectives, and open-ended design to support event updates. Then, based on the proposed method, the *7.20* extreme downpour (an extreme rainstorm disaster that occurred in Zhengzhou, Henan Province, causing severe casualties and property damage) was selected as the case study. We invited those who experienced the 7.20 extreme downpour to the survey of participatory design. Based on participants' risk awareness and climate knowledge, the game prototype was designed and applied in the online workshop for testing and iterating.

This paper contributes to the following three aspects. First, with multi-stakeholder participants in designing and iterating the prototype, we developed a potential method for the government and other stakeholders to apply interventions to reduce urban vulnerability to projected climate change. Second, gamification elements were adopted to increase residents' motivation, participation, and learning efficiency in response to extreme weather and emergencies. Third, the open-ended design can simplify the game content update process, enabling rapid iteration for multiple changing situations.

The remaining sections of this paper are as follows: *Related work and theoretical framework* describes the basic concepts and research status of adaptation to climate change, participatory design, and gamification design. The theoretical framework is constructed; *Method* provides a detailed description of the participatory game design method; *Case study* is a case study that describes the game prototype design, test, and iteration process; and *Conclusion* presents the conclusions and recommends a direction for further research.

Related Work and Theoretical Framework

Adaptation to Climate Change

Adaptation refers to the adjustment of ecological, social, or economic systems in response to actual or expected climate change and impacts (McCarthy et al., 2001). Smit and Wandel (2006) consider the adaptation in the context of climatology a quantitative study mainly aimed at factor extraction, adaptation measurement, and vulnerability indicators; the adaptation in the context of sociology is a risk response that occurs between environmental risks and human vulnerability or adaptability.

The shaping of adaptation is mainly considered from the three aspects, namely evaluation, design, and response (Eriksen et al., 2021). Pei et al. (2022) built an adaptation evaluation system for urban climate change from the natural, economic, and social dimensions. Then, combined with the entropy weight method, the spatial autocorrelation analysis, and the obstacle degree, they evaluated the adaptation to climate change of 258 cities in China. To achieve urban assessment based on citizen data, the HUB (Human Ecosystems Bologna) project was launched (HUB Report, 2015). It collects data from social networks and public expressions regarding the collaboration practices of the city, and utilizes visualization technology to present the assessment in real time. Seddon et al. (2020) emphasized the importance of the involvement of naturalists and sociologists in climate policy-making to ensure sustainable development while mitigating climate and biodiversity crises. Adger et al. (2013) focused on the moderate engagement of the individual and community in climate policy-making. For the implementation and technologies, Pour et al. (2020) explored a sustainable urban storm management system with low-impact development technology.

Multi-stakeholder participation is necessary for evaluation, design, and response. The adaptation evaluation involves the measurement and calculation of objective indicators (such as the climate monitoring index, the infrastructure construction status, etc.), and the subjective measurement of the residents' risk awareness and adaptability. Policymaking should not only consider the macro-control of government management departments and experts but also pay attention to the active participation of residents, businesses, and other stakeholders. Similarly, during response and implementation, the instruction for risk awareness and adaptability is significant in addition to technology development and facility construction.

Aiming to improve residents' risk awareness and adaptability, this paper looks forward to exploring a participatory instructional model for community residents from the perspective of climate change response and implementation.

Participatory Design

The emergence of participatory design was influenced by the Scandinavian democracy movement in the 1970s (Spinuzzi, 2005). Sanoff (2007) believed that participatory design is an attitude or perspective aimed at facilitating human-centered innovation and managing change. Sanoff pointed out that participatory design stems from the democratic ideal based on decentralization. To meet users' differentiated needs and preferences, participatory design introduces multi-stakeholder collaboration to complete design activities. It has been applied to a variety of problem scenarios, such as policymaking (Blomkamp, 2022), landscape architecture design (Kempenaar, 2021), community building (Carroll &

Rosson, 2007), open-source software design (Hellman et al., 2021), instructional design (Han et al., 2016), etc.

In participatory design, actors from different backgrounds complete design decisions and implementation with the assistance of the collaborative model. Due to the diversity of participatory design approaches, there is no absolutely unified method and procedure. Kujala (2003) considered the classic ways of participatory design to be the workshop and prototyping. Ostroverkh and Tikhomirova (2021) proposed a participatory design approach for learning environments, involving five steps: self-positioning, status analysis, goal description, problem definition, and problem-solving. The method is performed through meetings and group discussions. Shen et al. (2018) studied the workshop model based on the idea of participatory design and emphasized participatory design's role in activating residents' creativity and enhancing community cohesion.

Therefore, participatory design theoretically helps to integrate the knowledge of multi-stakeholders in the community, increasing the diversity of instructional content and promoting residents' motivation to participate. However, further exploration is needed to design a participatory approach process appropriate to motivate participants in conjunction with this research question. How to design a proper participatory method and procedure needs to be further explored.

Gamification Design

Gamification design is a design method that intervenes in user behavior by designing an information system similar to game experience and motivation (Koivisto & Hamari, 2019). Overall, gamification design includes three main components: affordances, psychological outcomes, and behavior outcomes (Hamari et al., 2014). The affordances refer to the elements and mechanisms utilized to build the game and create the gamified experience. The psychological outcomes refer to the change in the user's psychological experience through gamification, such as a sense of pleasure or participation. The behavior outcomes refer to behaviors and activities induced by the use of the gamification system such as physical activity in the context of exercise gamification, efficiency improvement in the context of instructional gamification, etc.

Currently, some studies have integrated gamification design into relationship improvement and risk awareness cultivation of community residents. To enhance youth's sense of community belonging, Lochrie et al. (2011) developed three location-based games using a participatory design idea. By building the connection between online tasks and offline community locations, community youth were inspired to explore the surrounding areas. Jones (2021) developed a social game based on cultural points of interest (POIs). The gamification was applied to encourage spontaneous content creation and commentary by citizens, leading to thinking and communication about cultural locations.

Meanwhile, recommendations for similar POIs can be provided based on users' comments. To improve residents' awareness of flood hazards, Mannsverk et al. (2013) designed a location-based game. Each player needs to cooperate in the game and reach the target location according to the map prompt in the app. Then they need to collaboratively complete the four tasks in the app – including virtual facility construction for flood protection, detection, evacuation, and rescue – to improve participants' sensitivity and decision-making abilities.

The above research utilizes gamification design to encourage residents' participation and facilitate behavior changes. However, these studies seldom consider multi-stakeholder participation during the game design. Besides, these games lack support for iteration and expansion which is not conducive to dealing with dynamically changing climate issues in the community. Thus, it is meaningful to explore a gamification design method that incorporates multi-stakeholder participation and supports expansion.

Theoretical Framework
Through the analysis and summary of the above concepts and theories, the theoretical framework of this paper is constructed, as shown in Figure 1. It specifically includes three concepts of adaptation, participatory design, and gamification design and their interrelationships. The interrelationships are in a state of upward spiral.

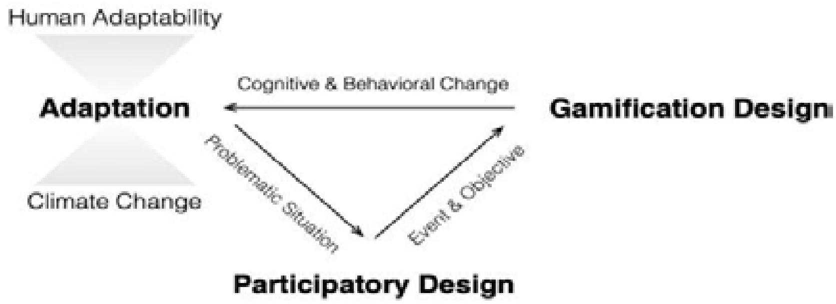

Figure 1. "Adaptation-Participation-Gamification" theoretical framework.

As mentioned above, adaptation is a balance between climate change and human adaptability. When the rate of climate change exceeds the level of human adaptability, the balance will be destroyed, which causes climate risks and response crises. In our theoretical framework, these risks and crises are used as a specific situation of participatory design and guide the participant selection and the determination of specific topics. Participatory design is introduced to deconstruct the specific situation, collect event contents (sliced experiences of participants), and refine instructional objectives (cognitive and behavioral intervention dimensions). These events and objectives are transformed into elements and mechanisms in game design. Then, a game prototype is output. This prototype can facilitate the player's cognitive and behavioral changes, thereby improving human adaptability and achieving a new balance between climate change and human adaptability.

Since climate change occurs continuously, the above balance is a relative balance; that is, the balanced state in which the asynchrony between climate change and human adaptability is within an acceptable range.

Method
Based on the theoretical framework of the subsection *Theoretical Framework*, a

gamification design method integrating participatory design is proposed (see Figure 2). The proposed method includes three parts: adaptation evaluation, participatory design, and gamification design. The adaptation evaluation refers to measuring and judging the balance degree between climate change and human adaptability by qualitative or quantitative methods. Based on the evaluation results, the climate adaptation level of the study subjects can be determined and the problematic situation to be addressed can be identified. In the participatory design phase, multi-stakeholders collaborate to collect and refine the event contents and instructional objectives. First, the designer, as the facilitator, should conduct desk research and the expert interview to build a preliminary understanding of the problematic situation and identify the main stakeholders involved. Through the semi-structured interviews with selected stakeholders, specific issues are identified and tasks for participatory design are determined. Then, a multi-stakeholder collaborative workshop is conducted to collect the specific events and instructional objectives involved in the problematic situation. Accordingly, game elements and mechanisms are designed. Through visualization and materialization, the game prototype is developed and gradually improved through testing and iteration. Finally, a gamification instructional tool is completed to improve the residents' adaptability.

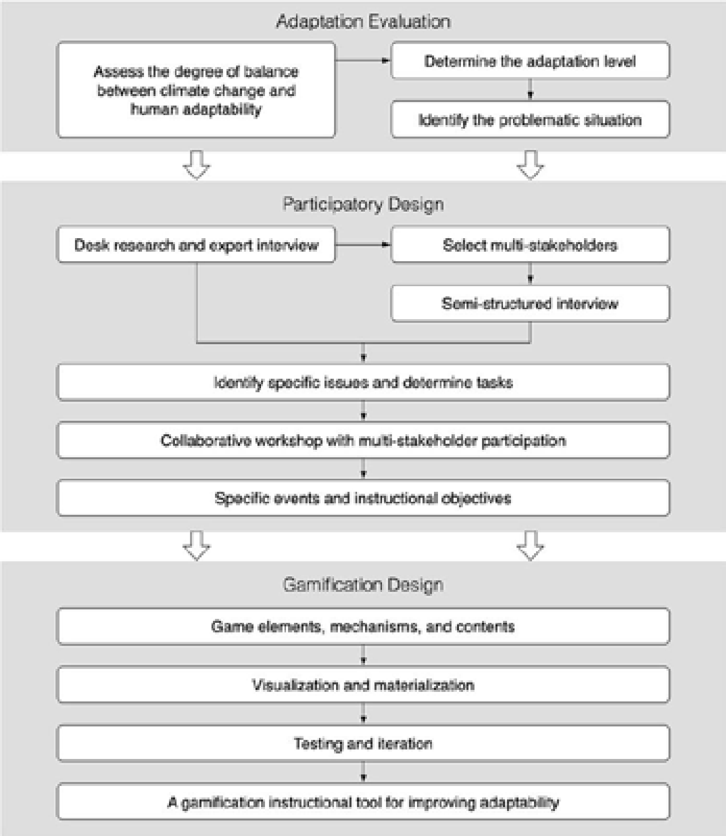

Figure 2. Method flow chart.

For the adaptation evaluation and the participatory design, this paper is mainly based on existing theoretical and practical research, and appropriate adjustments are made in combination with specific situations. For the gamification design, an open-ended game design framework is constructed, including three parts: the regularization of event contents, the associative construction between the event contents and the instructional objectives, and the associative construction between the instructional objectives and the gameplay, as shown in Figure 3.

In the initial design stage, the collected event contents first need to be regularized, such as normalization of the expression and structure. Then the event contents can be converted into normalized contents and a transformation rule library can be built. Next, the regularized event contents are clustered and refined to clarify the instructional objectives and an association library between contents and objectives is built. Finally, based on the normalized contents and instructional objectives, the gameplay (including elements, mechanisms, and contents) is designed and an association library between objectives and gameplay is constructed. After the initial design, the gameplay is output and three standardized relationship libraries, which can be used for subsequent iterations and updates, are built.

In the iteration and update stage, newly added event content can be regularized based on the transformation rule library. Then it needs to search for the instructional objective corresponding to the current content from the association library between contents and objectives: if there is a matching objective, it will be directly paired with the event content. Otherwise, the instructional objective of this event content needs to be refined and added to the association library. Similarly, based on the association library between objectives and gameplay, it searches for the game element and mechanism that matches the objective of the newly added content. If no element and mechanism is suitable for the objective, it is necessary to create the game element and update the association library.

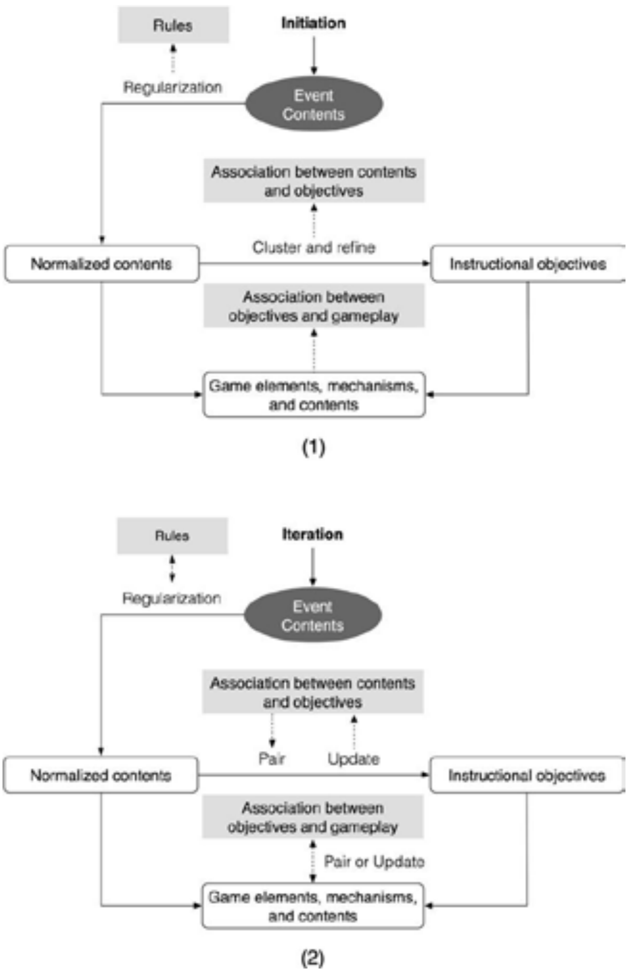

Figure 3. Initiation and iteration of the gameplay.

The proposed framework has the following three advantages: (1) universality. The framework can be applied in various climate change scenarios, and is suitable for gameplay generation in different problematic situations; (2) standardization. Standardizing the gamification design procedure ensures efficiency in conceiving game elements, mechanics, and contents; (3) open-ended design. By constructing the rule and association libraries, the framework is more inclusive of subsequent additions and helps update the gameplay instantly as the problem situation changes.

Case Study

This paper takes the 7.20 extreme downpour in Zhengzhou as a case study and focuses on the risk awareness and adaptability of community residents. Due to the actual epidemic situation in China, the procedure proposed in the section *Method* was adjusted. First, we obtained the information and data related to the 7.20 extreme downpour from the official reports. The adaptation level was interpreted (as detailed in subsection *Background*). Second, from a participatory design perspective, three semi-structured interviews (as described in subsection *Semi-Structured Interview*) and a collaborative workshop (as detailed in subsection *Online Workshop*) were designed and executed. Due to the epidemic, the workshop could only be held online. Considering the high learning cost of online collaboration tools for participants, the tasks of the online workshop were simplified. We (the designers) preliminarily extracted the specific events and instructional objectives based on the semi-structured interviews. Then, we completed the initial design of the game prototype (as detailed in subsection *Initial Design of Game Prototype*). The participatory tasks of the online workshop were adjusted to optimize the specific events and instructional objectives through communications among participants and to collect opinions and feedback about game design through experience and testing. Finally, we improved the game prototype based on participants' suggestions (as detailed in subsection *Iteration of Game Prototype*).

Background: A Brief Adaptation Analysis for Zhengzhou
Zhengzhou, referred to as "Zheng," is the capital of Henan Province. Zhengzhou is located in the north-central part of Henan Province, China. It is at the boundary between the middle and lower reaches of the Yellow River, between 112°42′-114°14′ east longitude and 34°16′-34°58′ north latitude, with a total area of 7,567 square kilometers.

In 2021, from 18:00 on July 18 to 0:00 on July 21 (Beijing time), Zhengzhou encountered a rare continuous heavy rainstorm. The city received heavy rain and extreme downpour, with a cumulative average precipitation of 449 mm. The disaster caused serious casualties and property damage. According to official statistics, from July 17 to 23, the disaster affected 14.786 million people in 150 counties (cities and districts) in Henan Province. In Zhengzhou, 380 people died or disappeared, and the direct economic loss reached 40.9 billion yuan (Xinhua News Agency, 2022). The rainstorm caused serious damage to residential, medical, educational, transportation, and other facilities.

Although the disaster was caused by extreme weather, it exposed problems in facility construction, decision-making management, awareness of prevention, etc. Especially from the perspective of risk awareness and adaptability, most residents paid no attention to the warning information about flooding and continued their daily activities. Figure 4 depicts residents riding through water.

Due to COVID-19, we did not specifically collect data to quantitatively evaluate adaptation. A large number of social reports (such as shown above) have reflected that Zhengzhou had obvious problems with adaptation to climate change in the 7.20 extreme downpour.

Therefore, for the research on adaptation to climate change, it is representative to select Zhengzhou as an object for case studies: (1) Zhengzhou is a national model city for sponge city construction, which is a policy supported from the national level; (2) Zhengzhou has faced severe challenges in climate change in the past decade, such as abnormal urban climate, frequent droughts, and floods, etc. It is representative in terms of objective nature; (3) Zhengzhou just experienced the 7.20 extreme downpour last year, and residents were very impressed. It is relatively urgent to find novel ideas and approaches to shape adaptation to climate change. This paper focuses on the risk awareness and the response of community residents in Zhengzhou and performs specific design activities.

Figure 4. Residents riding through water on the road. (Image source: https://www.sohu.com/a/485009431_267106)

Participants

In the past two years, we have conducted some studies on community building, such as a study applying sentiment analysis based on the public data from Meituan and Weibo to evaluate the restaurant facilities in the neighborhood (Liu et al., 2021). We organized or participated in some related activities, such as a Tongji-MIT workshop in October 2020 that invited more than seventy experts and scholars to discuss community response in the post-pandemic era. Therefore, we have a relatively mature understanding of the roles of stakeholders in the community. Meanwhile, stakeholder theory was utilized to reasonably identify the major stakeholders involved at the community level in the 7.20 extreme downpour. Since Freeman (1984) published the landmark book *Strategic Management: A Stakeholder Approach,* the concept of stakeholders has been applied to many areas such as sustainability management (Horisch et al., 2014), urban management (Beck & Storopoli, 2021), residents' perception investigation (Song et al., 2021), etc.

To identify different classes of stakeholders in the community, a theory proposed by Mitchell et al. (1997) was adopted. Mitchell et al. (1997) believed that power, legitimacy, and urgency are three key attributes that act as identifiers of stakeholder classes. Based on the number of attributes possessed, stakeholder types are divided into three categories: latent stakeholders (with one of the three attributes), expectant stakeholders (with two of the three attributes), and definitive stakeholders (with all three attributes). According to this theory, we identified and divided community stakeholders into three categories: (1) definitive stakeholders, including the municipality, community residents, community residents' committee, etc.; (2) expectant stakeholders, including enterprises and institutions in the community, social organizations in the community, etc.; and (3) latent stakeholders, including others who have a relationship with the community. Therefore, we gave priority to definitive and expectant stakeholders in the selection of participants.

We then determined four expected roles. Specifically, they included community residents (office workers and students who are definitive stakeholders), tradesmen (who are expectant stakeholders), and community workers (who are definitive stakeholders). These roles were selected for the following reasons: (1) all belong to definitive or expectant stakeholder groups; and (2) according to the desk research, their experiences are different. Since July 20 was a Tuesday, office workers had to go to work on time outside the community. However, for students, it was during the summer vacation of Chinese schools, and they usually stayed at home. Community workers and tradesmen usually work in the community. Community workers play a key role in information announcement and organization. For tradesmen, their stores' revenue is easily affected by climate change, and their materials and material channels play an important role during the disaster.

To recruit participants, we wrote a recruitment document, shown in Figure 5. We first contacted our classmates from Zhengzhou, and asked them to help us distribute the recruitment document via WeChat. Through this process, we recruited three participants who had personally experienced the 7.20 extreme downpour, an office worker, student, and tradesman, respectively. Then, because my hometown Jiyuan and Zhengzhou are located in Henan Province, my family asked their friends in Zhengzhou for help through WeChat and they contacted a community worker who was willing to participate in this workshop. Finally, four participants were recruited. Their basic information is shown in Table 1.

Recruitment of participants

Hello! We are a research team from College of Design and Innovation, Tongji University. The damage caused to us by the "7.20" extreme downpour is still difficult for us to forget. Under the rapid change of global climate, cities are facing unprecedented challenges. Recently, we want to develop a gamification design to shape community-based adaptation to climate change. We hope that this game will improve community stakeholders' awareness and behavior in response to the extreme weather.

We sincerely invite you to join the workshop. Let's talk about experiences and feelings about the "7.20" extreme downpour and play the developed game prototype together. We look forward to receiving your opinions and feedback. We hope to work with you to better improve the design method and game mechanics, and contribute to the education of residents' cognition and behavior in response to the extreme weather.

Recruits

Community residents, community workers and tradesmen

Personally experienced the "7.20" extreme downpour in Zhengzhou

Computer operation skills

Remuneration

Each participant with a gift worth 120 ¥

Participation Tool

Tencent meeting

Contact

[illegible] (WeChat)

[illegible] (WeChat)

[illegible] (Phone)

Figure 5. Recruitment document.

Participant	Name	Age	Occupation	Role in Participatory Design
1	Ms. Xiao	26	Product manager	Office worker
2	Mr. Li	23	Doctoral candidate	Student
3	Mr. Shen	22	Master candidate (his family runs a community store and he often helps with some work in the store)	Tradesman
4	Mr. Li	42	Community worker	Community worker

Table 1. Basic information of participants.

Semi-Structured Interview: A Participatory Process to Collect the Event Contents and Feelings

The purpose of semi-structured interviews includes three aspects: (1) understanding the real situation and residents' feelings from the perspective of different roles; (2) identifying specific issues about participants' adaptability to climate change; and (3) preparing for the online workshop. On the one hand, it deepens the familiarity between us and the participants through interviews. On the other hand, based on the contents of the interviews, specific events and instructional objectives will be preliminarily extracted, and an initial game prototype will be designed. These will serve as material for the online workshop.

Based on the purpose described above, we designed the interview topics from different stages of the disaster, namely the preparation before the rainstorm, the response during the rainstorm, and the recovery after the rainstorm. Then, an open interview outline was made:

- Before the rainstorm: What were they doing? Did they receive an alert? How did they view the alert? Were some actions taken?
- During the rainstorm: What happened to them? What were the impressive events? (Note: The events refer to not only some dangerous or sad experiences but also touching or warm experiences.)
- After the rainstorm: What happened in the community? What measures were implemented by the community? What has changed in the community?

The outline provides only some references for interviews. In the actual interview process, new topics or questions were added according to participants' stories and answers.

Due to the inconvenience of travel during the COVID-19 pandemic, we conducted online semi-structured interviews with three participants (Participants 1, 2, and 4; Participant 3 was not involved due to time conflicts). In each semi-structured interview, we first introduced ourselves, including the background, the basic information about the project, and the purpose. Then, referring to the interview outline, we communicated with each participant at different times. A high degree of openness was maintained throughout the process. According to the specific contents from the participant, interview topics were adjusted and deepened to dig out his or her rich experiences and feelings. After asking participants for permission, the interview contents were recorded by an iFLYTEK H1 Pro recorder. Then, an IFLYREC app was adopted to convert audio into text and we filtered out the contents that were less closely related to the community context. Table 2 shows some of the interview contents. It is obvious that the interviewees' awareness of climate risks is relatively weak.

Interviewee	Participant 1 (Ms. Xiao)	Participant 2 (Mr. Li)	Participant 4 (Mr. Li)
Date and Time	2022.6.5 22:02-23:36	2022.6.5 19:58-20:21	2022.6.8 20:03-20:32
Interview Format	Typing in WeChat	Voice-calling in WeChat	Voice-calling in WeChat
Preparation Stage	**(Specific events)** Participant 1: (1) It was raining heavily on the night of July 19th. I rode my e-bike home, and the flood exceeded my knees; (2) On the morning of July 20th, the rain became smaller, and I rode to the company. As a result, it began to rain again soon after arriving at the company, and then it continued; (3) I received a rainstorm warning. But there had been no flooding in Zhengzhou before, and I did not pay attention to this warning message. Participant 2: (1) My family went to work at the company and couldn't go home because of the flood. Because it was the summer vacation of students, and I was at home alone; (2) The Meteorological Bureau released the warning information. But the precipitation and the duration are more than everyone expects; (3) I did some daily measures, such as closing doors and windows; (4) I did not intentionally prepare supplies. Participant 4: (1) After receiving the notice released by the superior department, we informed the community to prepare for flood prevention, such as flood control sandbags; (2) Because Zhengzhou is an inland city, we did not realize that it would be so serious, and we first responded to it according to the common rainstorm; (3) Because Zhengzhou is an inland city, the community has less to organize daily training about climate risks. **(Suggestions)** Participant 1: For the extreme weather, I think some education on risk prevention is useful. Participant 2: I think that [the] community should emphasize the seriousness of the incident to raise the residents' vigilance.		
Response Stage	**(Specific events)** Participant 1: (1) Because of the heavy rainstorm, I stayed in the company all night on July 20th, and I went back the next day when the rain was not too heavy; (2) The community had no water supply, and the supply was restored after about 3 days. But the electricity was still in supply; (3) The Internet was disconnected during this period, and the cash was reused to buy food. Participant 2: (1) I was not facing the problem of material shortage, because I have the habit of stocking up some food (such as instant noodles, etc.); (2) For me, the biggest difficulty is the water, power, and internet interruption. The mobile phone had no signal. I was completely disconnected from the outside world; (3) Because the mobile phone could not be charged, the power saving mode was turned on to maintain the minimum power for emergency calls. I have relatives and friends living in different areas, and some of their homes had restored power supply. So, I quickly took my mobile phone, portable charger, etc. to charge. (4) The community had been flooded, and many vehicles have been damaged; even some roofs leaked due to the heavy rainstorm. Participant 4: (1) As a community worker, during the disaster period, my main job is to appease the residents; (2) The online payment was paralyzed due to the power and network interruption, and many residents could not buy anything at that time; (3) The smart water systems in the community also did not work due to the power and network interruption. **(Suggestions)** Participant 4: The intelligent disaster prevention system should consider the normal operation under the condition of the power and network interruption. Otherwise, these tools will not work when faced with truly extreme climate disasters. **(Impressive things)** Participant 2: I felt a little anxious and panicked in my mind, because I was almost completely disconnected from the outside world at that time.		

Recovery Stage	**(Specific events)** Participant 1: After the 7.20 extreme downpour, flood control measures has been implemented in many areas. For example, many flood control sandbags were prepared at the entrance and the exit of underground garages in many communities. Participant 2: The community has taken preventive measures, such as regular inspection and maintenance of drainage pipes to prevent blockages. Participant 4: (1) After the disaster, Zhengzhou has attached great importance to preventing rainstorms. In summer, the government requires the community to make a safety flood prevention plan; (2) For an inland city, even if the superior department requires the community to carry out residents' risk awareness training, the actual work is still difficult to implement. Because most residents hold an attitude of indifference. If we tell them some common sense of climate risks, the elderly could occasionally come to listen, and the young will hardly participate. **(Impressive things)** Participant 2: After the signal was restored later, multiple WeChat groups and online shared documents began to appear to help each other. The mutual help among neighbors and netizens, as well as the support from all over the country, moved me very much.

Table 2. Interview contents.

Initial Design of Game Prototype: A Game Design Process

According to the authors' experience, the online workshop requires participants to have the ability to use online collaboration tools such as Teamind. The participants in this study included middle-aged adults and students from non-design backgrounds. It takes effort and time for them to learn these tools, especially for complex design tasks like gameplay. Therefore, after discussion, the authors decided to make appropriate adjustments to the method proposed in the *Method* section. An initial game prototyping stage was added before the collaborative workshop. This stage was mainly completed by designers based on the results of desk research and semi-structured interviews. Then in the workshop, participants needed to experience the game prototype, give feedback, and collaborate with us to complete the prototype's improvement and iteration. In this way, the operation difficulty of online workshops was reduced and the feasibility was improved.

First, combined with the results of desktop research and semi-structured interviews, some specific events were organized and summarized. Then, the specific events were clustered and the instructional objectives were identified. This process is shown in Figure 6.

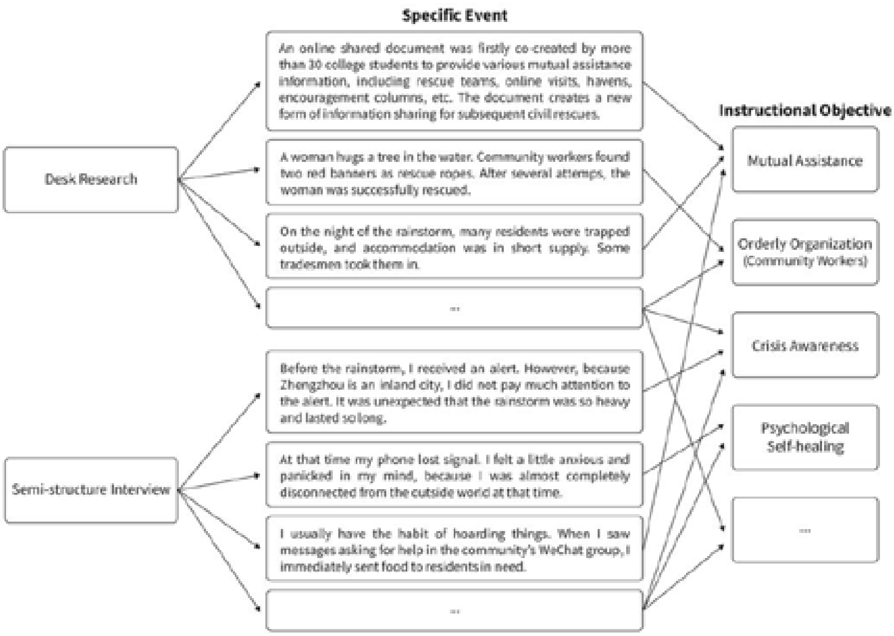

Figure 6. Clustering of specific events and identification of instructional objectives.

The crisis awareness and psychological self-healing ability are important for the four roles. Conscious cooperation and mutual assistance were necessary for office workers, students, and tradesmen. The community workers needed to pay attention to the information release and orderly organization.

According to specific events and instructional objectives, the gameplay (including game elements, mechanisms, and contents) was determined, and the initial game prototype was developed. The details are described as follows:

- **Cards:** Cards include event cards (positive event cards and negative event cards), role cards, and objective achievement cards. Each event card includes the description of the event content and the reward and punishment content. As shown in Figure 7, for the design of an event card, the first step is to perform a regularization. The regularization focuses on the adjustment of statement style (such as grammatical person, language style, etc.) and modification of positive and negative perspectives (for example, an event may describe an incorrect response behavior. If it is expected to be a positive event card, the event description needs to be rephrased). The regularized event content (called normalized content in Figure 3) will be put into the specific event card. For the positive event card, it is necessary to add the instructional objective (as an objective achievement) and illustration corresponding to the event content. For the negative event card, it needs to design a punishment mechanism according to the instructional objective, such as stopping the dice roll once. Then, the role cards represent the occupation of each player in the game. According to the role analysis in subsection *Participant*, four types of role cards were set, namely office workers, students, tradesmen, and community workers. Each objective achievement card corresponds to the instructional objective. Figure 8 shows the presentation of each card in the game prototype. The 28 grids around the chessboard are used to place 28 event cards. In the center, there are four role cards (the blue is the office worker, yellow the student, green the tradesman, and red the community worker) and six types of objective achievement cards.

- **Gameplay:** The game required four players to play the roles of the office worker, the student, the tradesman, and the community worker. After the role assignment was completed, the order in which the player sets off was determined by rolling the dice. The starting point was the square in the upper left corner, and the chess moved in a clockwise direction along the 28 squares. When a player stayed in a certain grid, he/she combined the characteristics of the role he/she was playing, and placed himself/herself into the event described in the card. Then, the player needed to tell the event as truthfully and interestingly as possible. After completing the event description, the player performed the corresponding operations according to the reward and punishment content in the card (such as obtaining an objective achievement card or a material card, staying in place, etc.). Once the achievement card was obtained by the player, he/she could take away the corresponding card, and subsequent players who stayed there would not be able to obtain the card. The cards were reset on the chessboard until any player returned to the starting point.
- **Win conditions:** Each type of role needed to collect the corresponding objective achievement cards. For example, the community worker needed to collect an information release card, an orderly organization card, a crisis awareness card, and a psychological self-healing ability card. The first player to collect all the required achievement cards wins the game.

When there is a content update, the newly added events can be seamlessly integrated into the current version of the game only by judging their corresponding instructional objectives, so it has high scalability.

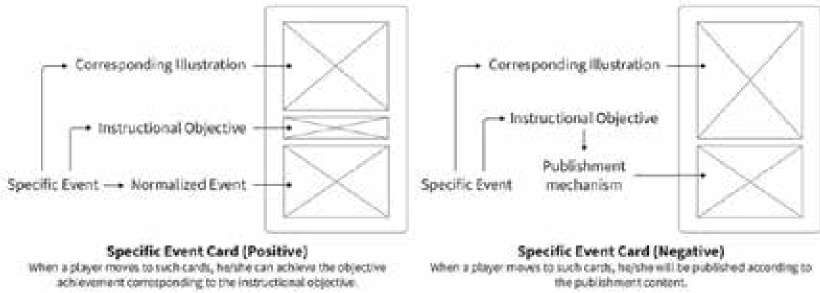

Figure 7. Game card design based on specific events and instructional objectives.

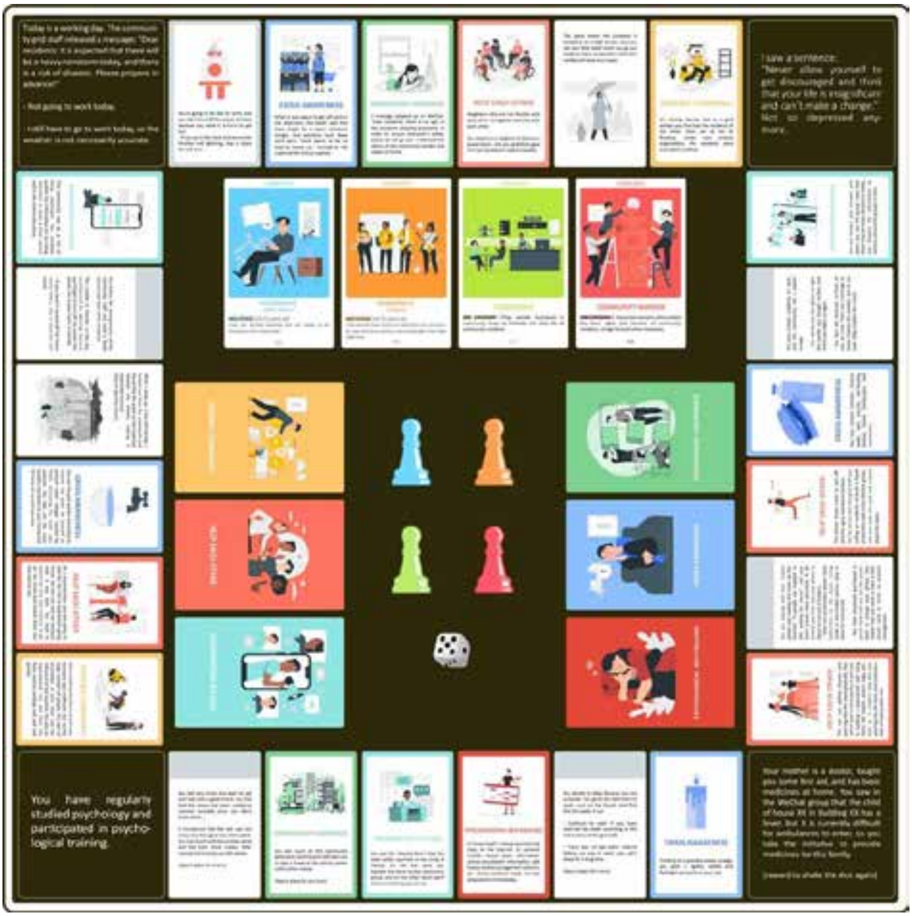

Figure 8. Game prototype (first edition).

Online Workshop: A Participatory Process to Communication, Experience, and Feedback
The purpose of the online workshop includes the following aspects: (1) confirm and supplement specific events and instructional objectives by conversations among participants about their experiences and feelings during the 7.20 extreme downpour; (2) invite participants to experience the first edition game prototype and collect feedback from them. To achieve the above purpose, the online workshop was designed in three stages, namely the round-table meeting, the game experience, and the game testing.

An online workshop was held from 9 am to 11:45 am on June 11th, 2022. Considering the ease of operation, Tencent Meeting App was used as a participatory platform. The online workshop involved six people, including four participants and two facilitators (Mao-en He and Ya-xin Long). Some photos of the online workshop are shown in Figure 9.

The round-table meeting lasted about one hour (from 9 am to 9:58 am). It focused on the events and issues that occurred during the heavy rainstorm on July 20. This process can obtain rich real materials, help to confirm and update event cards of different specific scenes, and optimize and enrich the game contents. Meanwhile, the 7.20 extreme downpour was personally experienced by all the participants. This topic activated shared knowledge among participants, helped increase their empathy, and was considered an ice-breaker in the workshop.

The results of the round-table meeting were broadly similar to those presented in Table 2. The following two are worth noting: (1) since the interview with Participant 3 has not been conducted before, the round-table gave us an insight into the tradesman's experiences and thoughts. He mentioned that his family's store does not deliberately consider the climate risks. He knows that the goods cannot be sold after being soaked in water. But Zhengzhou is an inland city, and the probability of events like the 7.20 is low. The additional attention or preparation could add to their cost. (2) In terms of attitude towards climate change, affected by the geographical location and past climate characteristics of Zhengzhou, everyone was relatively optimistic about climate risks. The community worker and the student were slightly more cautious than the office worker and the tradesman. The multi-stakeholders in the community still maintained past understanding of urban climate characteristics, which does not match the trend of global climate change. More and more cities are currently facing unprecedented climate change and risks. It is significant to draw the attention of residents to climate change.

The game experience stage lasted about 45 minutes (from 10 am to 10:47 am). This stage included two steps, namely gameplay explanation and experience, and aimed to help participants become familiar with the game rules. We utilized Tencent Meeting app's screen sharing function to share the game interface on the computer with other participants. At the same time, a dice emoji in WeChat was used to realize the dice rolling. The facilitator (Ya-xin Long) moved the chess pieces according to the number of points that appear on the dice emoji in the WeChat group. Another facilitator (Mao-en He) recorded the material and achievement cards that each player obtained. In addition, since the workshop was in the debugging and co-creation of the initial prototype stage, each participant directly selected the role corresponding to their occupation to verify the consistency of the game contents with the real situation.

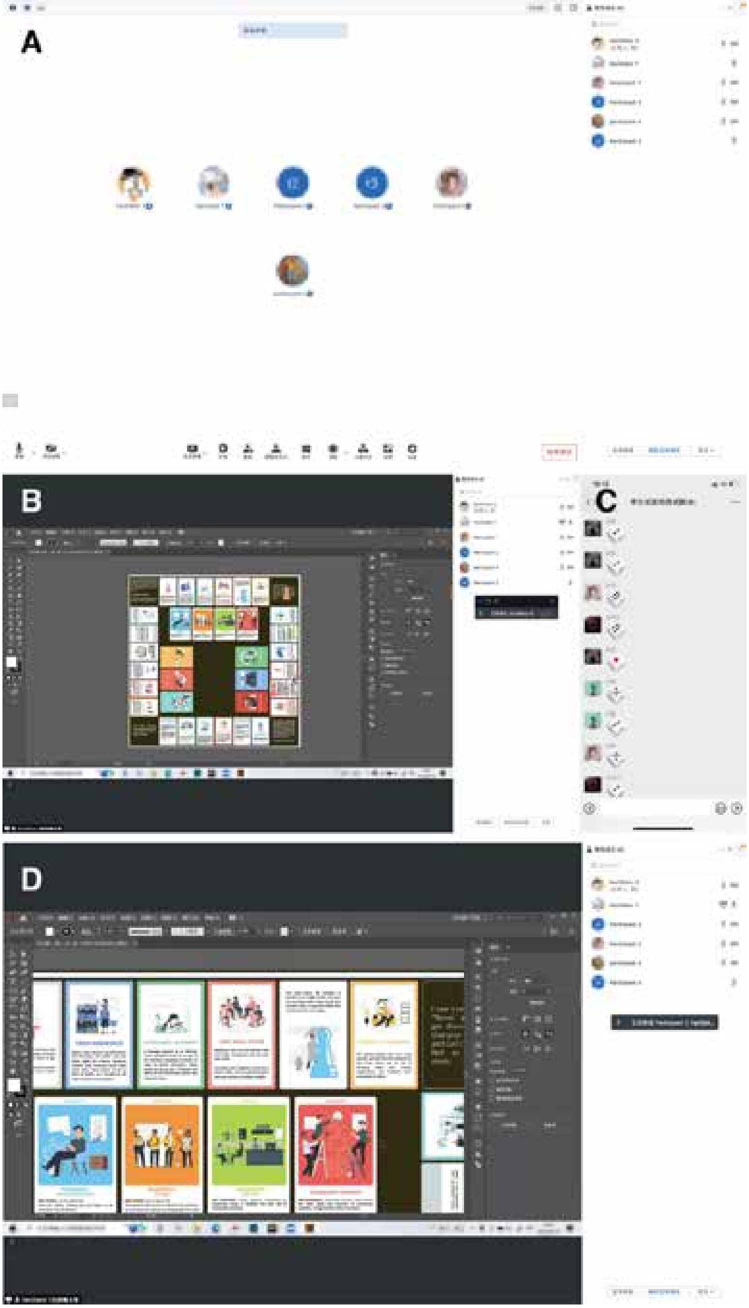

Figure 9. Online workshop. Screenshot A shows the round-table meeting, screenshots B and D show the scene of playing a participatory game prototype, and screenshot C shows the dice rolling in WeChat.

Through the game experience, participants were familiar with the rules and operations. After a five-minute break, the testing stage (from 10:53 am to 11:45 am, about 50 minutes) began, including the game testing and the player feedback. The steps in the testing stage were similar to those in the experience stage. The only difference was that the winner of the testing stage received an additional prize worth about 30 yuan.

Then, we conducted a brief interview with participants to judge the effectiveness of the game mechanism and to identify the direction of iteration. Overall, the four participants were satisfied and impressed with the gamified training process for climate adaptability. They believed that gamification helped them shape an adaptation awareness of climate change. For example, Participant 2 said: "I think this edutainment way is very good. What impresses me is that when encountering the extreme downpour, we should pay attention to psychological self-healing and material preparation." During the game, Participant 2 collected all objective achievement cards except the Crisis Awareness card. He had reached the position where he could obtain the Psychological Self-Healing card four times. However, he never reached the position where he could obtain the Crisis Awareness card. The event contents corresponding to the instructional objective Crisis Awareness were partly preparations of materials (such as water, instant noodles, flashlights, etc.). In order to win, he was eager for the chess piece to be moved to these specific event cards, which strengthened his crisis awareness about material reserves.

During the stage, participants put forward some issues and suggestions for game bugs, gameplay improvements, and subsequent promotion:

- There were contradictions between the events described in different cards, i.e. the starting point card and its adjacent event card were contradictory.
- In the regularization of the card event contents, firstly, the third person was used and the description was too specific, which was not conducive to scene immersion and role-playing for players. It is recommended to modify the language expression to make it more universal. Second, some words representing time led to chaotic relationships between events on different cards. Thus, it is recommended to weaken the time words.
- In terms of role selection, participants suggested that rolling dice be used to determine the role. Then different roles correspond to differentiated starting events according to roles' characteristics; for example, for the student, he or she can choose not to go out during a heavy rainstorm while for other roles, due to work requirements, they may have to go out during a heavy rainstorm.
- The location of the event card should be considered. It is necessary to comprehensively consider the winning probability of different roles to ensure the fairness of the game.
- Improve the reward and punishment mechanism. The current reward and punishment mechanism is too simple. Besides, there are unfair factors in the reward and punishment mechanism. For example, residents and businesses need to make unequal efforts to obtain the achievement card of mutual assistance.

- The richness of the gameplay. Is it possible to allow mutual aid between players? For example, the exchange of objective achievement cards or material cards, etc.
- In terms of promotion, it may be suitable for promotion in schools. However, in the community, the number of residents who actively participate is limited. It is recommended to place the game in community activity rooms, offline chess and card rooms, schools near the community, etc. as edutainment.
- In addition, participants suggested that a game for rural areas could be designed based on the proposed gameplay. Compared with urban communities, the basic monitoring equipment is not advanced in rural areas. When faced with climate disasters, villagers suffered serious losses. Villagers have an even more urgent need for climate adaptability. Moreover, this kind of game can also be used as entertainment for rural residents to enrich their lives.

Iteration of Game Prototype: A Game Optimization Process

Based on the participants' suggestions, the game prototype was iterated. The specific adjustments were as follows:

- Re-check and adjust the contents of the event cards for the self-contradictions between different events.
- Simplify the details in the event description, and change the third person to the first person to enhance the player's sense of immersion.
- Redesign the role selection method. The rolling dice is applied to determine the player's role (point 1 corresponds to the office worker, point 2 corresponds to the student, point 3 corresponds to the tradesman, point 4 corresponds to the community worker, and points 5 or 6 correspond to re-rolling the dice; the rolling dice order is determined according to random numbers; if a player rolls the same point number as the previous player, he or she needs to re-roll the dice).
- Consider the location of each event card to ensure the fairness of the game. The iterated game prototype is shown in Figure 10.

Figure 10. Game prototype (second edition).

Conclusion

Aimed at the climate adaptability of community residents, this paper explores an open-ended gamification design method based on participatory ideas from the theoretical and methodological levels, and conducts a case study. The results show that the developed game prototype can deepen residents' understanding of climate risks in a more interesting and immersive way. However, the presented research still has the following limitations: due to the restrictions of COVID-19 and the limited ability of participants to operate the online tools, the case study only verifies part of the proposed method. It has not achieved the participation of multi-stakeholders in the whole design process. The follow-up should further explore the implementation method of multi-stakeholder online collaboration.

In the *Case Study* section, the number of participants invited was insufficient, resulting in a limited collection of specific events and incomplete refinement of teaching objectives. In subsequent research, more participants should be invited to join the project to improve the integrity of events and objectives. Limited by the development time, this research does not establish clear rules for the event content regularization and association between instructional objectives and gameplay. Future research should continue to summarize and refine the rules to better support the scalability and practicability of the proposed method.

Author's Contributions

The authors CL and MH contributed equally. Conceptualization and methodology: CL, MH. Case study: MH, YL. Writing the original draft: CL, MH. Editing of the writing: CL, YL.

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IN A NEW CONTEXT, WE ARE ALL APPRENTICES: HOW DIALOGUE BETWEEN THE THREE STATES OF CRAFT EDUCATION IS A CATALYST FOR ADAPTATION

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Abstract
This essay argues that dialogue between the three states of craft education is a key mechanism for adaptation. Adaptation here is taken as the act or process of adjustment to changing circumstances (Merriam-Webster, n.d.), with a particular focus on communal knowledge of making. The three identified phases of mediaeval craft education – apprentice, journeyman and master – are not only relevant to current debate around workmanship (Pye, 1968; Adamson, 2009; Crawford, 2011; Sennett, 2008, 2012; Ingold, 2013; Korn, 2013), but also resonate in modern design education. Through reflection on key texts and case studies, this essay proposes these three phases can be seen as states which are fluid, coexistent and in dialogue with one another. Dialogue between these states is a key mechanism for adaptation, for which convivial (Illich, 1973) and dialogic (Sennett, 2012) environments are a prerequisite. In better understanding this mechanism, we can engage it to create resilient, adaptive communities of practice and learning.

Author Keywords
Craft; community; adaptation; dialogue; apprentice; conviviality.

Introduction

The act of making resonates far into our past and remains highly relevant to our future. Demanding physical acts are deeply embedded in our sense of self: neuroscientist Daniel Levitin (2014) describes how memories formed through arduous tactile engagement are chemically fixed in our brains more firmly and more readily retrieved. A lively debate focuses on the relevance of skill and craft in our modern, post-industrial society: Crawford (2009) argues that "choosing is not creating" and pinpoints making (and repairing) as key to our sense of agency within capitalism. Ingold (2013) proposes making not only as a means of agency but as a means of knowing – in engaging with skilled tasks, we benefit from a collectively held knowledge which underpins our responsive ability. Understanding the mechanisms which support and catalyse this collective knowledge is vital for our communal adaptation.

Background / Literature Review

Although rooted in the mediaeval guild system, the three-tiered hierarchy of apprentice, journeyman and master endures in many modern forms and remains highly relevant to understanding workmanship and learning (Pye, 1968; Sennett, 2008; Korn, 2013; Ingold, 2013). Mediaeval workshops were an analogue of the patriarchal family; the language of craftsman, journeyman and so on refers to this patriarchal tradition (though no bias for/against any gender should be inferred). Collectively, workshops formed guilds to harness and develop their "knowledge capital" (Sennet, 2008); Chartres Cathedral is described by Ingold (2013) as the embodiment of this collective knowledge, manifested in façades that embody subtle changes under sequential master masons. In this system, the apprentice would learn through hands-on instruction described as "imitation" or learning through copying, with a corresponding lack of differentiation between tasks (Sennett, 2008). The apprentice and master were bonded by a reciprocal agreement in relation to the collectively held knowledge; this had a legal basis, but its real legitimacy lay in the level of skill demonstrated by the master. Apprenticeships ended with the presentation of a *chef oeuvre,* a work which demonstrated the elemental skills of the profession and made manifest the direct instruction received.

To propagate this knowledge to other workshops, the apprentice was then expected to travel as a journeyman. Elaborate rituals of belonging developed by the guilds enabled travelling craftsmen to be accepted in new towns and cities. Arriving in a new workshop context, a *journeyman* was expected to show learning beyond "brute imitation" (Sennett, 2008); to do this, he had to critically negotiate the original master-apprentice relationship through reflection. Progression from the journeyman stage was embodied by presenting a further artefact, the *chef oeuvre élevé,* after which a journeyman would be entitled to set up his own workshop. Successful navigation of a wider community of makers by the journeyman therefore illustrated the success of that community in collectively supporting adaptation. In becoming a master of his own workshop, the craftsman became responsible for upholding the fluidity of knowledge within it to support adaptation. Sennett (2008), a former professional musician, describes how vital fluid knowledge is: when master luthier Antonio Stradivari failed to teach the secrets of his violins even to his sons, this adaptive mechanism failed – "his secrets died with him." For Sennett (2007), this is evidence of a wider shift towards the culture of artist as sole practitioner, a phenomenon which formed part of the decline of mediaeval workshops but also craft practitioners being collective holders of making knowledge. The apprentice-journeyman-master system, enabled by guilds, forms a community network able to sustain and adapt collective knowledge in practice. The character of this system and the roles played by apprentices, journeymen and masters were vital to both individual and communal adaptation.

The following section identifies key characteristics of each of these stages and reflects on their resonance in modern design education. It is then argued that these stages are states which are fluid and coexistent, and work in dialogue with one another in the adaptive process.

Apprentice, Journeyman, Master: Characteristics and Resonance

Apprenticeship

For the apprentice, direct instruction is necessary because learning in a new environment is undifferentiated. This osmotic learning approach can be found throughout the spectrum of apprenticeship and across diverse geographical locations. Polynesian apprentice navigators learn how refracted swell patterns show the presence of unseen land from "swell maps" made from a latticework of sticks (Gooley, 2016). In first-year architectural education in the U.S. and elsewhere, students copy from Francis DK Ching's *Architectural*

Graphics (1975), still the benchmark for the kinaesthetic act of orthographic hand drawing. “Modern apprentices” in the U.K. are given direct instruction jointly by industrial and further education providers, though Fuller and Unwin (2003) have criticised the sharing of the master role for lacking coherency. The apprentice therefore seeks and requires direct, osmotic instruction to develop skills in a new context. Adaptation in the apprentice state therefore requires fluidity of knowledge enabled by a master, forming the currency of the bond between the master and apprentice. As undifferentiated learning defines apprenticeship, progression from this stage requires differentiation and an increasingly reflective capacity.

Journeyman

If an apprenticeship requires a surrogate dependency on a master, becoming a journeyman requires holding this relationship up to a critical light. For mediaeval goldsmiths, the *chef d’oeuvre* embodied both learning and the surrogate apprentice-master relationship, and its scrutiny by a panel of expert peers marks the beginning of a reflective journey (Sennett, 2008).

Modern design education is strongly resonant of the apprentice-journeyman experience. In the *crit* system of assessment in schools of architecture and design, students present their work for critical review by a panel of tutors in front of their peers. This modular studio structure, typified by the Architectural Association unit system, is an analogue of the Beaux Arts system of nineteenth century Paris (Garric, 2017). As with the mediaeval guild, students applied as external candidates for acceptance to an atelier and presented final projects as *chefs d’oeuvre*; a panel of experts approved progression to the next level. Students in design schools currently apply using knowledge as a currency, often in the form of a portfolio. As with the mediaeval journeyman, the explicit aim for the modern design student is to gain as much knowledge as possible and propagate this knowledge in dialogue with others to achieve “mastery” of a subject. From the polar perspective of the apprentice-master relationship, the mediaeval journeyman sees this trajectory as leaving one status and aiming for another, with knowledge as the proof of success. The mediaeval journeyman offers his knowledge as a currency which results in pollination of collectively held knowledge, a model emulated by modern design education and academia more widely.

This fluidity of knowledge relies on confidence in process. Without community agreement on standards for exchange, the mediaeval workshop would be unable to replenish itself and would quickly stagnate like the workshop of Stradivari (Sennett, 2008). A robust apprenticeship and guild system gave confidence in the pre-modern era, and modern students in higher education expect that their degree certificate functions in a similar way. However, the author’s experience as a programme leader suggests that employers frequently value the craft qualities of a portfolio of creative work at least as highly as a degree certificate. With a portfolio, the graduate can travel to new contexts and seek work, just as the mediaeval apprentice benefitted from the mediaeval craft guild. This process is more than an echo of the mediaeval workshop system: the importance of the portfolio is a reaffirmation of the master’s status as upholder of this process of adaptation.

Master

The master appears to offer complete certainty, but only from the perspective of the apprentice, who displays undifferentiated learning. For the apprentice, subjective decisions can appear certain when filtered through the lens of direct osmotic instruction. The master therefore must choose to present as certain those things which are not absolute, but in which the master has sufficient certainty.

In distinguishing between confidence and certainty – degrees of knowing – a master also must engage with degrees of not-knowing. Much of the catalyst for an apprentice becoming a journeyman comes from a realisation that the knowledge of the master is not absolute, that there are other ways of doing things, and hence a compelling need to discover and appraise these in turn. But whereas the journeyman aims for a complete certainty of knowledge – to oneself and to others – the master acknowledges that learning is never completed. Csikszentmihalyi (1996) supports this, arguing that because *making* induces immersive learning through "flow," it is inseparable from continuous improvement. Making is widely recognized to be an act of profound learning and connection to tacit knowledge (Adamson, 2009; Ingold, 2013), suggesting that to engage in any craft meaningfully is to appreciate the impossibility of being "complete" in one's knowledge and skill. Pye (1968) goes further and argues that the "workmanship of risk" is inherently superior to work which stays within known parameters. In professional workshop environments, a workshop master knows that risk is an inherent part of making; this is what separates custom-made artefacts from off-the-shelf counterparts and justifies the additional expenditure. From the acknowledgement of risk follows an acceptance that uncertainty exists; the master therefore must embrace and understand uncertainty.

The complex role of master resonates throughout design education and practice, often placing direct instruction under scrutiny. The design educator must reconcile being a rule-maker who encourages questioning of those same rules. The master must also understand when something is enough; in addition to embracing uncertainty, imperfection must be accepted, at least in the current cycle of work – the trap of perfectionism must be avoided. Sennett (2008) describes perfectionism as a stopping of the clock, the removal of the possibility of improvement or change. The state of mastery requires understanding that perfection is part of a continuum, a longitudinal practice of shared knowledge founded in the common currency of making.

Each phase of the traditional craft apprentice system has characteristics and factors which either support or obstruct the adaptive learning process. The apprentice displays osmotic, undifferentiated learning and seeks direct instruction and reassurance. The journeyman learns through a dialogic exchange between his or her own knowledge and that of others, requiring an empathetic community. The master achieves a degree of peace with not-knowing but cultivates confidence that a solution will be found through trust in dialogue with the first two.

Fluid, Coexistent States

Identifying the characteristics and needs of the three phases of craft education – apprentice, journeyman and master – we can interpret them not as sequential phases but as fluid *states* which coexist and work in dialogue with each other. Using this as a theoretical framework, we can see that the dialogic exchange which characterises adaptation is therefore possible at any point, given the recognition and support.

In design education, it is tempting to draw a comparison between the apprentice-journeyman transition and the school-university threshold. There are several parallels: experienced university admissions tutors look for diverse experience in cohorts, just as a master might look for diverse intake of journeymen to enrich their workshop practice. In addition, the direct instruction methods familiar to the apprentice are common in secondary schools in the U.K. Transition to a university environment also entails not only a literal journey, but a challenging transition to a self-reflective learning style, a characteristic strongly identifiable with the journeyman.

However, aligning secondary education to apprenticeship would be an over-simplification. The qualities exhibited by first year undergraduate students are *also* reminiscent of the apprentice-state. First year undergraduate students require disproportionate levels of direct instruction; they seek more reassurance than other years and learn osmotically. Undergraduate study follows a similar duration to the apprenticeship – four years in Scotland – and concludes with presentation of a major project to a panel made up of experienced industry figures. In professional practice or postgraduate study, we again recognise the characteristics of the apprentice. *Interior and Spatial Design Studio* at the author's home institution exhibits multiple states of craft education; as in the stages of craft education, each project completion enables progression to the next. Like the workshop environment, a culture of open dialogic exchange proved beneficial to student development, in particular within the rapidly changing COVID-19 context.

Adaptation in craft apprenticeship linear progression occurs through physical relocation, but in the climate emergency we find ourselves adjacent to an environment. As an apprentice beginning work as a journeyman is confronted with the shortcomings of previous ways of working, we are suddenly aware of the inadequacies of our own systems of teaching, communication and practice. All three states of craft education are recognisable in our own adaptive response: we can see the apprentice-state in our need for instruction and support, yet as researchers and practitioners we have a journeyman's desire to apply and cross-pollinate our existing skillset. Simultaneously, we need a master's acceptance of not knowing the answer immediately but having confidence that solutions can be found through open dialogue within a community of practice. Identifying the three states of craft education therefore allows us to recognise that our own states are fluid and coexistent when faced with the need for adaptation.

The coexistence of multiple states is at odds with the sequential nature of skill development and undermines its authority as a model for learning. It might be argued that these states are not coexistent but constantly fluctuating, just as changing circumstances or market conditions might cause a mediaeval master to become a journeyman. But even if a master becomes an apprentice in a new context, he or she does not shed the knowledge which underpins previous proficiency; the two conditions coexist. Adaptation requires these states to be in dialogue with one another; direct instruction in a new context is overlaid with existing knowledge which informs and enriches it. When we identify the states of craft apprenticeship in communities of practice, these states are fluid, coexistent and work in dialogue with each other. Dialogue underpins adaptation because each state is in a reciprocal relationship with the others; the context in which this exchange takes place is therefore of utmost importance.

Community Dialogue and Adaptation

This section demonstrates how an environment that fosters open dialogue within communities of practice can act as a catalyst for adaptation. Two or more states are brought into dialogue with one another when there is an adaptive need. In a sequential craft apprenticeship, we see this dialogue when an apprentice arrives at the workshop of a master; when the apprentice graduates into a journeyman, able to travel between other workshops; and when setting up his or her own workshop as a master. These experiences are unified by a need to work together with others, and the nature of this exchange is crucial to the success of adaptation.

Dialogic Exchange and Conviviality

All workshop practitioners benefit from becoming reciprocally aware of others. This mutually beneficial state is what Richard Sennett (2012) calls “dialogic” rather than “dialectic” exchange; it functions through dialogue, and its goal is not a Hegelian synthesis but a greater understanding and appreciation of one’s own approach by better understanding others (Sennett, 2012; Wheat, 2012; Davis et al., 2019). The community is critical; as with successful apprenticeships, an empathetic workshop culture is a prerequisite for such exchanges, because seeking to establish a “winner” or zero-sum outcome undermines open dialogue between makers. For both apprentice- and journey-states to thrive, the workshop and education studio must become convivial tools, with dialogue between users open to all participants. Both the apprentice-state and journey-state therefore need dialogic, open communities of practice to thrive and progress.

Progression beyond the apprenticeship condition requires openness and dialogue. It is predicated on developing a critical awareness of both one’s own practice and the practice of others. Moving beyond the apprentice state therefore needs a community which reduces the perceived risk of critical reflection, one which displays empathy and the capacity to support individual agency rather than deferral of responsibility. Social philosopher and priest Ivan Illich (1973) described these as *convivial* qualities, where conviviality exists in opposition to industrial productivity, and tools are intrinsic to social relationships (p. 11, 21). Defining tools very broadly from basic hardware to large productive systems, Illich (1973) describes a social relation with tools as being critical in one’s own self-image: he contrasts “tools for conviviality” – “those which give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision” with industrial tools, most of which “cannot be used in a convivial fashion” (p. 21). From this viewpoint, we might describe a community of practice which displays empathetic qualities as a “tool for conviviality,” meeting both Illich’s (1973) definition as a large productive system that empowers individuals and Sennett’s (2008) definition of dialogic engagement.

Catalysing Adaptation in the Student Community

This section explores two case studies in design education which allowed students to inhabit the three states in dialogue with one another as a mechanism for adaptation. In the first, a mentorship system increased confidence in the apprentice state and fostered reflection amongst those more senior. In the second, a compressed timescale was used to catalyse dialogic exchange and overcome social barriers to achieve communal knowledge exchange.

Dialogue as Catalyst for Community Adaptation: Interior Design Studio Mentor Scheme

To catalyse adaptation to the post-lockdown physical studio environment, the author and programme team implemented a system of mentorship for all students on the BDes (Hons) Interior and Spatial Design programme at Edinburgh Napier University in September 2021. The mentoring scheme was designed to foster dialogic exchange to support adaptation by sharing knowledge and rebuilding a sense of conviviality within the programme (Illich, 1973). Building from the experience of colleagues in nursing and engineering, the scheme was made an essential part of the programme, with feedback collected through self-reflection sheets submitted alongside the final portfolio review. Every fourth-year student was given a second-year student to mentor, and every third-year student a first-year student; allocation was at random but those with common experience of direct entry from another programme were matched. There was no stipulation for the meeting format beyond at least one face-to-face coffee (or similar) to establish how the relationship might be of professional benefit.

As we saw in the mediaeval workshop, the currency of knowledge is a means of earning authority and hence developing confidence in the self; seeking assistance and receiving it builds confidence that communal knowledge exists and could be drawn on when needed. In this way, a dialogue between the states of master and apprentice was introduced, with the effect of building confidence in the fluid nature of knowledge. The programme team specifically hoped this confidence would counter the uncertainty which inhibited students from learning effectively upon return to physical learning. Participation was good; of the eight in ten students who managed to meet with their mentor at least once, 90% reported at least some positive benefit in terms of confidence. Respondents felt that the mentor scheme "created more confidence for new students... encouraged self-improvement and motivation" and "enabled [students] to discover things from different perspectives [and] different ways of thinking" (student feedback from trimester 1 self-reflection, December 2021).

Encouraging open, dialectic exchange benefits confidence in the apprentice-state and encourages the reflective character of the journeyman-state in design education. By making design studios and systems of tutorial support conviviality, we can foster the open culture of collective knowledge which functioned in mediaeval craft workshops and persists today in highly skilled workplaces.

Time Compression as Catalyst for Community Adaptation: Student Workshop in Zhengzhou, China 2019

Time compression can stimulate dialogue between fluid states and catalyse adaptation. For a one-week workshop with 98 design students in Zhengzhou, China, the author and colleagues developed intense design tasks in which all participants transformed everyday artefacts into the function of the neighbouring artefact. The "working quickly" approach (Firth et al., 2016) was employed to break the inertia and need for direct instruction normally displayed by first and second-year students. Time compression inverted the default relationship of student as apprentice needing direct instruction from visiting educators before proceeding. In a new temporal context, the participants became journeymen, pollinating knowledge in small "workshop" groups of ten participants. The outputs of these workshops were then aggregated into one long modular piece of furniture (see Figure 5), a linear chef d'oeuvre made over the period of a single week. The outcome from this process was a public procession of work which was displayed publicly to the wider university in the manner of a guild. Compression of time in this instance was able to catalyse adaptation because urgency induced states of being normally inhibited by social or professional hierarchies.

This time-compressed approach also fomented reflection in the participants, captured via a short student questionnaire about each item. Respondents described a new fluidity of knowledge: "we feel different academic thinking," and described the benefit of making for collective knowledge and community: "the tacit understanding and clear division of labour [created] the team atmosphere" (student participant, 2019). Overall, the compression of time heightened the importance of conviviality (Illich, 1973) and dialogic exchange (Sennett, 2012): "We learned that teams should co-operate with each other. To shorten the time and improve the efficiency, it is necessary to improve the division of labour between the internal departments. When everybody adds fuel, the flames rise high" (student participant, 2019).

Figure 1. A drawer becomes a plant pot – students at ZZULI Environmental Design programme, Zhengzhou, China (2019) (photo credit: author).

Figure 2. A plant pot becomes a bookshelf – students at ZZULI Environmental Design programme, Zhengzhou, China (2019) (photo credit: author).

Figure 3. A file holder becomes a light – students at ZZULI Environmental Design programme, Zhengzhou, China (2019) (photo credit: author).

Figure 4. A desk fan becomes a stool – students at ZZULI Environmental Design programme, Zhengzhou, China 2019) (photo credit: author).

Figure 5. Collective linear furniture assembly: catalysing dialogic exchange to build community capital – students at ZZULI Environmental Design programme, Zhengzhou, China (2019) (photo credit: author). Workshop designed and run collaboratively by Paul Kerlaff and Antonia Cairns.

Despite the significant technological and cultural differences between mediaeval craft and modern design education, all three states of craft apprenticeship are evident in both case studies. Addressing the osmotic, undifferentiated learning style of the apprentice was a priority in the Zhengzhou case study. Younger students, particularly those in the Edinburgh mentorship scheme, sought direct instruction and reassurance. The journeyman state was catalysed by introducing a dialogic exchange through teamwork and mentoring respectively. Each student found that exchange between his or her own knowledge and that of others requires an empathetic community. Participants in both experienced some of the qualities of the master – a degree of peace with not-knowing but a confidence that a solution will be found through trust in dialogue.

Conclusion

Awareness of and dialogue between the three states of apprenticeship, journeyman and master is a key mechanism for adaptation. Characteristics of the three states show that they are fluid, coexistent and work with one other. In acknowledging the coexistence of these states, we can induce and support dialogue to catalyse adaptation. Because both external and internal dialogues require civility, we need to foster communities of practice which are convivial and support dialogic exchange to enable us to adapt successfully.

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LIFE-CENTERED DESIGN AND INTERSECTIONALITY: CITIZEN SCIENCE AND DATA VISUALIZATION AS ENTRY POINTS

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Abstract
Europe is calling for an ecological transition (Dewberry, 2018; Boehnert, 2019) able to influence social groups and territories. Life-centered approach is an ethical framework in which life is the ultimate source of value (Orr, 2006) in a process that includes both digital and physical components, social justice and environmental outcomes. Life-centered design is considered by the authors as an approach related to posthuman design (Forlano, 2017) which investigates overcoming the centrality of "humanity" starting, mainly, from two points:

- The concept of the Anthropocene leads us to reconsider the nature/culture duality. Some theoretical frameworks, such as critical posthumanism (Braidotti, 2013), propose an alignment of those concepts in a cooperative perspective.
- Since the Enlightenment, *humanity* has referred to humans that often present the same characteristics (Western, white, male, etc.) (Braidotti, 2019). The progressive diffusion of inclusive development frameworks pushes us to rethink this model, assuming diversity as a key element.

On this pathway towards a just transition, design is a field that involves humans acting as aggregators of creative practices and facilitating the coevolution of socio-technical aspects of transition phenomena (Geels, 2005). This coevolution is supported by an impulse that comes from the use of data collection techniques for citizen science. Digital tools, such as cheap sensors, are considered non-human actors which can act as mediators (Latour, 2005), affording new ways of social mobilization around knowledge and feeding new epistemologies in citizen science. Life-centered design could integrate different forms of collaborative action with a focus on the design of the "possible" and with emphasis on the responsibility of design (Lotti, 1998; Thackara, 2005). In this process, technologies are at the service of the inclusive socio-economic components, with direct results in new

languages of ethical and free-of-bias relationships (Portugali et al., 2012). The aim of this paper is to outline life-centered design through data visualization and citizen science initiatives carried out by the research group in order to activate an intersectional perspective in relation to climate citizens. The objectives of this research are:

- To increase diversity and intensity of participation through an intersectional approach.
- To address socio-technical aspects of climate change problems through the co-design of accessible tools.
- To reduce distance between citizens and academia through tailored communication.

Research communication should clarify the implications for individuals who identify themselves in diversified socio-cultural categories (such as age, gender, sexual orientation, education, ethnicity, ability) in order to favor equal participation (Lakomý et al., 2020). Several gaps in this communication process must be considered: cognitive biases, especially in the social network society (Lauwereyns, 2011); data overexposure and "spectacularization"; data extractive approaches and behavioral economy; and the complex perception/reality relationship. Paradigms of this communication will be identified in order to understand which roles and responsibilities of the different target groups influence their ability to deal with climate change challenges.

Author Keywords
Citizen science; design; life-centered; just transition; data communication.

Citizen Science and Data Visualization: Processes in Coevolution

Europe is calling for an ecological transition (Dewberry, 2018; Boehnert, 2019) able to influence social groups and territories. Life-centered approach is an ethical framework in which life is the ultimate source of value (Orr, 2006) in a process that includes both digital and physical components, social justice and environmental outcomes. Contemporary global challenges (Gaziulusoy & Öztekin, 2019) are raising a design debate around the prototyping of new forms of collaboration for a systemic reaction to the climate crisis (Irwin, 2015; Tonkinwise, 2015; Fuad-Luke, 2009). Life-centered design is considered by the authors as an approach of design cultures and practice related to posthuman design (Forlano, 2017) which deals with global challenges and wicked problems by overcoming the concept of "human-centered" in favor of facilitating the construction of new relationships between multi-actor assemblages and the environment inhabited by them. Starting in the 1980s, design practices and studies have seen a change in their research objectives coinciding with the diffusion of user-centered and human-centered approaches. In that case, the main object became the individuation of "design problems" starting with user (then human) needs. Human-centered approaches, even if they may appear more "inclusive"[1] than functionality-led processes, started becoming unable to deal with global crises as long as they are caused by "man" and "anthropo" centric ways of acting (Braidotti, 2019). The core of user or human-centered approaches of design is that a plurality of perspectives is included in the design process by using specific methodologies that have been developed in the disciplinary context (such as design thinking).

One of the critiques that may be made of this kind of approach is that including a plurality of (user) viewpoints does not necessarily lead to plurality (or diversity) as long as the people involved in the process present similar needs due to similar characteristics in the ways in which they live. In this paper, we are assuming that the humancentric (mancentric) vision that has been a pervasive perspective since the Enlightenment and the anthropocentric vision (i.e. considering humans supreme with regard to other species) have contributed to contemporary social and climate crises and since design cultures have seen an increasingly important role in facing systemic and wicked problems (Tonkinwise, 2015), this is a matter of design. The diffusion of the concept of the Anthropocene (and/or Capitalocene) leads us to reconsider the relationship of nature and culture no longer as a duality but as a continuum (from nature/culture to natureculture) (Braidotti, 2019). This has opened debate in various fields such as humanities around the necessity of reframing the relationship between humans (and human actions) and "natural" ecosystems. Concerning design cultures, this debate has seen a growing importance regarding three aspects:

- Some theoretical positions, such as critical posthumanism (Braidotti, 2013), propose an alignment of culture (humans) and nature (non-humans) in a cooperative perspective.
- Some theoretical frameworks invite us to consider artifacts (objects) as actors able to influence knowledge transfer processes (Latour, 2005).
- Feminist studies invite us to deal with global crises also by rethinking the concept of "humanity," assuming diversity as a key element and proposing more inclusive[2] development frameworks, both with regard to creating new relations between humans and machines (Haraway, 1991) and with regard to creating alliances with other species towards ecological justice for all (Balzano et al., 2022; Figueres & Rivett-Carnac, 2020; Escobar, 2018; Light et al., 2017).

On this pathway towards ecological transition, design is a field that involves humans acting as an aggregator of creative practices and facilitating the coevolution of socio-technical aspects of transition phenomena (Geels, 2005). This coevolution is supported by an impulse that comes from the use of data collection and data visualization techniques for citizen science.

The term citizen science (CS) refers to scientific research processes involving the participation of citizens and non-specialized actors in one or more stages (ECSA, 2015). The practice has seen growing popularity, both from an institutional point of view, i.e. becoming an element of interest within national and European funding programs and, from the point of view of participants, due to the spread of online platforms and tools – such as Zooniverse, which has more than 50 CS projects and 2.4 million users[3] – that are able to create a link between the academy and non-specialized actors. Those platforms usually support participatory data collection by giving tools for sharing data with academia or the research group that organizes a CS project and providing resources or indications in order to favor the collection of reliable data from a scientific perspective. Among the main critiques that can be made of this model – which is relevant for the purposes of this paper – is the fact that these processes generally favor the participation of individuals with similar characteristics: generally male, highly educated or otherwise already interested in scientific subjects (Khairunnisa et al., 2021; Lakomý et al., 2020; Raddick et al., 2013). In order to improve the participation of a more diversified public in those kinds of processes which enable participants to achieve new skills and knowledge, more accessible data collection devices should be used on the one hand, and, on the other, more inclusive scientific communication should be designed.

Regarding the devices to be used, they should be designed with attention to accessibility and the diversification of the public that will use them in order to favor a data collection process enabled by an intersectional perspective (D'Ignazio & Klein, 2020). Regarding communication between academia and citizens, data visualization (DV) practices may be used as a channel to favor the diffusion and the critical elaboration of collected data. Science and publishing have used data visualization as a communication tool for hundreds of years to enable the study of complex phenomena and make large streams of information accessible to different actors, from institutions to citizens. A selection of data-driven graphical elaborations, still used as models today as described below, has been diffused mainly driven by two needs: knowledge and emergency. The need for knowledge gave rise to visualizations with the aim of analyzing and understanding phenomena relating to large-scale problems, which often led to important discoveries such as Galton's weather charts in 1861 (Figure 1), which enabled the discovery of anti-cyclonic movement of wind around low-pressure areas. On the other hand, the use of data visualization as an enabler for understanding, and sometimes solving, urgent social, health and economic crisis and emergencies assumes the role of civic tool, as in the case of John Snow's cholera map or Florence Nightingale's coxcomb diagrams which allowed them to save lives during health emergencies.

Looking at the history of data visualization, there are also attempts at being a medium for dissemination to citizens as in 1913 in New York (Figure 2). For statistical exhibits in the municipal parade, the employees of the city of New York, and "the Health Department, in particular, made excellent use of graphic methods, showing in most convincing manner how the death rate is being reduced by modern methods of sanitation and nursing" (Brinton, 1914).

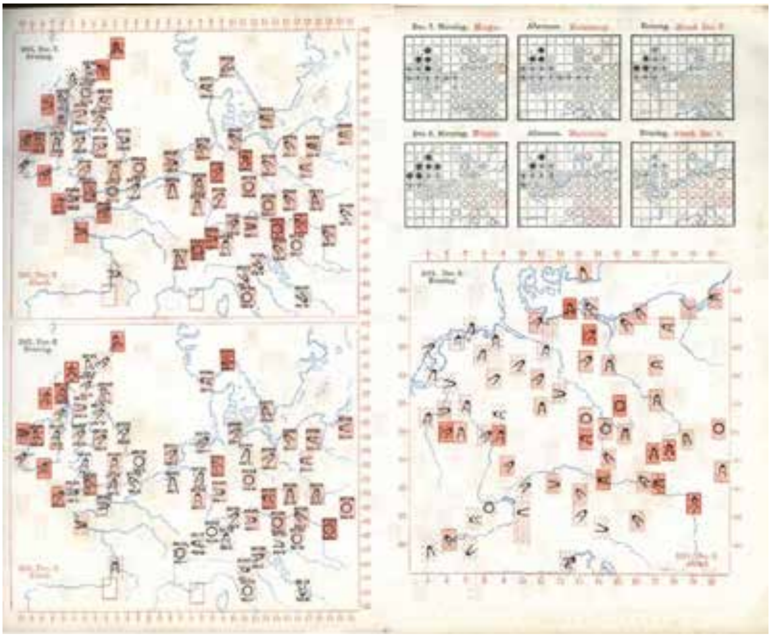

Figure 1. Early example of data visualization: weather maps by Francis Galton, 1861.

Figure 2. Photo from The Statistical Exhibits in the Municipal Parade by the Employees of the City of New York, May 17, 1913.

Although data visualization acquired more of an infotainment role (Holmes, 1984) in the 1970s in parallel with the information age – when it went from being an awareness-raising tool to purely aesthetic entertainment (Tufte, 1990) – with the recent Covid-19 pandemic, it may regain its function as an awareness-raising and emergency communication tool. Another phase regarding data visualization that gained relevance between the information age and the Covid-19 period is the so-called social network society, during which the advent of social media in the early 2000s completely revolutionized socio-economic structures. Digital devices such as smartphones have become an extension of the human world (McLuhan & Laphalm, 1967). Humans act on social networks about six hours per day (Starri, 2022), turning the digital social network environment into a place where we actually live as in real life.

All types of information today are influenced by social networks, which are nowadays a major channel for disseminating news and results and a medium of mass communication towards users and citizens. However, social networks are only a limited-explored field in the disciplinary history of data visualization.

In the area of data visualization for climate citizens, we report two examples:

- With the aim of increasing the effectiveness of communication to target communities, Will Media Italia[4] is a news channel that uses social media to report on "the changing world," often addressing major world issues such as climate change, with 1.3 million followers aged between 18 and 45.[5] Will Media Italia does not make a copy/paste of data visualizations for print media, but builds user experiences tailored to the space and time of the social media, exploiting, for example, the carousel tool of Instagram to gradually unveil the information according to precise storytelling and graphic design values applied to the construction of the message and the accompanying data visualization.
- Considering social media as an awareness-raising tool, the famous data visualization gif/video *The Climate Spiral* (2016)[6] (Figure 3) spread around the world and was nominated that same year for the prestigious *Kantar Information is Beautiful Awards.* Ed Hawkins, the British scientist who authored the visualization, posted his work on Twitter on 9 May, 2016 and it reached 3.4 million views in its first year. The animated DV shows the rise in temperatures from 1850 to 2017. The success of the visualization lies, as in the case of Will Media Italia, in finding the right way to exploit social network dynamics to spread a message while respecting the above-mentioned principles of user space and time and the principles of adaptability of the project according to the dynamics and characteristics of the selected social platform.

Intersectional Framework for Life-Centered and Responsible Design

Life-centered design could integrate different forms of collaborative action, with a focus on the design of the "possible" and with emphasis on the responsibility of design (Lotti, 1998; Thackara, 2005) through the improvement of the human-centered design approach considering the "life" centrality. The close relationship between design culture, studies and practices and research and responsible innovation (RRI)[7] is increasingly acquiring significance for science, technology, innovation policy and research and innovation practices (Succini et al., 2021). It offers forward-looking approaches and methods for reflecting on societal impacts, with a focus on participatory research and innovation aspects (Owen et al., 2012; Uyarra et al., 2019). The European Commission included sustainability as a key area for stakeholder dialog in the RRI agenda at a later stage, which has resulted in the underdevelopment of the operationalization of environmental concerns – and more particularly climate change – in the set of tools available for RRI. The six RRI key areas for dialog with stakeholders include: (i) public engagement; (ii) gender equality; (iii) science education; (iv) open access; (v) ethics; and (vi) governance. Lately, two more areas were added: sustainability (environmental) and social justice (Ligardo-Herrera, 2018; Carbajo & Cabeza, 2019).

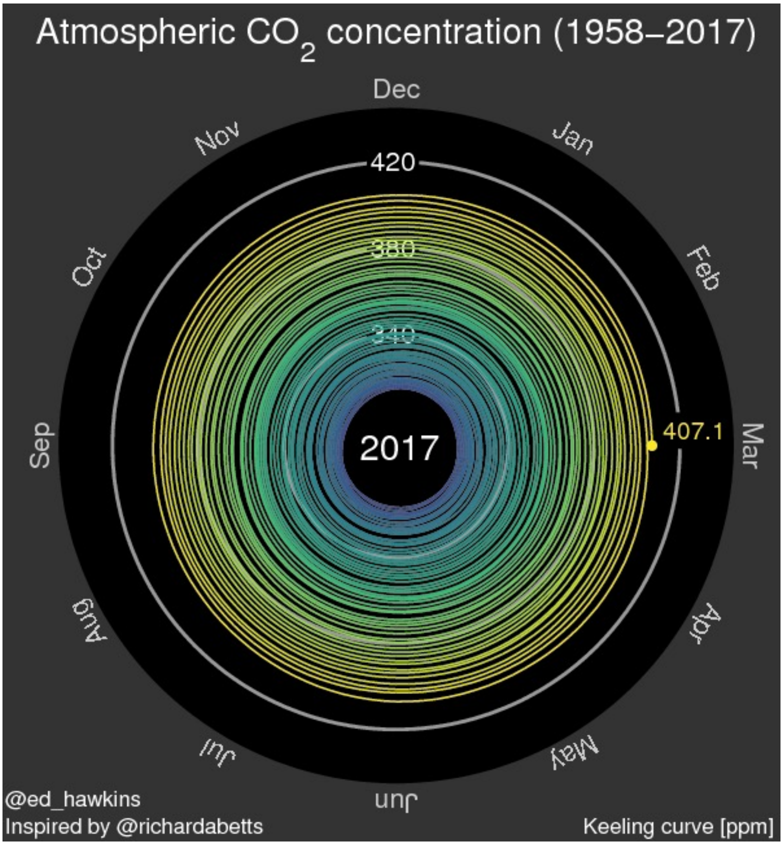

Figure 3. A frame extracted from the animated data visualization *The Climate Spiral* by Ed Hawkins (2016).

Natural hazards and the influence of climate change produce distinct exposures, sensitivities and adaptive capacities (Thompson-Hall et al., 2016) based on the intersection between existing inequalities determined, for example, by social dimensions of gender and identity and the different ecological, economic and climate contexts, providing evidence that the greatest level of risk is often related to high inequality and barriers to accessing people's rights in their everyday life. This evidence is taken into account by climate and disaster risk reduction research, policy and programming with specific focus on vulnerable and marginalized groups (people with disabilities, women, children, older persons, minority and Indigenous groups, LGBTQIA+, people with chronic health conditions and others who are contextually marginalized), but they are usually considered as a collective category or separately as specific groups of people.

A paradigm shift is needed to let the value of intersectional approaches emerge and to recognize that groups of people who experience marginalization have different identities, needs and priorities. Moreover, to support vulnerability reduction, it is necessary to take complex contextual realities into account and understand intra-group differences and the existence of multiple axes of identity that govern an individual's or group's relationship to power (Osborne, 2015).

Intersectionality is assumed to be a theoretical framework to guide the participatory methodologies in citizen science processes and data collection, interpretation and visualization. Starting from this assumption, our research group is designing methods, tools and technologies that address challenges faced by underserved communities in a process of adaptation able to intercept the complexities (context conditions, power relations, resources) that impact participants' ability to be engaged as active partners in inclusive participatory design and citizen science process. Participatory design methods (workshops, do-it-yourself, crowdsensing and crowdsourcing, etc.) with a special focus on climate change seek to engage participants in the research and design process as co-researchers, but there are still challenges and gaps in fostering agency among members in underserved communities. The creation of situated knowledge and located accountabilities allows for the collection of alternative viewpoints, agency and questions of how knowledge is produced, by whom and under what conditions (Suchman, 2002).

Intersectionality supports a paradigm shift, moving from the description of the unique experiences of a singular master social group or subgroup (Hancock, 2007) to examine the fluidity, variability and temporality of interactive processes generated between and within multiple social groups, institutions and social practices (Few-Demo, 2014).

There is increasing recognition that the term "intersectionality" was popularized by law professor Kimberlé Crenshaw in her 1991 article "Mapping the Margins" (Mays & Ghavami, 2018), supported by Collins's (1999) strengthening of the concept throughout the 1990s. During that time, social sciences especially investigated the ways social categories combine at various developmental stages to shape outcomes directly influenced by the context of power, privilege and disadvantage (Del Toro & Yoshikawa, 2016; Ghavami et al., 2016). All these considerations provide important insights into the design and co-design processes for the development and experience of usable products, buildings and systems, assessing the role they play in people's lives.

Responsible design is nourished by the complexity that arises when the subject of analysis expands to include multiple dimensions of social and ecological life, improving the categories of analysis. In particular, reflexivity, one of the RRI pillars (Stilgoe & Guston, 2017) revolves around the role of design, stimulating new reflections from a thematic point of view about tools, processes and methodologies (the convergence of design methods and future-focused thinking), of transformative value (the co-generation of futures and participation in the construction of collective futures) for a life-centered approach that encouraged negotiations of roles, goals, and technology.

In this process, technologies, especially the ones related to data gathering and visualization, are at the service of the inclusive socio-economic components, with direct results in new languages of ethical and bias-free relationships (Portugali et al., 2012).

Methods and Practices for Diversity and Inclusion

The aim of this paper is to outline life-centered responsible design through data visualization and citizen science initiatives carried out by the research group in order to activate an intersectional perspective in relation to climate citizens:

- To increase diversity and intensity in participation through an intersectional approach. The proposed research lines aim to extend beyond the gender-specific and empowering categories of social identity (youth, old age, disabilities, non-heteronormative sexualities, minority ethnicities, income, religion and more) an intersectional perspective with a focus on a variety of multi-level interacting social forces, narratives, norms, factors and power structures that shape and influence the life of climate citizens. To address the coevolution process mentioned above, the research unit is working on the update and cross-fertilization of participatory practices and methods, assuming intersectionality as an innovative design framework. This has the potential to advance understanding of, and action on, inequalities by highlighting processes of stigmatization, but mainly to encourage a critical reflection to move beyond singular categories, foregrounding issues of equity. Accordingly, and in line with the United Nations' Sustainable Development Goal #5 "gender equality"[8] and MoRRI gender equality indicators,[9] a reflection about socio-demographic (age, gender, migration background, ethnicity, etc.), economic (income, living conditions, etc.) and territorial (specific socio-economic contexts, percent of people with disabilities, local digital skills level, etc.) variables is adopted to maximize impacts through engagement strategies and specific intermediate bodies, adopting a language that reflects these complexities. This helps prevent the simplification of complex local realities and aids in selecting enabling tools (physical and digital) to promote the inclusive involvement of people.
- To address socio-technical aspects of climate change problems through the co-design of accessible tools, digital tools such as cheap sensors are considered non-human actors which can act as mediators (Latour, 2005), affording new ways of social mobilization around knowledge and feeding new epistemologies in citizen science. The proposed research aims to define a model for collective monitoring of natural and urban phenomena by gathering data through both using digital devices and involving humans through participatory methods. In order to achieve one of the objectives of citizen science's approach – to enable knowledge transfer

to the involved communities – digital tools involved in data gathering should be accessible to use from an intersectional perspective (e.g., accessible and usable by non-conforming bodies) and should be treated as an object for favoring the discussion around research's specific topic.
- To reduce distance between citizens and academia through tailored communication.

Research communication should clarify the implications for individuals who identify with diversified socio-cultural categories (such as age, gender, sexual orientation, education, ethnicity, ability), in order to favor equal participation (Lakomý et al., 2020). Several gaps in this communication process must be considered regarding the contemporary context of communication (also considering the social network) and cognitive and perceptive limits of people inside and outside social context, such as bias. Regarding the concept of bias, it is necessary to distinguish between the general concept of bias and the negative one. According to Lauwereyns (2011), the general concept of bias refers to the way in which the human brain makes choices in response to information or stimuli, being a natural process which is related to human living.

Meanwhile, the concept of negative bias has to do with subjective or collective stereotypes that are related to individual experience and context of living. Dealing with bias is necessary when working with data as long as they pretend to present "objective knowledge," even if they are collected and elaborated by machines, because they are influenced by human perspective (which designs or defines the way in which machines will collect data). The concept of negative data bias which may lead to a misuse of databases that may influence marginalized communities (D'Ignazio & Klein, 2020) must be taken into account when operating in a highly participated in and public environment such as social media.

On the Ground Investigations and Open Reflections

Since the middle of 2021, the research unit has been involved in experimental initiatives with a threefold aim:

1. To determine on the ground the critical aspects related to the adoption of an intersectional approach in public engagement connected to citizen science, with a particular focus on those related to climate change and communities.
2. To map out leading sociotechnical practices and tools that are useful at better understanding or interpreting climate change topics through an intensive and more aware use of data in the different phases of the citizen science processes.
3. To investigate the empathic and perceptual limits of data visualization about climate change in the social media environment to better address the communication and dissemination of projects.

These three objectives are mainly connected to the reflections that emerged due to direct participation in two Horizon 2020 (H2020) projects, GRETA and RESET. H2020 Green Energy Transition Actions (GRETA)[10] was launched at the end of 2020 with the aim of paving the path to active energy citizenship and communities, starting from the conditions and barriers for their creation and consolidation. The project intends also to apply a gendered perspective in the energy transition, to propose answers to the unequal access to resources in a system that still favors established voices, resulting in an unbalanced representation of the European population in both decision-making processes and policy outcomes. The research unit is working on the Bologna case study in a multicultural, socio-economically stratified district: an area with a high percentage of elderly and immigrant residents, but also teenagers and families. Its population is mostly unaware of questions related to energy, with a limited understanding of technical subjects. The first actions promoted were related to engagement strategies to enable better understanding, with tailored messages for the different inhabitants, using and sharing energy data in a user-friendly mode and co-designed, tailored, place-based solutions for the specific areas. A series of collaborative workshops around community topics of interest (reduction of energy expenditure, planet care, renewable energy installations) has been set up, with a multi-voice support (institutions, companies, associations, citizens, students) to combine different needs, resources and opportunities deriving from human and not-human elements.

Restarting Economy in Support of Environment through Technology (RESET)[11] is a project financed by the European Union's Horizon 2020 FET Proactive Programme which aims at improving green and environmental investments by proposing a process based on environmental intelligence (Mulligan et al., 2020). In the urban case study of Bologna, a mixed data collecting approach based on ground-based weather stations and citizen science will deal with thermal extremes and how urban green areas can act as a heat mitigator. The research process is aimed at combining machine-sourced data with crowdsourced data collected by the citizens through a process of continuous exchange and communication based on data visualization methods (Figure 4).

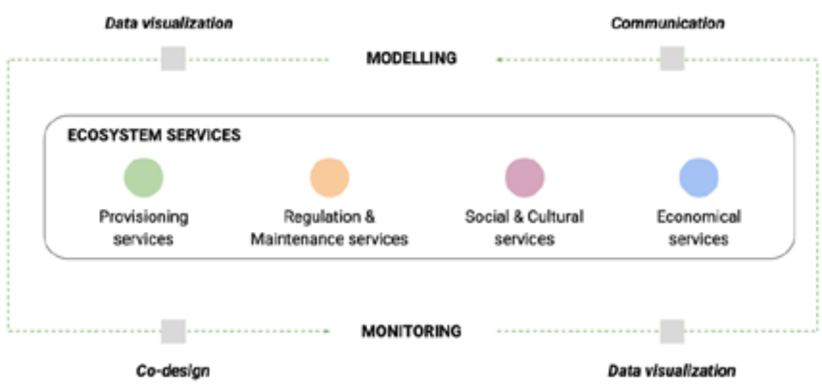

Figure 4. Methodological process of RESET in Bologna.

During 2022, preparatory activities have been carried out in order to:

- Define the experimental design for the ground-based monitoring in Bologna. Along with the municipality, a group of green areas has been selected for weather stations that will collect data about thermal extremes in areas near the city center (highly built environment), former industrial areas (open air environment) and areas further from the city center (less built environment).

- Constitute a network of stakeholders that will act as intermediate bodies to involve citizens and communities. Other than the university, municipal institutions and local associations, representatives of people with disabilities, LGBTQIA+ communities and elderly people have been involved in directly hosting weather stations and in facilitating the situational citizen engagement.
- Test a digital open platform for citizen science. Over 80 university students have been involved in data gathering in order to map the existing green areas in terms of public services and thermal extremes mitigation perception. During this activity, students monitored existing services and barriers using a Spotteron-based smartphone application that was selected for its usability. During the activity, the participants registered over 200 spots that are now available on an online open map provided by the application.[12]

All these preliminary activities are preparing the ground to open RESET citizen science initiatives to a larger community of participants. To couple the co-creation initiatives of these two projects, the research unit is investigating new communication pathways, especially through social media, to test impacts in terms of perception and empathy of data visualization about climate change and intersectionality, starting from the results of the experiment "From Data to Stories" (Licaj & Raffo, 2018) about the phenomenon of migration on Mediterranean Sea routes using data and information collected on the UNHCR platform, and adapting the emerged model to these new initiatives. The model was tested in two ways: through the tools provided by the social network (sponsorship, engagement rate measurements, views, clicks, etc.) and through a series of live tests with users (Figure 5).

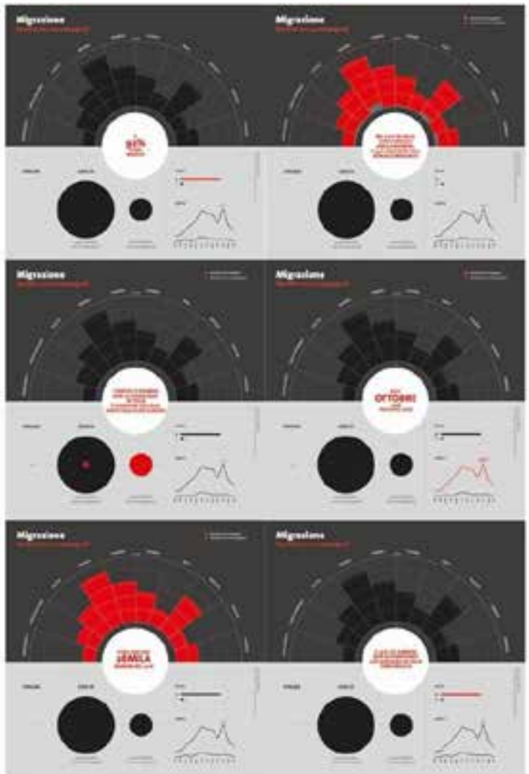

Figure 5. Data visualizations used for the test sessions with users during the experiment "From Data to Stories."

The results from the various tests defined three areas of focus:

- The perception of data reliability not only in relation to the official source – in that case UNHCR – but also the person or the page that shared the information.
- The increased capacity of people to understand data and the explicit and implicit message beyond visualization. For example, in the 2018 experiment, within the first three seconds, the testers immediately understood the first level of information and within the next five seconds they had all understood the second level of reading.

The digital medium – and specifically the context of social networks – determines a basically limited time of fruition and defines the need to capture the user's interest in the first seconds of interaction. The aim of the further experiments combined with the GRETA and RESET projects is to maintain the balance between complexity and level of entertainment, trying on the one hand to avoid information and message overload and on the other hand, pushing too far towards the threshold of so-called infotainment.

The use of data visualization in this communication pathway should not turn into a merely superficial fruition but, thanks to explicit messaging, a balanced distribution between primary and secondary data and balance between complexity and simplification, it becomes an effective experience for different users according to their digitalization comfort level.

All research activities will continue during the coming months, nurturing citizen science processes related to specific initiatives and experimenting with inclusive public engagement practices that see diversity as a key value. Moreover, the common view of research focuses on the concept of “data as a medium” where data, its collection, processing and representation are considered as an element of ecosystemic and inclusive mediation.

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[1] In this context, the term “inclusive” is considered to mean “broad in orientation of scope.”
[2] In this case, the term “inclusive” has to be understood as meaning “aiming to involve and integrate everyone into an activity or process.”
[3] https://www.zooniverse.org
[4] https://willmedia.it/
[5] https://masterx.iulm.it/news/interni/will-start-up-under-31-fondata-imen-jane/
[6] https://web.archive.org/web/20190816215511/http://www.climate-lab-book.ac.uk/2016/spiralling-global-temperatures/
[7] https://www.rri-practice.eu/about-rri-practice/what-is-rri/
[8] https://sdgs.un.org/goals/goal5
[9] https://morri.netlify.app/
[10] https://cordis.europa.eu/project/id/101022317

[11] https://cordis.europa.eu/project/id/101017857
[12] https://www.naturespots.net/map

MATERIAL KIN: FASHIONING A CELLULOSE-BASED FOAM FLOATATION DEVICE IN CLIMATE BREAKDOWN

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Abstract

Devastating bushfires and flooding have been ravaging the eastern and southern states of Australia since 2019. Living in Australia amidst climate breakdown demands we transition towards regenerative and sustainable material systems, but the challenge posed to designers is how do we design without extractive and exploitative processes? How do we make kin with new materials? Responding to this context, this paper highlights an alternative mode of interaction between materials and designers and shows how a critical design piece can emerge from practice-led research that promotes material kinship. I have developed the Material Kin Relational Ontology (MAKRO) – a framework that promotes a way of working and collaborating with materials and processes where ingredients, materials, and myself are all considered kin. Being kin implies relationships of reciprocity and care, which in the context of bio-based materials design can mean cultivating, cohabiting, and regenerating. This paper will position MAKRO in context and conversation with the *Earth Logic: Fashion Action Research Plan* (Fletcher & Tham, 2019), Haraway's (2016) string figures, Bennett's (2010) *Vibrant Matter* and Stengers' (2018) manifesto for slow science. It will present a case study of MAKRO in action, showing the development of novel cellulose-based foam materials which are then fashioned into a critical design object – a biobased and biodegradable lifejacket responding to Australia's rapidly rising flood waters. The lifejacket is intended to trouble the distinction between a product and a critical design object: it provides buoyancy, but it also prompts those who encounter and use it to imagine a post-petrochemical materials world, a future where we show responsibility and care towards the world and material kin.

Author Keywords

Design research; materials; materiality; ontology.

Introduction

Summer 2019, on the east coast of Australia: the air was thick, smoky and insidious, the sky orange. Sirens wailed from police cars and fire trucks raced down the highway in the opposite direction. We had chosen to cut our holiday short and get out while we could. The beach had not provided comfort; ash and burnt leaves floated on the surface of the water and sand. Growing up in the blue mountains west of Sydney prepared me for this scenario, as bushfires were a present and lurking threat. Sandbags were handmade by neighbours/residents to plug gutters, sprinklers were installed on our roof, hoses were at the ready. However, this summer, for many people, such preparations proved inadequate against the intensity of the fires. Three years later, and during the last week in February, we experienced the wettest seven-day period on record, with over 50 sites in northern New South Wales (NSW) and southern Queensland measuring over 1000 millimeters in rainfall (Australian Bureau of Meteorology, 2022). Lismore, a town in the eastern state of NSW, has now endured two catastrophic floods in under two months. Thousands have been left homeless. Brisbane and parts of Sydney were also severely impacted by flooding. Images of people seeking refuge on the roof of their homes, wet and cold, waiting to be rescued by boats or helicopters were broadcast by Australian mainstream media.

The climate is breaking down because of our reliance on fossil-derived materials and our habits of overconsumption. It has become apparent to many Australians that we need to adapt by reducing our consumption of goods as well as changing our unsustainable material systems. A reduction of resource consumptive actions by at least 75% is required for us to live within the earth's means (Fletcher & Tham, 2019) in order to match our resource consumption to the earth's resource production. Changing our current material systems to produce biobased materials that are sustainable, regenerative, and repairable is one way that we could lower our material footprint so that we can live through climate breakdown and fashion a recuperation of earth.

Designers are still working out our role in this transition. For some of us, this means relearning how to work with biobased, living, and regenerated materials. This paper outlines a methodology relevant to both professional designers and citizen designers working with materials and shows this methodology in action through the development of cellulose-based foam materials. The methodology demonstrates how we can make kin with biobased materials[1] to help us imagine designing without extractive and exploitative processes.

MAKRO

Material Kin Relational Ontology (MAKRO) is the methodology that I have developed and is a way of working and collaborating with materials and processes. The philosophical underpinnings for the MAKRO are mostly concerned with ontology (what exists) and phenomenology (what is experienced) (Smith, 2018). Ontological systems provide classification of a thing, a manifestation or what exists in the world; these classifications help craft peoples' identities and aspirations (Bowker & Star, 1999, p. 4), while also informing our attitudes and actions. For designers, discussions of both ontology and phenomenology are important as they each provide a solid foundation on which to base our attitudes and behaviour towards things, combinations of living and nonliving, human and nonhuman. Alternative ontological systems have also been proposed as a way to overcome dualisms between object and subject (Cole, 2013, p. 106), nature and culture (Wagner, n.d.).

Ontological classification systems used by design practitioners and researchers vary widely, ranging from object-oriented ontology (Harman, 2018), vital materialism (Bennett, 2010), meshwork (Ingold, 2012), actor-network theory (Latour, 2005a), and process philosophy (Whitehead, 1960). Whitehead's (1960) philosophy has informed feminist philosophers such as Haraway (2016) and Stengers (2018). These scholars of ontology have articulated metaphorical ways to describe relationships between making and materials. Harman (2018) articulated "object-oriented ontology," (OOO) a theory for levelling out the ontological differences between the human, non-human, natural, cultural, real, or fictional, as these are all objects. Harman (2018) also discounts phenomenology, arguing that experience exists primarily of objects. There are seven principles for OOO. One of the more challenging is that objects are complete, discrete units and they never touch, which means that there is no exchange or interaction between objects as they are fixed and static. The objects are "being" and not "becoming." For a designer, this stance is conceptually quite challenging and problematic as it proposes materials that are inert, static and unresponsive, which is different from how we think of material and our relationships to the objects we make from them. Bryant (2016) proposes folding to overcome the OOO principle that real objects do not touch. For Bryant (2016), folds and folding are a continuous action so the becoming and being are indistinguishable – the origami of being. The fold is also a link between the field and thing with potential for a multiplicity of folds, folds underneath folds, which are coiled within folds radiating out. Whilst Bryant's (2016) origami of being is a beautiful descriptor of relations between objects, it seems like a poetic workaround to connect OOO to his experience of the world.

Actor-network theory (ANT) was developed by Latour (2005a) and others in the 1980s and proposes that the world is made up of different entities (actors) and linkages between these entities (networks). Agency of the entities is enacted through the relationships and networks between actors. Ingold (2008) later proposed a meshwork instead of ANT: meshwork describes an openness or porosity of entities, which adds further complexity to how these relationships could be understood.

> [Meshwork] is not a closed-in, self-contained object that is set over against other objects with which it may then be juxtaposed or conjoined. It is rather a bundle or tissue of strands, tightly drawn together here but trailing loose ends there, which tangle with other strands from other bundles. (Ingold, 2008, p. 211)

"Leaky things" is another way that Ingold (2012) describes the porosity of entities in meshwork. The deliberate use of the word "thing" is an intentional shift away from the subject/object divide (Brown, 2001), as a thing implies more agency and action than an object. Leaky captures the exchange of "living," where things take from their environment, consume, ingest, and also discharge. Things exist because they leak; this shifts the thinking from solid and defined material culture towards material ecologies.

New materialism argues for the agency of materials and the aliveness of matter, which changes the value placed on it and reshapes interactions with it. Bennett (2010) argues that new materialisms "inspire a greater sense of the extent to which all bodies are kin ... inextricably enmeshed in a dense network of relations" (p. 13).

New materialisms, OOO, and ANT are often grouped together along with speculative realism as all these ontologies promote "being or becoming" as primary, with other forms of philosophical enquiry being secondary. Boysen (2018, p. 225) and Cole (2013) crudely labelled these theories "flat ontologies." The term "flat" is used to highlight the non-hierarchical structure between humans and objects, but it also implies a loss of richness and complexity that is found in all these ontologies.

Feminist philosophers have also worked alongside and adjacent to new materialism and ANT; however, OOO prompted a reply – object-oriented feminism (OOF). OOF brings feminist thinking in the philosophy of things, namely politics, erotics, and ethics (Behar, 2016). OOF uses humour and can adopt multiple, and sometimes contradictory, perspectives. "Shifting focus from feminist subjects to feminist objects extends a classic tenet of feminism, the ethic of care, to promote sympathies and camaraderie with nonhuman neighbors" (Behar, 2016, p. 8).

New materialism perspectives are enriched by concepts from process philosophy, particularly from Whitehead's (1960) philosophy of organism. Organism is a metaphysical alternative to the notion of substance (Latour, 2005b). Organism is where objects momentarily "become" through a complex web of interactions and histories, but then fades away to inform and influence future manifestations. "Concrescence: the many become one and are increased by one" (p. 32) is the term and definition that Whitehead (1960) uses to describe this process. Organism is in stark contrast to substance, where objects endure and exist by themselves (which is the ontological standpoint of OOO). For Whitehead (1960), the philosophy of organism offers an adventure into the unknown as concrescence is an ongoing evolving process.

Process theory has been woven into designers' vocabulary with the term "material processuality" (Tonuk & Fisher, 2020), giving vocabulary to material qualities that shift. Similarly, Ingold (2012) picks up on the changing nature of material qualities and suggests we tell the materials' histories (p. 434). Telling a material's history positions the material not as an object but as a thing that reacts and responds to different environments.

The MAKRO standpoint weaves together many of these theoretical threads to recognise the agency and vitality of materials within a meshwork of relations that are in a constant process of becoming. MAKRO as a methodology is about adventure and creativity (Whitehead, 1967), storytelling, and wild open-ended kinship (Haraway, 2016). Stengers (2021), continuing James's (1940) call that "philosophy must keep the windows and doors open" (p. 100), contends that keeping the windows and doors open is an active ongoing process, which allows for imagination and curiosity to reside with us. MAKRO as a methodology offers a way for citizens to navigate climate breakdown in the Anthropocene by promoting kinship relations between designers and materials. Becoming kin with materials is a way of staying with the trouble of climate breakdown and to continue the ongoing working with kin to fashion a recuperation of earth.

Classifying a relationship formalises the type of relation, but it also brings expectations or rules for exchanges that are applied to that relation. Family relations have expectations of care, solidarity, support. Kinship can carry the same expectations of familial relations, but it can be applied to people who do not share the same genealogy. While kinship between humans is a common occurrence that can be seen in many cultures today, extending kinship to other species or indeed to materials is a radical step, although in Indigenous cultures there are long traditions of more-than-human kinship (Chao, 2018). Haraway (2016) calls on us to "make kin not babies" (p. 160), to embrace unstable definitions and the troubling murky waters of non-human kinship. Becoming in the world with kin allows us to enact new possibilities with matter and the material world. A relational ontology provides a theoretical way for kinship relations to be applied to intra-human relations.

Becoming kin starts with an encounter, exchange, or leak, and it leads to sympoesis.[2] Becoming kin also carries an expectation of care, responsibility, and learning "to live and die well" (Haraway, 2016, p. 140).

Extending Haraway's (2016) work, I also consider design materials in kinship relations. To put material kin in the context of designing for an uncertain future, we might ask what does living well and dying well look like for material kin? Living well requires a slowing down and opening up where we learn about and from each other while we cultivate and cohabitate. Dying well implies disassembling, composting, and ultimately regenerating.

In her book *Slow Science,* Stengers (2018) advocates for slowing down and opening up to questions, different contexts, and becoming sensitive again, sensitive to the frictions and hesitations that speed ignores. To care for our kin, we need to slow down, ask questions, and "know more" both contextually and critically about our kin, which then situates us and holds us accountable (van Dooren, 2014) so that we stay with the trouble. Caring for material kin also recognises material fragility and embraces repair and maintenance as a practice of care (Denis & Pontille, 2015).

MAKRO in Action

MAKRO work is done primarily in a design kitchen. The MAKRO kitchen uses kitchen appliances and recipes, and shares intergenerational knowledge. Using the kitchen as a site of experimentation builds upon MAKRO's foundations of feminist philosophers, environmental humanities, and slow science. The design kitchen is a meeting place that is neither workshop nor lab, where both designers and scientists, professionals and amateurs can come and collaborate. The kitchen can also be understood as a site of care. The book *Foodies* describes how making and sharing food is an act of caring (Johnston, 2015). Situating MAKRO research and the development of novel materials in the kitchen troubles both science and design and allows serendipity, embodied learning, and unexpected collaborations to take place. The kitchen as a site of experimentation also provides an intuitive food-based cooking vocabulary to help "stay with the trouble" as Haraway (2016) suggests. I draw on this lexicon and the kitchen as a metaphor in this section to wade through the murky waters of material kin and MAKRO.

The MAKRO method requires a pantry. This is well-stocked, as it has been accumulating ingredients for quite a few years now. The ingredients in the pantry are either common food ingredients, food grade chemicals, or dried waste biomass. The table below shows the variety of ingredients in the MAKRO pantry grouped into ingredient types.

Water soluble binders	Methyl cellulose, hydroxypropyl cellulose, carboxymethyl cellulose, hydroxypropyl methyl cellulose, hydroxyethyl cellulose, xanthan gum, locust bean gum, gum arabic, pectin, guar gum, modified guar gum, agar, sodium alginate, carrageenan (kappa), amphoteric starch, cationic starch, modified starch, tapioca starch
Food industry chemicals	Vinegar, glucono delta lactone, alum, sodium chloride, calcium chloride, bicarb soda, tannic acid, calcium lactate, cream of tartar, baking powder
Household chemicals	Urea, sodium silicate, borax, soda ash
Plasticisers	Glycerin
Protein additives	Gelatin, Transgluatminase, Gluten, Sodium Caseinate, Albumen
Stabilisers	Microcrystalline Cellulose, Microfibrillated Cellulose
Surfactants	Sodium lauryl sulfate, mono and diglycerides, soy lecithin powder
Waste biomass	Coffee grounds, paper pulp, hemp fibre, sawdust, wool fibre, egg shells, oyster shells
Wax and wax additives	Beeswax, stearic acid, magnesium stearate

Table 1. MAKRO pantry ingredients grouped by type.

Together, the ingredients in the MAKRO pantry and I started to do some initial experimentation using recipes from various do-it-yourself biomaterial cookbooks and resources.[3] Current recipes I use now rely on the knowledge bank from previous tests along with the addition of academic material science papers and industry investigations as well input from polymer chemists. The initial experimentation generated tacit knowledge of the ingredient qualities and uncovered synergies between ingredients. An example of a synergy between ingredients can be found with locus bean gum and agar; combining the two ingredients enhances the ingredient qualities well beyond the properties of each singular ingredient. This experimentation helped to set up the kitchen and other environmental conditions which best suited the samples. The preliminary exploration was undertaken before adding another key ingredient – air.

MAKRO Foam

"Material with pockets of air" is the definition I have developed of a foam-type material. The pockets of air can either be sealed off or the pockets can interlink with other pockets to form a web-like sponge structure. Air can be mixed with material to make foam in many ways, from whipping egg whites (mechanical foaming), to raising agents like baking powder (chemical foaming), to aerosol whipped cream (pressurised foaming), or to a pocketed surface texture like a knitted scarf (engineered foam).

Mechanical foaming techniques were selected as a starting point for investigation as it is an accessible entry point for foam discoveries. Verbs that describe this process include "whip," "beat," "shake," "agitate," and "steam," while the tools used to create mechanical foam range from "fork" to "whisk," "paint stirrer," "milkshake maker," "food processor," and "blender." Mechanical foam requires the material to be aerated while it is liquid and then dried to a solid state.

Cellulose was also chosen as the primary ingredient to undertake mechanical foam testing as it is insoluble, there are various forms of cellulose, and it has the properties of either a binder or filler. Cellulose can also work in different environments with a range of temperatures and pH levels while also having a high level of resistance to mould and other microbes.

I undertook extensive testing of cellulose foam materials, which allowed me to develop a detailed understanding of different foam properties as well as mechanical foaming processes. A selection of the foamed cellulose tests can be seen in Figure 1. The testing led to an ongoing intimate knowledge of the materials, and in some instances, required me to alter my design practice. This series of encounters (tests) was instrumental to forming kinship relations with the foam materials. While I engaged the materials to promote unstable relations with air, the materials answered, instructing me to work with them, forcing me to rethink the processes and methods of working together. Exchanges of this nature are part of becoming kin with material.

Figure 1. Cellulose foam tests.

The material has its own intelligence and its own agency, and it asserts this during the testing and making, showing the agency of materials and the aliveness of matter described by Bennett (2010). The exchanges that took place were subtle but insistent, requiring me to open my way of working and respond to the material. For example, I found that the liquid viscosity of the mixture to be foamed impacted the density of the foam. If a soft billowy type of foam was required, the mixture needed to be quite runny but still sticky (somewhere between the consistency of an egg white and mayonnaise). If the mixture was too runny, the foam would collapse before it dried out, and if it was too thick, it was hard to incorporate the air, or the air would form one big pocket rather than lots of small pockets.

Through making kin with the material, I learnt that low temperatures with low humidity for a long time produced the best results for drying the foam. If the time that the material took to dry was too long, the foam would collapse, and if the heat was too aggressive, it would cause cracking, crumbling, and deflation. Shrinkage of the material and warping also would occur as water left the material, and upscaling the recipes amplified the drying times and foam deflation.

Tests were undertaken to foam mixtures with less water to minimise shrinkage and drying time, but the foams lost their integrity and became a solid material. A solution for how to decrease the water content of the mixture while still maintaining foam integrity was to make a cellulose Eton mess.[4] The cellulose Eton mess is made by combining small pieces of dried foam and short cellulose fibres to a whipped cellulose mixture. The types of dried foam can be varied along with ratios of foam to whipped mixture to make material kin with differing qualities. The Eton process reduces the overall amount of water, speeds up the drying time, and minimises shrinkage and is used to develop the critical design piece.

The MAKRO Lifejacket

The lifejacket I have designed using a MAKRO approach and with the intention of making kin with the foam material is an experiment in transforming foam into a wearable flotation device. It can function as a safety aid to provide buoyancy in an emergency, be worn during a particular activity, or be carried in anticipation of rapidly rising waters. The lifejacket was designed using the MAKRO methodology in response to the weather conditions caused by the Anthropocene and consumption habits that have led to climate breakdown. The lifejacket has been situated in this context, so, while it utilises a biobased alternative to ethylene-vinyl acetate[5] (EVA) foam lifejackets, the goal is not to promote this lifejacket as drop-in replacement for EVA, but to think through solutions for material buoyancy – a crucial property in the context of rising waters

This piece has been modelled to fit within the level 100 lifejacket class, using the Australian standard AS4758 (NRMA, 2021). This means that the lifejacket has a neck brace that keeps the head out of water and provides 100 Newtons of buoyancy. There are more comfortable life jackets that fit closer to the body (level 50) that are designed to maximise the body's movement, but they do not provide any neck support. This lifejacket is designed to be disassembled and packed away as the neck balloon separates from the buoyancy board. Placing the emphasis on storage when not in use implies that the lifejacket is designed to be worn as an emergency item rather than for recreational fishing or sporting use.

Figure 2. MAKRO lifejacket sketch.

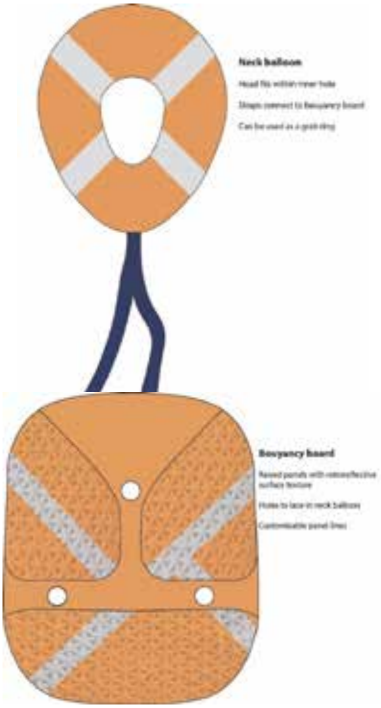

Figure 3. MAKRO lifejacket components.

The MAKRO lifejacket uses a very lightweight foam made from methyl cellulose (MC) and dried brewer's spent grain. MC has a unique property of forming a gel in high temperatures, which allows the moisture to be taken out of the material quickly without deflating the foam too much. The brewer's spent grain is a waste byproduct from brewing beer. In the brewing process, the grain (usually barley) is cracked and steeped in water to extract the soluble sugars from the grain. Once most of the sugar has been extracted, the soggy spent grain is now a waste by-product. The spent grain is quite high in cellulose and hemicellulose with some residual sugars. Brewer's spent grain is a lightweight filler and adds body to the foam without adding too much weight.

A lifejacket should be able to resist and absorb knocks and bumps that might occur; to this end, a strong rigid foam (which looks similar to rye bread) has been developed as a casing for the softer, more buoyant foam of the MAKRO lifejacket. The "rye bread" foam uses carboxymethyl cellulose (CMC), a starch binder, and three different kinds of cellulose. Micro fibrillated cellulose gives it stability as a foam while it is drying. Sawdust and recycled paper pulp bulk out the material and bind strongly with the CMC and starch, while the hemp fibre gives the foam extra reinforcement.

Figure 4. Rigid foam (as a liquid).

Unlike most lifejackets available in Australia, there is no fabric covering the foam of the MAKRO lifejacket. Rather, the foam has been coated with casein waterproof glue, which provides protection from the water. The MAKRO lifejacket has been divided into twelve sections and sealed, so if a leak occurs it can be contained to its section and not jeopardise the functionality of the lifejacket.

Bright yellow is the most common colour of lifejackets available worldwide. The casein coating of the MAKRO lifejacket has been coloured with a vibrant yellow pigment made from turmeric, bought in the spice aisle of a supermarket. The casein coating also gives a gloss shine coating, making the colour punchier.

Retroreflection is particularly useful for search and rescue situations. Retroreflection reflects light from the rescue party back to the source. Retroreflection is produced by the geometry of the interior corner of a cube. The three surfaces of the cube bounce the light from one surface to the next before it is reflected back in the direction of the original beam. To create a space-efficient surface texture, the corner of a cube can be cut off, embedded into the surface, and repeated so that there are many "internal cube corners" on the surface of the object. This surface texture, shown in Figure 5, has been embedded into the surface of the lifejacket.

Figure 5. Multiple internal cube corners surface texture prototype.

Conclusion

In this paper I have introduced MAKRO, a methodology for making material kin. To do so, I began by outlining the conditions of the Anthropocene that have motivated this work: the intense fires and floods on the east coast of Australia – a manifestation of climate breakdown – along with unsustainable resource consumption. Shifting to a regenerative material system – which includes working closely with biobased materials – is then proposed as a way to fashion a recuperation of earth. I then offered a theoretical underpinning to explain how MAKRO was developed, including the threads of new materialism, feminist phenomenology, ANT, and meshwork, and incorporating themes of kinshipand care. Finally, I presented a design experiment applying the MAKRO methodology to the fabrication of the MAKRO lifejacket. This work is ongoing and iterative. The nature of working in a design kitchen with an emerging methodology means there are as many questions raised as there are "finished" products. Some of these questions are: as designers, how can we work with and be responsive to biobased materials? How do we have to change our assumptions on what materials can do and our practice working with them? Together with material kin, how can we foster a culture of care and regeneration? MAKRO offers a guide for developing material answers to these questions and others.

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[1] Biobased materials are materials that are cultivated and sourced from living and growing systems.
[2] “Sympoesis [making-with] is a carrier bag for ongoingness, a yoke for becoming with, for staying with the trouble of inheriting the damages and achievements of colonial and postcolonial natural cultural histories in telling the tale of still possible recuperation” (Haraway, 2016, p. 125).
[3] Recipes such as: *CHEMARTS cookbook* (P. Kääriäinen, N. Riutta, L. Tervinen, T. Vuorinen & Aalto University, 2020), Materiom website (Materiom, n.d.),
https://issuu.com/nat_arc/docs/bioplastic_cook_book_3
https://issuu.com/miriamribul/docs/miriam_ribul_recipes_for_material_a
https://issuu.com/johanviladrich/docs/bioplastic
https://issuu.com/juliettepepin/docs/bookletbioplastic
[4] Eton mess is a British dessert made by combining broken pieces of meringue, fruit, and cream.
[5] Ethylene-vinyl acetate is a common synthetic foam; yoga mats are commonly made with EVA foam.

PREPARING TO REPAIR: USING CO-DESIGN AND SPECULATIVE DESIGN METHODS TO EXPLORE THE FUTURE OF IOT RIGHT-TO-REPAIR WITH CITIZENS AND COMMUNITIES

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Abstract
In an effort to stymie electronic product obsolescence, the U.K. government introduced the Eco-Design for Energy Related Products and Energy Information Regulations, commonly referred to as the right-to-repair, in July 2021. Mirroring the European Union's 2020 *Circular Economy Action Plan,* manufacturers are now required to integrate a degree of repairability into certain electronic products sold within the U.K., as well as supply replacement parts for ten years after production. However, this still does not create an equitable form of right-to-repair as the regulations capitulate to manufacturer-sanctioned repair services, rather than helping to foster innovative, citizen-oriented cultures of repair.

Importantly, the right-to-repair also only applies to a limited range of household products and does not account for the rapid increase in the unsustainable consumption and disposal of networked or so-called "smart" internet of things (IoT) devices. This is despite ever greater volumes of electronic waste being characterised as IoT – it is estimated that by 2030, there will be over 25 billion globally active smart electronic devices (Vailshery, 2021). Furthermore, smart phones, voice assistants and wearables can easily become "bricked" when their physical hardware no longer supports digital updates such as the latest software.

This paper outlines initial research which begins to explore how design approaches can be harnessed to better understand how citizens might be empowered to increase IoT device right-to-repair within their local communities. Our work was carried out as part of a funded design research project which seeks to identify sustainable and equitable pathways that challenge the top-down hegemony which currently characterises IoT right-to-repair policy and practice.

To investigate these possibilities, the research team collaborated closely with The Making Rooms, a community makerspace and the eminent creative hub for digital innovation and fabrication in the northwest of England. The paper firstly discusses how we designed and delivered two co-design workshops (Sanders & Stappers, 2014), during the second of which we introduced right-to-repair speculative design probes (Tsekleves et al., 2017). Secondly, we use thematic analysis techniques (Braun & Clarke, 2006) to map the collated workshop data. Thirdly, we discuss an initial vision for a local IoT right-to-repair ecosystem as co-created with participants. We conclude that our initial findings begin to contribute to growing discourse calling for community adaptation towards circular economy principles (Ellen MacArthur Foundation, 2021) to redress national and international e-waste issues.

Author Keywords
Right-to-repair; internet of things (IoT); e-waste; social innovation; circular economy; sustainable futures

Introduction

As the consumption of electrical and electronic equipment (EEE) continues to grow, so too does the volume of electronic waste (e-waste) reaching global landfill sites. In 2019 alone, the world generated 53.6Mt (million tons) of e-waste, a figure which is expected to grow to 74.7Mt by 2030 (Forti et al., 2020). Across Europe for example, less than 40% of e-waste is subject to sustainable recovery, that is, “post-lifespan” processes such as material recycling and reusable component harvestry (Eurostat, 2021). This unsustainable growth is reinforced by planned obsolescence – which is to say that devices are purposely designed to have short lifespans and be quickly usurped by newer models and lack specification for long-lasting repair (Remy & Huang, 2015; Cooper & Salvia, 2018).

In an effort to stymie electronic product obsolescence, the U.K. government introduced the Eco-Design for Energy Related Products and Energy Information Regulations (Conway, 2021), commonly referred to as the right-to-repair (R2R), which came into effect on 1st July 2021. Importantly, the current R2R also only applies to a limited range of household products and does not take into account the growing environmental and social impacts that result from the unsustainable production, consumption and disposal of billions of networked and so-called “smart” internet of things (IoT) devices like phones, fitness wearables and home voice assistants (Stead & Coulton, 2022).

This paper outlines initial research which begins to explore how design approaches can be harnessed to better understand how citizens might be empowered to increase IoT device R2R within their local communities. Our work was carried out as part of a funded design research project which seeks to identify sustainable and equitable pathways that challenge the top-down hegemony which currently characterises IoT R2R policy and practice.

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Right-to-Repair

Legally and ethically complex, the current U.K. R2R legislation mirrors the E.U.'s *Circular Economy Action Plan* (2020). The legislation's key proviso is that manufacturers must begin to integrate degrees of repairability into certain electrical/electronic products that they produce and sell, as well as supply replacement parts for said products for at least ten years after manufacture. Whilst these stipulations might appear progressive, U.K. citizens' R2R and reuse the products they have purchased is still impeded as the legislation only sanctions "authorised" third parties to carry out repair work. Furthermore, the R2R does not ensure that spare parts and repair services will be affordable nor that consumers will have access to the information they require to personally carry out repairs themselves (Peake & Vallauri, 2021).

Importantly, as illustrated in Figure 1, the law's focus is also restricted to six specific types of products (West, 2021). The legislation currently ignores the growing volumes of EEE being characterised as IoT products – physical electronic objects which have built-in wifi, sensor and software capabilities. These products can connect and transmit data to and from internet platforms/services as well as with fellow internet-connected devices. It is estimated that by 2030, there will be over 25 billion physical IoT devices being actively used worldwide (Vailshery, 2021). Unfortunately, due to the way they are presently designed, IoT devices can easily become "bricked" (inoperable) when their hardware physically breaks or they can no longer support digital updates such as the latest software (Stead et al., 2020). Consequently, billions of IoT devices will likely end up in landfill sites as e-waste.

Thus, whilst the law requires manufacturers to begin to (re)design products for repairability, it does not create an equitable form of R2R. The regulations capitulate to manufacturer-supplied parts and approved repair services, rather than helping to foster innovative, citizen-oriented cultures of repair. The latter, Perzanowski (2022) asserts, is crucial for modern societies because as "we diagnose and fix the things we own, we are reconfiguring our interactions with the world around us...we are refining our understanding, developing new skills, and strengthening social ties within our communities."

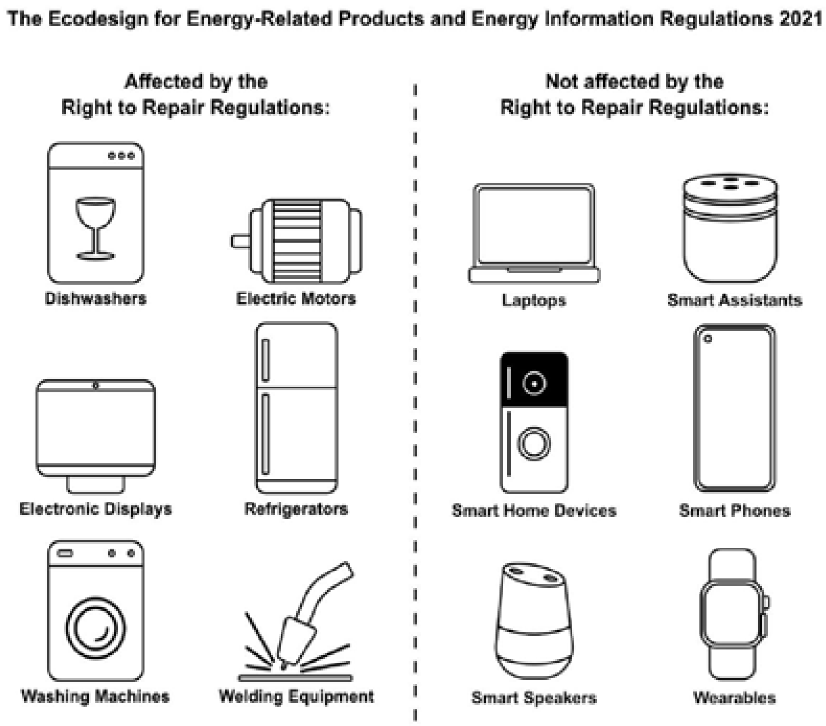

Figure 1. The limited range of electronic products included in the current "Right-to-Repair" legislation (left) compared with the growing numbers of IoT devices not sanctioned for citizen or even professional third-party repair (right) (after Conway, 2021).

Preparing to Repair

To curtail the Western trend of disposing of electronics in their entirety (Cooper, 2010), activist groups like Right to Repair Europe (n.d.) and the Restart Project (n.d.) have long highlighted the deleterious impacts of e-waste and campaigned on the benefits of product repair and reuse. Rooted in maker, hacker and open-source communities, this grassroots movement aligns closely with circular economy thinking (Ellen MacArthur Foundation, 2021). The introduction of the new legislation for E.U./U.K. citizens is thus a step forward in tackling planned obsolescence and can undoubtedly be viewed as a positive outcome for the R2R movement.

Yet, in the long term, the efficacy of the new R2R law will ultimately be reliant on citizens and their communities availing themselves of this right. Given that repairing and maintaining devices often requires specialist knowledge, skills and tools, it will be difficult to assess how effective this right may prove to be in practice. Furthermore, due to their complex, physical/digital nature, it is more difficult to maintain and repurpose IoT devices than conventional non-connected counterparts (Stead & Coulton, 2022; Perzanowski, 2022).

Initiating Partner Collaborations
Rather than choosing to investigate the above issues through a broad lens such as, for example, a national framework, at this early stage of our research we wanted to focus on a localised, situated context for future R2R. This, we posited, would help us start to better assess and understand the effectiveness of current R2R legislation amongst citizens and communities as well as consider how far the law must evolve to include IoT repair, which stakeholders should be involved in such developments and to what extent. In addition, this approach enabled us to begin to consider the role that design can play in facilitating such social and environmental transitions – both in practical and theoretical terms.

Partnering with the well-connected community makerspace The Making Rooms afforded us the opportunity to directly engage with a wide range of key stakeholders. This engagement took the form of two foundational workshops, discussed below.

Design Methods for Engaging with Stakeholders
Doos et al. (2016) determine the common method for exploring the benefits and challenges that new technologies and their regulatory policies pose for future society is to converse with “experts” drawn from industry, academia and government. Tskeleves et al. (2017) stress that this approach can be problematic as it regularly excludes citizens from the development phases of technologies/policies that will ultimately have direct effect upon said citizens when implemented. Thus, as Irvin et al. (2004) assert, increasing the type of stakeholders included in these important dialogues should be seen as an “ethical opportunity.” These arguments are highly pertinent to the ongoing implementation of current R2R legislation, as well as to how it might be expanded to include IoT. These perspectives therefore informed the planning of our two workshops.

Firstly, to gauge *informed* perspectives regarding current R2R law and the likely drivers, barriers, risks and benchmarks that need to be considered to potentially expand the policy for IoT, we chose to hold an initial workshop with “expert” industry, academia and local government stakeholders. Our workshop delivery was built around six key research questions:

1. What is your opinion of the current R2R legislation and its scope?
2. Have you seen any changes or impacts following the introduction of the legislation?
3. What do you think of existing support for repair or e-waste collection/recycling?
4. How accessible are current repair infrastructures?
5. What are your thoughts on smart devices and their capacity for repair?
6. Who do you think are the key stakeholders required to create a local smart device repair ecosystem?

For our second workshop, we wanted to collaborate directly with citizens to explore the relationship between R2R and IoT. The democratic approach of co-design (Simonsen & Robertson, 2013) was the most appropriate method for us to utilise. Steen et al. (2011) emphasise that through co-design techniques, citizen participants are essential to the design process. Empowering them in this way means that they can creatively contribute their personal experience, knowledge and expertise to generate new insights within the collaborative environment (Sanders & Steppers, 2008).

Following Sanders & Stapper's (2014) "co-design framework" to help facilitate valuable discussion regarding our six key questions, we incorporated a series of design probes. Sanders & Stappers (2014) contend that this approach allows researchers to create a "generative space" for both "designing with" and "designing for" their participants. For the creation of our probes, we drew upon speculative design practice (Auger, 2013), specifically design fiction (Bleecker, 2009). Bowen (2009, 2010) argues that speculative interventions are extremely useful as they help multiple stakeholders begin to collectively think prospectively and critically about possible future alternatives to the present-day status quo. Baumann et al. (2017) emphasise the potential of such probes to facilitate participants in considering timely social, ethical and legal debates. Speculative design probes can take many forms including, but not limited to, tangible 3D objects, 2D visualisations, drawings, games, scenarios, installations, storytelling and written documents, as well as integrate techniques from art, literature, film, psychology, philosophy, anthropology and ecology (Tskeleves et al., 2017).

Workshop 1 – Engaging Informed Stakeholders (WS1)
Our first workshop was held virtually in April 2022. Nine participants were in attendance and represented a variety of sectors – technology design and manufacturing, local government, consumer rights organisations and academia. The two-hour workshop was staged and audiovisual was captured using a combination of the online video conferencing platform Zoom and the interactive whiteboard platform Miro. The decision to run the workshop online was twofold: the effects of the Covid-19 pandemic were still present in the U.K. at the time while virtual attendance also made it easier and quicker to bring participants together who were dispersed geographically across the country.

The aim of this first workshop was to gauge *informed* perspectives and attitudes with regards to the current R2R law and to also ensure that the research team's understanding of the existing practicalities and challenges for possibly repairing and reusing electronic devices was accurate. The six questions posed to the workshop participants (above) were designed to provoke responses on the technical design requirements of current IoT devices, the existing repair infrastructure that surrounds the end of life of IoT and helps or hinders sustainable IoT reuse and whether the recent legislation caters for an inclusive, equitable society.

Participants were logged into Zoom and Miro at the same time and could interact with both platforms in real time. We therefore encouraged them to actively make use of the Miro platform as a location to note any additional thoughts or comments related to the main line of discussion that was taking place on Zoom. To facilitate this, each of the six key questions was given its own individual "mini-board" on Miro. The six "mini-boards" were also divided into four future-focussed quadrants – driver, opportunity, risk and barrier. Participants were asked to place their virtual Post-It note(s) into the quadrant that they felt best corresponded with their comments and ideas. Prompts and "agreeance markers" were also included as part of the activity – the latter could be used by participants to signify their agreement with another participant's comment. We felt this "semi-structured" process would help the research team to identify deeper levels of data granularity during

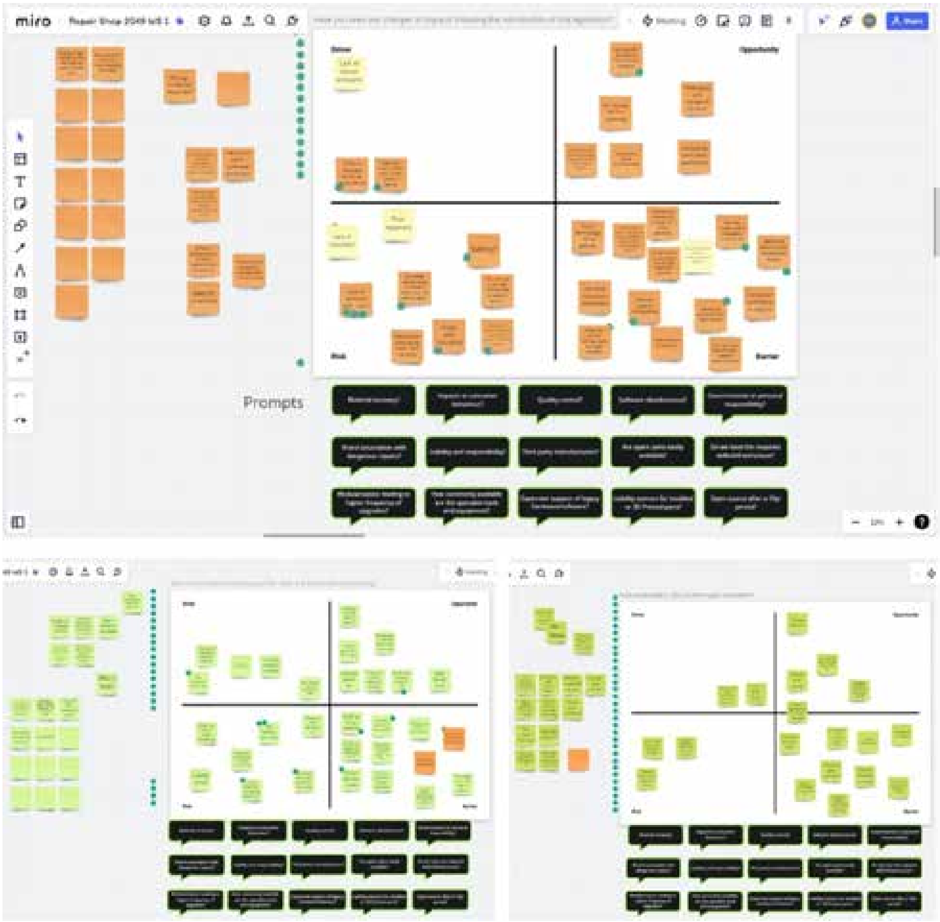

Figure 2. The "mini-boards" designed for each of the six key questions on Miro and used by participants during the virtual workshop to share insights. Question prompts and "agreeance markers" (green dots) can also be seen.

Workshop 2 – Engaging Citizen/Community Stakeholders (WS2)
The second workshop was an in-person event held in Blackburn town centre at the start of May 2022. There were a total of twelve participants in attendance who represented local repair professionals, repair enthusiasts, makers and community group members alongside the research team. Like the first event, the workshop's audiovisual component was recorded but this time via a video camera and digital voice recorder. The objective of this workshop was to open democratic and inclusive dialogue directly with members of the local Blackburn community who likely experience regular issues with the existing R2R framework and who could potentially benefit from positive changes to the legislation – including its embrace of repairable IoT hardware and software. For delivering this workshop, The Making Rooms' digital fabrication lab granted the research team access to a vacant retail space sited opposite the lab in Blackburn town centre.

To ensure consistency across both workshops, we asked the participants the six key questions we posed to "informed" stakeholders in the first event. As the discussion flowed, the participants were similarly encouraged to write and share any comments and responses in note form onto a whiteboard, but this time physically, using Post-It style memo squares which they could place onto a large sheet of paper split into the four quadrants. Each time the discussion regarding a particular question had drawn to a natural close, the quadrant sheet containing all the corresponding comments was removed from the table and pinned on the retail space's wall (Figure 4, top row). This created a visual record of the workshop's progress.

Significantly, the use of the retail unit also granted the research team the time and space to introduce at various points three speculative design probes (Sanders & Stappers, 2014; Tskeleves et al., 2017):

- Smart Device Bingo game (Figure 5) – designed to "kickstart" conversations regarding IoT R2R, we introduced this "icebreaker" probe at the beginning of the workshop. We wanted to better understand what types of IoT devices were owned by the participants and which electronic products they believe to be covered by the current R2R.
- 3D printed modular smartphones (Figure 3, top left) – with their modular hardware, Fairphone's smartphones (2022) are, to a degree, repairable. The brand and its devices have yet to become a mainstream choice amongst end-users however. Other precedents for smartphone repairability are Google's Ara modular phone concept (2022) and the PhoneBloks project (n.d.). Using the latter's open-source design files, we 3D printed tangible models for participants to interact with and discuss in the context of future IoT device repair.
- Self-Service IoT Repair Station (Figure 3, top right and bottom) – to begin to demonstrate the range of equipment required as well as the expertise needed to carry out localised repair, we installed a fictional future IoT repair station in the retail space.

Our probes were used as a means to provoke discourse and ideation practices amongst the workshop participants (Knutz et al., 2014). As Huusko et al. (2018) emphasise, such probes can be "used as a workshop tool [but] while the workshop context creates certain needs for the tool, [the probes] can help in building the workshop." Originally scheduled for two hours, the enthusiasm and engagement of the participants was such that the workshop continued for around four hours total.

Analysis

To analyse the data, we employed thematic analysis techniques. Braun & Clarke (2006) explain how this technique can be utilised to interrogate and interpret the participants' qualitative feedback as collated via the workshop activities. We followed their process of "data familiarisation" and iterative coding to identify recurring themes – "patterns of shared meaning underpinned by a central concept" (Braun & Clarke, 2006) – within the collated data. These themes are outlined in detail in the following sections.

Figure 3. (top left): 3D printed modular smartphone prototypes. (top right, bottom): Participants engage with the speculative Self-Service IoT Repair Station during the workshop.

Results

Informed Insights

The prevailing sentiment towards the current R2R amongst the first workshop's participants was one of disappointment. They argued that it denies the decentralised and democratic repair of IoT devices in the U.K. The participants were not only critical of the narrow scope and reach of present R2R but also lamented the manner in which IoT device/service manufacturers, and electronic product producers in general, continually push back against intergovernmental, activist and citizen-led attempts to make the industry more environmentally and socially responsible, accountable and sustainable through the conception and implementation of such regulations as the R2R. To this end, three key themes emerged during our analysis of the first workshop's discussions.

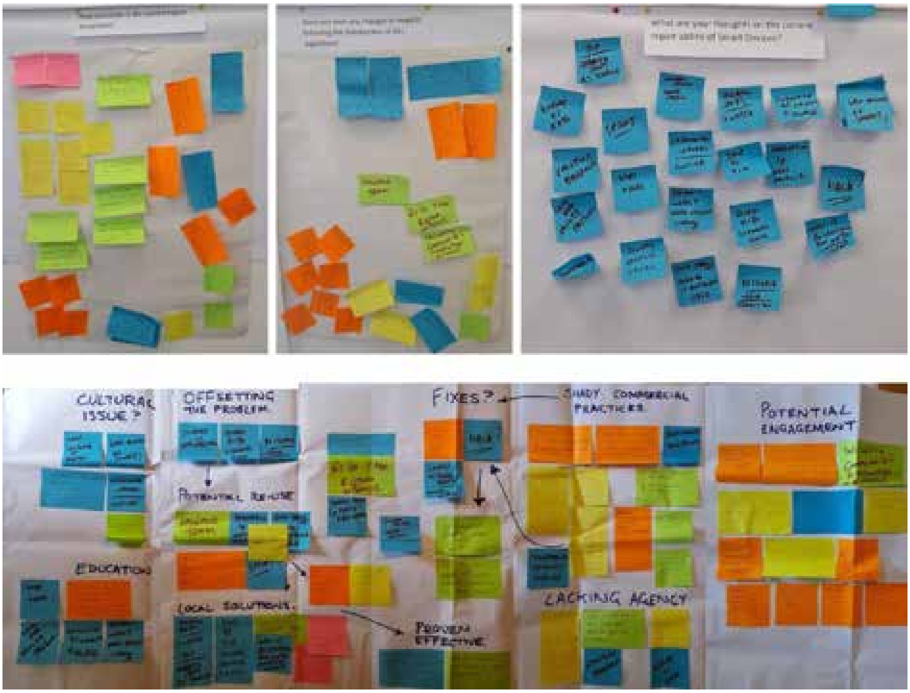

Figure 4. (top row): The range of participant comments collected during the second workshop. (bottom row): The combined "thematic mapping" (Braun & Clarke, 2006) as carried out during the post-workshop analysis process.

The Difficulties of Repair

There was no shortage of criticism levelled at the lack of existing networks and infrastructure available for repairing IoT. Participants persistently pointed out that very few manufacturers are supportive of the R2R and that these entities hold dominion over the transition to IoT repairability. This hegemony is demonstrated by the way manufacturers continue to release products that are not designed to afford effective and efficient repair and reuse. Examples include how it is regularly difficult to carry out simple forms of fault diagnosis on IoT devices and when parts are eventually replaced, there is a stringent requirement for these to be validated by the original manufacturer, or if very lucky, a registered third-party supplier.

Participants also confirmed that in many instances, a device's warranty often becomes void should any repair work be attempted by anybody other than the original manufacturer. This annulment can even be triggered through initial diagnostics to ascertain the root of the problem – not through any actual repair work. This led to discussions regarding third party repairers increasingly becoming risk – and therefore repair – averse due to fears of revoking liability and negating customer warranties through the work they attempt to carry out.

Further criticism was also levelled at the current legislation since it does not include repair support for device/network firmware nor for wider yet operationally essential forms of software. Participant 7 (WS1) opined that this design *and* policy flaw were increasingly to blame for IoT devices becoming inoperable (or "bricked") when they are no longer supported by the manufacturer and/or associated service platforms, regardless of whether the devices' hardware remains functional. Interestingly, a key point raised by participants was that there was also growing concern amongst policy-makers and end-users that should devices become more easily repairable, they could consequently become less reliable and durable due to changes or even deterioration in their physical and digital specifications.

Changing Attitudes
Crucially, participants also countered the above criticisms with a number of optimistic contributions with regards to our relationship with IoT technology and its impact on the environment. Participant 2 (WS1) stressed that there has been a perceptible shift in greater consumer adoption of professionally refurbished products in recent years. They noted how more and more consumers are deciding that they do not always need to purchase a brand-new device nor the latest "throwaway gadget." The participants collectively determined that the impetus for this shift is likely the result of increased public awareness surrounding the global challenges that modern societies currently face, principally climate change and the need for Global North countries in particular to transition to more sustainable ways of living.

The prospect of the E.U. possibly broadening their R2R legislation to include IoT devices was also actively raised. All participants agreed that such a change would result in a positive impact across Europe as it would help to start to reduce e-waste streams. It was also posited that such a move could also force the hand of the U.K. government to follow suit and make similar amendments.

Opportunities for Education
The final key theme that emerged from the first workshop was the potential to improve knowledge and education of repair. The discussion around this particular subject was led by two participants who were representatives of the local council. Participant 5 (WS1) and Participant 9 (WS1) explained that there are plans currently being drawn up by the local educational authority to improve schooling and run specific lessons regarding basic electronics repair and reuse/recycling processes. This led to further discussions around the capacity for introducing electronics repair and reuse as fundamental and applied skill sets across U.K. STEM subject curriculums (STEM stands for science, technology, engineering and mathematics – these four subjects are considered critical, interrelated disciplines in the U.K. education system). It was felt that such developments presented a considerable opportunity which could feed into wider attempts to educate the U.K. public about the R2R legislation, their technology consumer rights and sustainable social, environmental and technological transitions in general.

Citizen/Community Insights
We commenced the second workshop with our icebreaker probe Smart Device Bingo. Each participant was asked to mark on their game sheet which of the depicted "smart

devices" they owned, and which they thought would be covered by the existing R2R legislation. The collected responses are shown below in Figure 5. The figure indicates that there is a low level of awareness amongst our citizen participants regarding the R2R. This was affirmed following the bingo game. The majority of participants stated that they had not even been aware of the new legislation prior to attending the workshop.

Significantly, the second workshop's discussions, whilst similarly critical of the practices of IoT device manufacturers and the insufficiencies of current repair infrastructures, were primarily centred on the unsustainable behaviour and ongoing attitudes of consumers. Having analysed the workshop's data, a second set of three key themes emerged.

Distrust in the System

The community participants displayed an evident "distrust in the system" when discussing both IoT manufacturers' ongoing unsustainable practices, and the current lack of local IoT repair/recycling infrastructures. Similar to discussions in the first workshop, participants found manufacturers untrustworthy when it came to providing continued hardware and software support for their devices. Several agreed that they feared the wider introduction of restrictive software by manufacturers designed to artificially impinge upon – or "throttle" – their devices' capabilities and consequently limit their hardware and battery lifespan over time. It was also suggested that manufacturers are unethical in their approach to the design of current IoT devices as there is little-to-no support for their long-term durability and repair.

Figure 5. The collated results of our icebreaker probe – Smart Device Bingo – depicting the number of participants who own the featured IoT devices alongside which electronic products they believe to be covered by the R2R – the correct devices are highlighted in orange.

Participant 6 (WS2) bemoaned how, in previous generations, electronics and electrical goods used to be "socially valuable" and actively repairing such products was part of everyday life. They felt that these repair practices, businesses and mindsets have all but been eroded over recent decades as technology has become widespread, cheaper and therefore more disposable. There was further distrust and disappointment amongst the participants with regards to what they consider a poor standard of local e-waste collection and recycling services/facilities. Several participants expressed their anger towards the nefarious practices exercised by a number of privileged Global North nations who strive to offset the problem of e-waste by shipping it to Global South countries rather seeking to improve repair or sanction manufacturers and retailers.

Friction

Building upon the above conversations, Participant 8 (WS2) introduced the term *friction* to describe the barriers faced by consumers when trying to handle and dispose of their e-waste in a sustainably appropriate manner. The participants' consensus was that there is a collective "want to do the right thing" regarding the e-waste they were generating but it was often unclear what the positive move could or should be and how they might initiate such a shift. It was suggested by Participant 3 (WS2) that a main contributing factor to this inertia was a lack of education regarding the impacts of e-waste on the planet and societies. Participant 4 (WS2) strongly concluded that this was in large part a cultural problem – specifically a Western mindset – since in other parts of the world, they have very different attitudes towards the economic and social benefits of repair, with devices' ongoing repairability being a major factor when making the decision to purchase a particular product or not.

Improving public awareness and education was consequently raised as a method for better equipping U.K. citizens and local communities with basic knowledge for understanding both their repair rights under the legislation and how to discern if an IoT device is likely to be repairable or requires further investigation and support from expert repairers/repair services. Subsequently, several examples of "repair hacks" were discussed which had been completed by online community members to fix hardware/software issues that had been identified by other members. Whilst the group agreed that "hacking" technology and devices was a "good thing," they collectively concluded that people should not be in a position where this is necessary in the first place, since device repair support should be now provided by the manufacturers/service providers.

Local Solutions

Given the community-oriented pedigree of the participants, they were eager to highlight how to both "localise" repair and reuse of IoT and emphasise that the solutions to do so were already present and correct within the community. A primary idea put forward was collecting e-waste from residents and/or refuse centres for refurbishment and materials and components recovery. Renewed devices could then be sold in charity shops, while harvested parts could be dispersed for appropriate reuse or recycling. This network could run in conjunction with existing local council and charity network schemes. Anecdotal stories from participants who had experience attending and using the services of local "Repair Cafés" were also offered. Importantly, Participant 8 (WS2) and Participant 2 (WS2) noted with excitement that solutions such as these could also provide means to engage with and include disadvantaged communities and groups in repair and reuse practices.

Co-Envisioning a Localised IoT Right-to-Repair Stakeholder Ecosystem

The mix of optimism and urgency that is required to instigate effective sustainable transitions informed the final task we requested our second workshop participants to complete. Lyckyi et al. (2018) discuss how participatory activities can also be employed to facilitate "the creation and use of [further] design fictions." Indeed, for the final task, participants were asked to work together to speculate with regards to what a future local IoT repair ecosystem might look like – specifically, could they collectively envision who the key stakeholders in such an ecosystem might be?

This collaborative process led to the creation of a "low-fidelity" socio-technical imaginary for a future local R2R IoT ecosystem. Figure 6 depicts a graphic iteration of this speculative vision. The participants' imaginary aims for the minimum amount of e-waste to be dispersed to recycling centres, or worse, landfills, by integrating a combination of sustainable channels and responsible stakeholders. This criticality is significant as it identifies our participants' main concerns regarding the relationship between R2R and IoT devices.

Using socio-technical imaginaries as a design frame is an effective approach for creating a shared vision of the social, technological, economic, political and environmental impacts that must be negotiated to achieve constructive, collective change (Jasanoff, 2015; Speed et al., 2019). This method also corresponds with Ceschin & Gaziulusoy (2016) who argue that while the sustainability of individual products and services is important, we must start to design more holistically for the wider infrastructures and ecosystems that give rise to problems like e-waste. This is so that we can one day collectively transition beyond these issues.

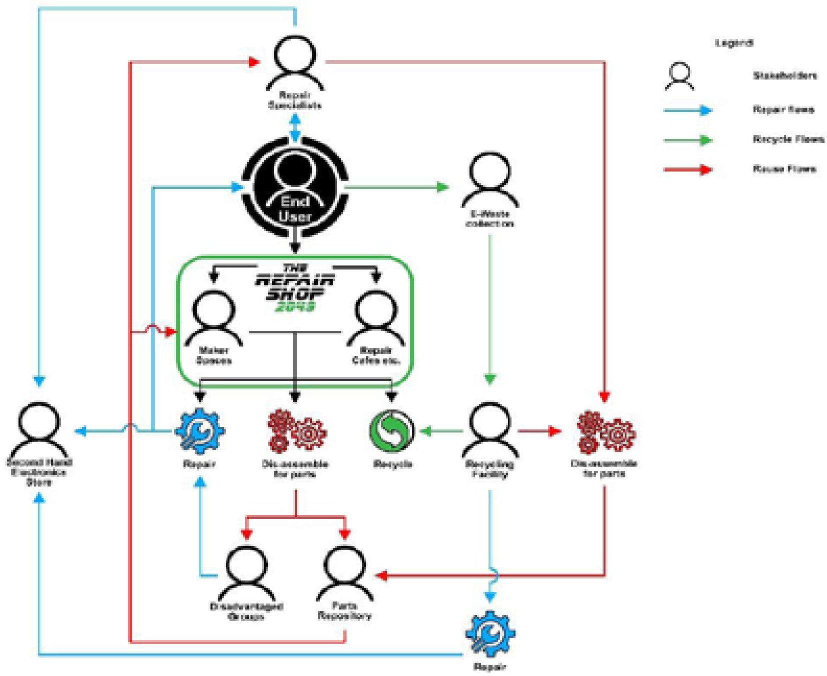

Figure 6. A speculative closed-loop local IoT repair ecosystem as co-envisioned by the citizen/community workshop participants.

Repairing the Future

This preliminary research has helped to lay the foundations for impactful follow-on work (in the form of further funded research) through which we will continue to explore the convergence between IoT R2R ecosystems, sustainable socio-technical development and citizen-driven innovation. At the close of the second workshop, participants were invited to join a Whatsapp group to be kept up to date with the progress of the research. This has resulted in an active group who have been regularly sharing ideas and relevant repair case studies. Trust has been built between the research team and The Making Rooms/Blackburn community. Our work with the workshop communities will hopefully help us to “recruit” further stakeholders to be part of the forthcoming research activities.

Future work will include new workshops to further solidify the granular connections between key stakeholders, supply chains and physical-digital resources. To aid this process, we will also produce more advanced speculative design probes that critique the limitations of today’s R2R legislation, while at the same time offering potential visions for more sustainable and equitable repair futures. We also plan to run practical workshops with partner The Making Rooms to upskill the local public in basic IoT device fault diagnosis and repair.

Conclusion

Through this research, we have revealed a number of the drivers and opportunities that both of our stakeholder groups foresee as necessary efforts to scale up IoT R2R practices and infrastructures. Equally, several barriers and risks were also outlined; a key issue for both groups is the lack of public awareness of the current R2R and how it falls short with regards to supporting better repairability of existing IoT devices and the volumes of devices that will proliferate throughout society in the years to come. Both groups acknowledged that, although consumers are becoming more galvanised around certain sustainable practices such as low carbon travel and ethical food choices, a throwaway electronic device culture still persists across society. However, they also highlighted how this lacuna creates an opening for education – increasing public awareness of the need for, and training in relation to, IoT device repair, as well as improving access to knowledge and tools. This, our participants felt, is an opportunity to be actively seized; they also felt that such education could commence early in communities during school years so that succeeding generations possess the innate competencies to complete device repair.

Our participants also spoke of a "distrust in the system" and that power dynamics regarding repair currently favour manufacturers and service providers over device owners. This leads to what was described as "friction" where, due to the said power hierarchy and lack of an available IoT repair infrastructure, it is exceedingly difficult to carry out and/or solicit effective repair at a local or wider level. As Mattern (2018) stresses, "repair" is regularly framed through negative rhetoric – that is, it is a sign of a decadent and decaying society, yet it should, she contends, be considered more as a positive reflection of societal agency and a driver for change. Both groups also highlighted further concerns, including the need to ensure that next-generation IoT devices are designed so that repair is safe to practise, that their software is (to a degree) repairable alongside their hardware and if future repairs are carried out by citizens/communities directly or through third parties, producers evolve device warranties so that they are still preserved. This said, overall, our participants also shared a similar positive perspective to Mattern (2018). They were steadfast in their collective enthusiasm and drive for making positive steps toward a more sustainable and equitable form of IoT R2R. Indeed, for both groups, localised, democratised repair and reuse of IoT devices was posited as a genuine, feasible route forward. This is reinforced in the coenvisioning of the localised R2R stakeholder ecosystem (Figure 6).

Fundamentally, there is a need to develop new ways to extend and improve the lifespans of billions of IoT devices. E-waste generated via IoT is a significant contributor to the rise in harmful carbon emissions which contribute to global climate change. Resultantly, we contend that our findings, although emergent, begin to contribute to a growing discourse which calls for community adaptation towards circular economy principles (Ellen MacArthur Foundation, 2021) to redress e-waste as well as wider international imperatives to achieve Net Zero 2050 decarbonisation targets (Global Climate Action, 2020; IPCC, 2021).

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PROPOSAL FOR A WORLDBUILDING CURRICULUM

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Abstract
Design practice, adaptive or otherwise, requires research to inform its work. In addition to instruction in design tools, technologies, and methodological practices, a well-rounded design education course must propagate the intellectual knowledge and emotional dispositions, as well as the ethical and cultural awareness essential to creating visionary, equitable, and sustainable solutions for present and future global design opportunities. In response to the challenges of what has come to be termed the Anthropocene (i.e. the current geological age in which human activity is seen to have a dominant influence on climate and the environment), the Worldbuilding Curriculum proposes a pedagogy for a planetary imaginary that transcends physical, political, and ideological boundaries. The curriculum draws upon scholarship from a global, postcolonial perspective, situated within the humanities, sciences, and design theory. It investigates broad conceptual categories to develop a deeper understanding of critical domains affecting the planetary future, and hence their implications for the strategies and tactics designers might employ in response. The Worldbuilding Curriculum is intended to be applicable to undergraduate or graduate study or used as a basis for professional development and is broadly relevant to other disciplines.

Author Keywords
Curriculum; theory; planetary imaginary; sustainment; worldbuilding.

Introduction
In "The Social Life of Design," Appadurai (2013) states, "Human history … could be re-written as a history of design" (p. 254). For Appadurai, design is not only the purview of traditional artisans or modern industrial professionals; it is more broadly a mode of adaptation, the way in which humans have creatively sought to acclimate, as it were, to their environment, from the fashioning of the earliest prehistoric tools to the latest digital technology innovations. Moreover, design is not simply limited to the creation and production of functional objects; it is an essential part of social interaction and meaning-making, from the

simplest prehistoric societies to contemporary global civilization, including the systems and cultures within which they circulate. Design objects do not exist in isolation but are connected in a chain that extends from the things themselves to the physical, social, and cultural networks of which they are a part.

For example, the modern toaster sitting on the kitchen counter presumes the ability to connect to the electric power grid outside the home and exists in everyday life as part of a Western cultural practice known as "breakfast" (Molotch, 2005). Arguably more dramatic, the private automobile is connected to a system of "automobility" (Urry, 2004), the vast complex of technical, economic, social, and cultural networks of original equipment manufacturers (OEMs) and multi-tiered global supply chains; sales, distribution, and service centers; petroleum extraction, refining, and distribution; commercial and consumer finance; road construction and maintenance; urban and suburban development; and more. Automobility is on the cusp of major transformation with the proliferation of electric vehicles and autonomous driving, both of which require radically reconfigured infrastructures and supply chains as well as regulatory systems.

Certainly, the primary challenge for design in the present is responding to the environmental conditions of what has come to be termed the Anthropocene, the current geological age in which human activity is seen to have a dominant influence on climate and the environment (Crutzen, 2002; Crutzen & Stoermer, 2000). Climate change, or more accurately planetary warming, and other deleterious effects on the environment have been increasingly exacerbated since the mid-twentieth century as part of what is termed "The Great Acceleration" as industrial civilization has proliferated around the world (Steffen et al., 2015; McNeil & Engelke, 2016). Earth systems scientists have tracked the positive correlation between socio-economic trends tied specifically to economic activity, such as urban population, gross domestic product (GDP), primary energy use, fertilizer consumption, transportation, and telecommunications, since the early eighteenth century with earth-system metrics such as greenhouse gasses, surface temperature, ocean acidification, tropical forest loss, and terrestrial biosphere degradation, the most exponential impacts of which have occurred since 1950. Designers have contributed to those negative trends, albeit for the most part inadvertently, given their position within the industrial process.

In response to the challenges of the Anthropocene, the Worldbuilding Curriculum proposes a pedagogy that embraces a planetary imaginary (Chakrabarty, 2021), transcending existing physical, political, and ideological boundaries. The Worldbuilding Curriculum is an attempt to "[bring] theory to design so as to be able to think design in new ways in order to develop new design practices" (Fry, 2009, p. vii). Indeed, as Fry (2009) notes, "it is no longer possible to be a responsible designer and act ethically as such without being theoretically literate" (p. vii). The term worldbuilding was first used, according to the Oxford English Dictionary (OED), by Eddington in 1920 to describe the creation of hypothetical worlds with different physical laws as part of articulating the theory of relativity. It is now more commonly used to describe the construction of environments, from the micro to the macro, in fiction, film, game design, virtual reality, and other media. Recently the worldbuilding concept has been used to describe the ways in which architects and designers over the past century have fashioned world-scale projects to realize a planetary future (Sarkis et al., 2020). It is this last sense from which the Worldbuilding Curriculum takes its cue.

The Worldbuilding Curriculum draws upon scholarship from a global, postcolonial perspective, situated within the humanities, sciences, and design theory. (See, for example: Chakrabarty, 2021; Escobar, 2017; Foster et al., 2010; Fry, 2009; Santos, 2016; Tassinari & Staszowski, 2020.) It investigates broad conceptual categories to develop deeper understandings of critical domains affecting the planetary future and hence the strategies and tactics designers might employ in response. The Worldbuilding Curriculum supplements technical and methodological instruction to facilitate a well-rounded design education course that propagates the intellectual knowledge and emotional dispositions as well as the cultural awareness and ethics essential to creating visionary, equitable, and sustainable solutions to present and future global design opportunities. It is adaptable for undergraduate or graduate study or as professional development. It is broadly applicable to the discipline at large, as well as to other disciplines, and is a work in progress.

Conceptual Categories

The Worldbuilding Curriculum has defined five broad categories of investigation to outline, question, and develop deeper understanding of the theoretical domains affecting the planetary future and thus design practice:

- **Culture:** the complex and diverse structures, relationships, and meanings that govern individual and group human interactions, whose emergence in prehistory signified an evolutionary milestone of the genus *Homo.*
- **Communication:** all forms of data and information flows, from genetic code to the binary digit, as well as the media through which they have been transmitted and archived, past and present.
- **Technics:** skills, methods, and processes that humans have used to adapt to the environment, from the rudimentary implements of the emergent genus *Homo* 2.3 million years ago to the latest digital mechanisms and networks of the present.
- **Exchange:** the broad range of interactions between various life forms, vectors, and objects, including sentient and non-sentient actants (Latour, 2007), as they have evolved on a planetary scale.
- **Ideas and ideals:** the origins and development of the nöosphere (Vernadsky, 1945), the third stage of planetary evolution, from inanimate matter – the geosphere – to the biological layer – the biosphere – to the emergence of sentient beings, especially humans, whose consciousness and environmental interventions (Haff, 2013) have transformed the geosphere and biosphere, and whose impact threatens a new mass species extinction.

Outcomes

Adopting Guattari's (2008) ecosophical principles, the Worldbuilding Curriculum is intended to foster the following outcomes:

- **A mental ecology** that repairs the psychological damage that centuries of anthropocentric and colonialized subjectivities have had on individual consciousness and enables the potential to envision a sustainable, equitable future across the planet.

- **A social ecology** that dismantles systems of oppression and exploitation, past and present, that have divided the planet and its inhabitants and depleted its resources and instead preserves ancient and contemporary wisdom and cultures and provides structures for an intersubjective, multipolar future.
- **An environmental ecology** that heals the metabolic rift with nature at the root of the current ecological crisis (Angus, 2016; Foster et al., 2010), which has been exacerbated by human intervention into the ecosystems of the planet and threatens to render it uninhabitable, and instead promotes regenerative practices for a future that is sustainable and equitably distributed.

Worldbuilding Curricular Organization

In its current iteration, the Worldbuilding Curriculum comprises three units. The content and organization of these units are general guidelines and may be expanded or contracted in keeping with specific learning outcomes.

- **Unit I:** The Earth's material history, the emergence of life and hominids, and the subsequent development of culture as part of the evolutionary process.
- **Unit II:** The development of human culture across space and time, surveying the development of world cultures from antiquity to the modern period.
- **Unit III:** The above-noted conceptual categories that constitute the foundation for imagining, following Foucault (1970), a new episteme (i.e. the underlying assumptions that guide the potential horizons of thought) of a planetary future.

Unit I

Unit I reviews the planet's origins out of solar debris from around the sun in the Hadean eon 4.6 billion years ago up to the current Phanerozoic eon, which began some 540 million years ago and during which hominids first emerged. It introduces the conceptual frame of "-spheres" through which to view Earth's development and structure. It then traces humankind's early existence from the prehistoric to the Iron Age.

Planetary Cosmology and the "Spheres"

Unit I starts with the planet's physical cosmology. It uses the International Commission on Stratigraphy's geological time scale to depict the large spans of time of the planet's development. The timeline reviews major developments of the four planetary eons: Hadean, with the earth's formation 4.5 to 4 billion years ago; Archean, with the first formations of life 4 to 2.5 billion years ago; Proterozoic, with early life 2.5 billion to 541 million years ago; and Phanerozoic, with more complex life forms 541 million years ago to the present.

As part of surveying the planet's evolution, the curriculum studies the five great mass extinctions (MacCloud, 2013): the Ordovician-Silurian, the first major and second-most catastrophic extinction event some 450 million years ago; the Late Devonian, 360 to 372 million years ago; the Permian-Triassic, 250 million years ago and the most severe extinction event; the Triassic-Jurassic of approximately 200 million years ago, after which the dinosaurs emerged as the dominant terrestrial invertebrates; and the Cretaceous-Paleogene 66 million years ago in which the non-avian dinosaurs went extinct. These extinction events are studied in anticipation of considering the Holocene-Anthropocene, the sixth great extinction that some believe is currently underway and is the result of human activity as a "global superpredator" (Darimont et al., 2015; Kolbert, 2015). The implication of design as directly responsible for and potentially remediating this reputed current extinction is a topic to be taken up in dialog with studio practice in terms of material exploration, value-chain adaptations, waste-stream management, user interface, and environmental logistics, to name but a few areas of opportunity.

Dating back to Aristotelian physics, which defines the four elements of earth, air, fire, and water as constituting the earth's "terrestrial spheres," the concept of "spheres" continues to be used to describe planetary subsystems in both the sciences and the humanities. Unit I takes up the concept in establishing a framework for subsequent study. The most fundamental sphere originates with the planet's material formation in the Hadean eon and is termed the geosphere. This includes rocks and minerals from deep in the planet's molten core to the soil, sand, and rocks on its surface. It also includes the nonliving parts of plants and animals that may have become fossilized over time, as well as water (which is sometimes seen as a separate sphere, the hydrosphere), and the atmosphere.

Coined by Suess in 1875, the second sphere is the biosphere. Later taken up by Vernadsky (1945) as the second stage of Earth's development, the biosphere is the global ecosystem of all living things, flora, fauna, and microbes. The biosphere has its origins in the Archean eon at least 3.5 billion years ago in abiogenesis, the natural process in which life arose out of non-living matter such as simple organic compounds. The biosphere is the thin layer of life that resides on top, just above, and just below the surface of the geosphere in the Earth's crust. It has evolved over time, as has been scientifically studied, and, along with the geosphere, is now being affected by human intervention to the point that a new geological age, the Anthropocene, has been introduced as an object for scientific consideration (Crutzen, 2002; Crutzen & Stoermer, 2000).

The third stage of the planet's development as defined by Vernadsky (1945), following Teilhard de Chardin, is the noösphere, the biospheric transformation that occurred with the emergence of human cognition. For Vernadsky, the noösphere emerged at the point where humankind began to use transmutative technologies to create new materials from naturally existing elements. (For example, extracting metal from ore and subsequently creating alloys.) For anthropologists such as Geertz (1973b), the development of culture is a major step in the noetic evolution of the human mind. Foucault's (1970) concept of the episteme can be seen as a noetic construction in the broadest sense. Recent media theory has adapted the concept of the noösphere under the guise of notions such as collective intelligence (Levy, 1999) and hive mind (Kelly, 1995), in which human consciousness is taken to be interconnected via the global network of digital communication technologies. The dramatic impact of human intervention into the geosphere and biosphere, recently termed "the technosphere" (Haff, 2014), has interrupted many of the planet's natural cycles, often to deleterious effect. As with consideration of the Holocene-Anthropocene extinction, the implication of design in developing, perpetuating, and remediating the deleterious effects of the technosphere on the planetary future is an imperative consideration to carry over into studio practice. In this respect, the Worldbuilding Curriculum seeks to develop the consciousness of designers as they intervene in the planetary ecosphere in visionary, equitable, and sustainable ways.

The Emergence of Humankind

The second part of Unit I traces the archeological record of humankind's emergence in Africa and migration across the planet in what can be understood as the first example of globalization. It then reviews humankind's early history. It is particularly informed by what is known as the "world-systems" approach (Chase-Dunn & Lerro, 2014).

According to the scientific record, the earliest specimen of the genus *Homo* dates back some 2.8 million years with the modern human, *Homo sapiens,* emerging in Africa approximately 300,000 years ago in the Middle Paleolithic period. Humans are then believed to have migrated from Africa to Europe, Asia, and finally the Americas over the subsequent millennia (Harari, 2015; Litt et al., 2021). The first humans in Europe and Western Asia were Neanderthals with *Home erectus* populating the more eastern regions of Asia. Humans arrived in the Americas approximately 15,000 years ago.

Though there is evidence of the use of stone tools by hominids as far back as 3.3 million years, the Upper Paleolithic period (50,000-12,000 B.C.E.) is generally recognized as when the behaviors, technological innovations (i.e. design), and cultures that constitute modern humankind began to emerge. During this period, humans lived as hunter-gatherers and developed pottery and textiles (Chase-Dunn & Lerro, 2014; Garcea, 2013). The development of agriculture, which marks the beginning of the Neolithic period, first occurred 12,000 years ago in Southwest Asia, the "Cradle of Civilization," and spread throughout the rest of Asia, Africa, and Europe over the next several thousand years (Chase-Dunn & Lerro, 2014; Colledge et al., 2013). It also independently occurred later in Mesoamerica (Scanes, 2018). Access to consistent and predictable sources of food led to the development of fixed communities with built structures, animal husbandry, and more refined tools fabricated from metal (Chase-Dunn & Lerro, 2014). This period also saw development of the first forms of writing (Woods, 2010).

Metallurgy dates from approximately 5000 B.C.E. with evidence of copper smelting in Eastern Europe. Adding tin to copper gave strength to the compound and marked the transition into the Bronze Age, which lasted from approximately 3200-1200 B.C.E. (Chase-Dunn & Lerro, 2014). Alloys were used in the manufacture of tools, utensils, weapons, and decorative objects. This period also witnessed the development of urban cities, early civilizations and empires, and trade networks. The Bronze Age introduced aspects of modern culture in terms of social stratification, governmental and economic administration, organized religion, mathematics, etc., leaving evidence that constitutes the early recorded histories of humankind.

The Iron Age is the final stage of humankind's prehistory. It conventionally begins by world region according to when iron and steel advanced to the point where they replace bronze implements for common use, which archeologists typically date to c. 1200 B.C.E. (Milisauskas, 2002). This is also about the time that alphabets and written languages begin to appear, and as a result, written history (Chase-Dunn & Lerro, 2013; Lam, 2010).

Unit II

Unit II traces the development of human culture and its articulations across space and time. It begins by surveying the development of world cultures in antiquity. It subsequently investigates historical developments by world regions to construct what Foucault (1977) terms "a history of the present," a genealogy of diverse human cultures leading to the emergence of a global imaginary (Steger, 2008), a perspective that is critical for design practice in the twenty-first century. It again draws upon the world-systems approach to understand human development from the early regional empires – with limited, if any, contact between them – to the interconnected global system of today (Chase-Dunn & Lerro, 2014). By taking a world-systems approach, Unit II seeks to inculcate a decentered perspective among designers with respect to arenas in which they will operate.

The ancient world

What constitutes ancient history is typically defined as extending from the invention of writing to the early centuries of the Common Era, although the exact end dates continue to be debated (Morris & Scheidel, 2016). The period from 800-200 B.C.E. is often referred to as the Axial Age and covers developments in ancient Greece, present-day Iran, China, and the Indian subcontinent when trade and communication across the regions proliferated, including the rise of the Silk Road (Eisenstadt, 1986). This period also witnessed broad changes in religious and philosophical thought. Unit II surveys the ancient empires and civilizations before studying the histories of the world's regions up to modern times.

The earliest empires include the Sumerian Empire in Mesopotamia, the Egyptian Empire along the Nile, and the Qin dynasty and Han Empire in China. In India, the Vedic Period (1759-600 B.C.E.) laid the foundation for Hinduism. The Mediterranean Sea enabled the exchange of goods, technologies, and ideas initially to foster the development of the Minoan and Mycenaean civilizations in Europe, eventually culminating in the dominance of the Roman Empire over the region. Over the millennia, trade by land and sea began to expand between Europe and Asia, along with the establishment of centers of power and culture (Chase-Dunn & Lerro, 2014). In the Americas, empires began to arise as early as 2500 B.C.E. (Fagan & Beck, 1996). These include the Zapotec Empire (700 B.C.E.-1521 C.E.), Mayan civilization (2000 B.C.E.-the Spanish Conquest), and later, the Aztecs (1300-1520 C.E.). Other significant Mesoamerican cultures include the Olmecs (1500-400 B.C.E.) and the Toltecs (950-1150 C.E.).

In Africa, the Aksumite Empire (100-940 C.E.) controlled trade in the southern part of the Red Sea in what is now Ethiopia and the Bab el-Mandeb Strait (Phillipson, 2013). The Kushite Empire was an advanced civilization with its own language and script, and the Kushites developed innovations in technology, medicine, and mathematics (Wellsby, 2013).

"Post-Classical" History

"Post-classical" is a term used by the discipline of world history (the field of historical studies that looks at history from a global perspective) to describe the period from approximately 500-1500 C.E., roughly coinciding with the European Middle Ages (Stearns, 2017). Recognizing its Eurocentric bias (Goody, 2006; Santos, 2016; Wolfe, 2010), the concept is useful in organizing the content that follows. World history identifies certain trends that appear to have occurred broadly across the globe. Stearns (2017) notes the expansion and growth of civilizations, particularly the Islamic Empires in Western Asia and Northeastern Africa, the Byzantine Empire in Eastern Europe and Western Asia, the Songhai and Mali Empires in West Africa, and Wari and Inca Empires in South America. China also continued its dynastic development.

Universal religions also developed, with Buddhism spreading from India to China; Christianity, divided into Roman Catholic in Western Europe and Eastern Orthodox in Eastern Europe and parts of Asia, continued to supplant so-called pagan religions; and Islam spread across North and West Africa, the Iberian Peninsula, and into Central Asia, India, and as far east as Indonesia. Trade expanded across Eurasia with the Silk Road under the stabilizing effects of the Mongol Empire, as well as water routes for the trade in spices (Chase-Dunn & Lerro, 2014). China extended its influence in the East and the Americas established its own trade, restricted to the continent. The Oceanic islands also established trade with one another. After studying the larger trends of the post-classical period, Unit II introduces a series of regional studies up to the beginning of the modern period, which is generally defined as 1500 C.E. to the present (Stearns, 2001).

Modern History in Global Context

The early modern period (c. 1500-1800) is characterized by the acceleration of technological innovation and science, and, importantly, the emergence of the modern European nation-state, along with the economic developments of capitalism and the first phases of colonial expansion, in particular into the Americas, by European powers (Chase-Dunn & Lerro, 2014; Stearns, 2001). The period also saw the dominance of the Ottoman Empire in Southwestern Asia, the Ming dynasty in China, and the Mughal Empire in India.

In the late modern period (c. 1800-present), Western European nation-states and worldviews came to dominate most of the rest of the world (Chase-Dunn & Lerro, 2014). The late modern is the period of European imperial expansion into Africa, Asia, and Oceania to supplant earlier regional empires, the dramatic acceleration and spread of industrialization, and the increasing integration of the global economy. The nation-state model came to dominate the global order, with challenges to the European imperium beginning after the Second World War with postcolonial independence movements, particularly in Asia and Africa. Most recently, what has been termed a "transnational" or "global" capitalist system has arisen with super-state entities such as the World Bank, the International Monetary Fund, and international corporations exerting economic, political, and cultural influence, especially in lesser-developed parts of the world (Chase-Dunn & Lerro, 2014; Robinson, 2004; Sklair, 2001).

Unit III

Whereas Units I and II are organized along axes of time, Unit III is organized conceptually.

Culture

"Culture," as Williams (1983) notes, "is one of the two or three most complicated words in the English language" (p. 87). Its Latin root, *colere* (to till, dwell, worship), forms such words as *cultura:* cultivation; *culter:* knife or plowshare; *cultor:* planter, also worshiper of the gods, hence the English word "cult" (Kroeber & Kluckhohn, 1952, p. 145). Its early usage in English was to tend something, essentially crops or animals. The metaphorical usage to mean human development, as in "to be cultivated," does not come until later in the eighteenth century (Williams, 1983, p. 88). There are now several distinct uses: the physical descriptor, i.e. "germ cultures"; the process of human development, i.e. to be a "cultured" person; to describe a particular way of life of a people, period, and/or place, i.e. "early American culture"; and intellectual and artistic works and practices, i.e. "high" culture (Williams, 1983, p. 90). Culture is both a material thing and a symbolic practice. Designers, along with visual artists, musicians, writers, craftspersons, etc., are cultural producers in both senses of the term.

Unit III surveys the field of cultural production as it is broadly understood, taken to mean "the social processes involved in the generation and circulation of cultural forms, practices, values, and shared understandings" (Chandler & Munday, 2011). It is the object of study of several disciplines, including anthropology, sociology, psychology, history, philosophy, and economics. Aspects of culture include but are not limited to the arts, religion, and all manner of tools, as well as social structures and political organizations, mores, rituals, culinary practices, and all modes of interaction among and between individuals and groups. Several aspects of culture, specifically communication, exchange, technologies, and ideologies, are also investigated as separate yet interlocking concepts below.

As Geertz (1973b) notes, culture emerged as a mode of adaptation in human evolution, enabled by the higher-order brain functions of *Homo sapiens* when compared to earlier hominids. Unit III explores different theories of culture with an eye toward deconstructing and decolonizing Western hegemonic constructions (Kimmerer, 2013; Smith, 2012). It is especially concerned with investigating and retrieving indigenous cultural practices that have been subject to what Santos (2014) terms "epistemicide," the eradication of local knowledge under colonization and exploitation by the Global North (see also Escobar, 2017; Goody, 2006; Wolfe, 2010).

Communication

The Oxford Dictionary of Media and Communication defines communication as "most broadly, a process of interaction through messages or signals among or within humans, animals, machines, or plants" (Chandler & Munday, 2011). It is enabled via systems of agents, codes, channels, and relationships, which can be face-to-face or mediated, interpersonal or mass, synchronous or asynchronous, intentional or unintentional, as expressed in one of the earliest and most influential models, Laswell's 1948 "Who? Says what? In which channel? To whom? To what effect?" (in Chandler & Munday, 2011.) A communication is also the product of the communication process, an object studied by semiotics and other forms of linguistic analysis. Unit III examines communications through the lens of mediation, the process whereby communications are encoded, transmitted, and received, and the epistemological and structural relationships they enable (Chandler & Munday, 2011; Innis, 1950; Williams, 1983, p. 204-207), which has had a profound impact on the past development of design as a practice and for its future potential.

For example, the appearance of broadcast television after the Second World War can be seen as both a technological innovation and a cultural form (Williams, 1975). Although television technology was available much earlier, it was only with the proliferation of the suburbs after the war that the medium emerged as a major communication apparatus and social institution. By virtue of its ability to transmit sound and images across space to a mass of individual households physically separated from the interactions of the urban environment, television provided a form of social cohesion for what Williams (1975) terms the condition of "mobile privatization" (p. 19). Through its programming distribution and flow, television organized the daily routine from morning commuting information and weather reports to midday newsbreak to evening entertainment, culminating in the nightly sign off, all the while promoting the ostensible benefits of a mass industrial consumer utopia. In the 1950s and 1960s, television was a relatively stable system, drawing an increasingly suburban and decentralized population into a homogenized national imaginary (Williams, 1975, p. 77-120). The advent of cable television and programmable VCRs in the 1970s offered the opportunity for time shifting with even greater flexibility and individualization is now available with on-demand digital streaming services.

A communications perspective that seeks to strike a balance between technology and culture, as well as historical and structural methods is Debray's (1996) mediology, the "study of the ways and means of symbolic efficacy" (p. 7). The primary theoretical framework is the mediasphere, the entire milieu of the transmission of meanings and people in particular places and times. The structure of the mediasphere has undergone three principal transformations over the millennia: the logosphere in which writing dominates the transmission of ideas; the graphosphere in which printed texts impose rationality on the symbolic environment; and the videosphere in which audiovisual systems rule (Debray, 1996, p. 171). There is also acknowledgment of a "premediasphere" prior to the invention of writing, termed the mnemosphere, in which the spoken word and the "arts of memory" prevail (Debray, 1996, p. 27). With all analog forms of media – visual, verbal, textual, audio, and combinations thereof – now being remediated (Bolter & Grusin, 2000) by the binary digit for worldwide transmission through a variety of networked and wireless devices, there is cause to consider the possibility of a newer mediasphere, the datasphere in which all thought and expression dissolve into a ubiquitous information flow without subjectivity in the philosophical or political sense.

Technics

The OED defines "technics" as being "of or relating to the arts or sciences; (later) of or relating to technology. Also: of or relating to a particular art or science or its techniques; technical. Skillfully made or constructed." Although the OED notes that these usages are now rare, having been supplanted more commonly by "technology" and "technique," Unit III retains the term to stress the notion that humans have used their experiences and creativity to devise implements and methods to adapt to their environment, from the emergence of the genus *Homo* up to the present. Technics comprise the rudest stone tools of primordial times as much as the latest digital mechanisms and networks. Unit III surveys the evolution of technics as material and as culture in recognition of Appadurai's (2013) notion, articulated at the beginning of this paper, that design is part of humankind's history nearly from its very beginnings.

The development of technics, in the form of tools, machines, knowledge systems, and methodologies, is central to human evolution, enabling the species to perform tasks that the body alone cannot. The most rudimentary technics apply knowledge and materials to adapt to the environment in things such as the sticks and unmodified stones believed to be used by the earliest hominids some two to three million years ago (Delson et al., 2000). The earliest manufactured stone tools, made from chipping flakes off stone to form an edge for chopping, sawing, and cutting, are evidence of a cultural evolution based on the application of knowledge to artifacts, a measure of human adaptation to the environment. Learning to control fire is another major evolutionary technic for purposes of warmth, light, cooking, and keeping dangerous animals and pests away. Control over fire contributed to socialization in the groups that would cluster around it for heat and safety. Control of fire was crucial for two later technics: firing clay for pottery and manipulating raw ores in the development of metallurgy.

One category Unit III uses to understand technics is White's notion that human development has advanced by virtue of its ability to control certain forms of energy (cited in Knight & Smith, n.d.). The major phases using this frame are the leveraging of the body's own physical power, the energy from domesticated animals, the energy of plants (i.e. agriculture), the use of natural resources (i.e. solar, water, wind, carbon, and fossil fuels), and nuclear power. Energy is used in combination to create a major development in human technics, electricity, which is derived from harnessing the natural resources of water, wind, solar, carbon, and mostly fossil fuels (primarily coal, oil, and natural gas) in its generation.

Another category is based on Lenski's view of humankind's intellectual development, using knowledge and creativity to shape the environment (cited in Knight & Smith, n.d.). Lenski's perspective sees the level of communication as key: initially genetic information passed through heredity, then the point where humans learn and pass on information based on experience to the use of language and written systems of communication. Humans develop societies based on these forms of communication, from the hunter-gatherer to the agricultural to the industrial, with certain societies adapted to specialized functions such as maritime.

Energy is critical to a just and sustainable future. The global dependence on fossil fuels is driving the planet's ecology to the crisis point as reported by the Intergovernmental Panel on Climate Change (Working Group III, 2022). The per-capita energy use of the Global North far exceeds that of the Global South, although the developing economies of China and India have become major contributors to the rise in greenhouse gasses (Fuhr, 2021). Moreover, the legacy of colonialism continues the inequitable distribution of life opportunities and future potential in lesser-developed parts of the world (Davis, 2017; Roberts et al., 2003; Rodney, 1981). At the same time, the political, economic, and cultural hegemony of the West has virtually obliterated Indigenous knowledge and practices that were based in sustainable relationships with local environments (Escobar, 2018; Santos, 2016). Facilitating equitable sustainment and safeguarding local cultures and environments for the long term are the major challenges, and indeed imperatives, facing design practice now and in the future (Appadurai, 2013; Fry, 2009; Escobar, 2018).

Exchange

Life is inconceivable without exchange (Slater & Tonkiss, 2001, p. 7). At its most basic, exchange is "the action, or an act, of reciprocal giving and receiving: of things in general, of goods and merchandise" (OED). Exchange comprises a range of interactions: of things in the common sense, for example, the exchange of one item for another in barter; or actions, i.e. in the exchange of gunfire in combat; or the exchange of thoughts and ideas, as in a conversation or debate. Exchange can likewise take place in an economic market, again as commonly understood, when the exchange is some form of monetary value given in receipt of a thing or service. As anthropologists note, gifting is also a form of exchange with the reciprocity being in the nature of the relationship between giver and receiver, for example of kinship, honor, or power, and what that relationship connotes within the sociocultural milieu in which it takes place (Malinowski, 2014; Mauss, 1954; Slater & Tonkiss, 2001). As Latour (2007) notes, exchange may not only take place among sentient beings but can be any form of reciprocal action, between machines, for example, or chemically, as in the transfer of a nucleus from one molecular environment to another.

Different societies emphasize different modes of exchange. Modern Western thinking about exchange generally assumes the dominance of one particular type – market exchange – and all that implies socially, economically, and politically. Slater and Tonkiss (2001) distinguish between marketplaces – physical spaces of exchange which are found in a wide variety of societies historically and globally, only some of which are strictly dedicated to commodity transactions – and modern markets, which are products of the West. Modern markets are conceptual spaces of exchange where producers and consumers are said to meet to negotiate supply and demand based on price. Notions regarding modern markets emerged in the late eighteenth century in Western Europe with Smith's (1776/1976) treatise *The Wealth of Nations,* first published in 1776, which sets out the case for market exchange specifically in the context of the mercantile system of early colonialism.

Unit III surveys the development of the market society from its origins in eighteenth century Europe to its current state as the global paradigm for exchange. The unit reviews mercantilism and its relation to the Western colonial project, including the transatlantic slave trade, which was instrumental to the growth of modern capitalism (Beckert, 2015; Chase-Dunn & Lerro, 2014; Horne, 2018; Williams, 2021). It reviews the classical, neoclassical, and neoliberal theories of economics, as well as heterodox perspectives on the left and right. Emphasis will be placed on more recent global perspectives from both the North and South. Unit III also considers the gift as a model of the animating inspiration of creativity, which is realized in the form of cultural productions that circulate and establish relationships among their recipient communities (Hyde, 2019).

Habermas (1991) has studied the historical development of exchange from marketplaces into markets, tying together notions of social, economic, and political exchange in his theory of the public sphere in which news from distant marketplaces served early on as a valuable resource for profitably exchanging commodities, as well as a valuable commodity in its own right. The exchange of information, mediated via printed newsletters, pamphlets, gazettes, and the like, additionally gained value as political discourse in the emergence of democracy in what has been termed the marketplace of ideas.

Ideas and Ideals

Ideas are "simply any product of mental apprehension or activity, existing in the mind as an object of knowledge or thought; an item of knowledge or belief; a thought, a theory; a way of thinking" (OED). The capacity of the mind to conceive ideas is part of human evolution (Geertz, 1973b; Vernadsky, 1945). That humankind developed the consciousness to manipulate the planet's resources to its own ends marks the emergence of the nöosphere (Vernadsky, 1945). That the nöosphere has developed into a globally interconnected apparatus of information exchange is acknowledged under recent media theory (Levy, 1999; Kelly, 1995).

Ideals can be understood in two senses: "Existing as an idea or archetype; relating to or consisting of ideas in the Platonic or theological sense" and "Conceived or regarded as perfect or supremely excellent in its kind; answering to one's highest conception" (OED). As understood in the first sense, Plato's philosophical notion of ideal form holds that things in the material world, a chair, a circle, a tree, etc., only exist in their perfect state as philosophical concepts. The second sense derives from the first and is the sense that Unit III addresses, as applied socioculturally.

In the eighteenth century, Destutt de Tracy termed the scientific study of ideas "ideology" to distinguish it from ancient metaphysics (Williams, 1983, p. 154). The term was originally used to study epistemology and linguistics and the OED continues that connotation in its first definition: "The study of ideas; that branch of philosophy or psychology which deals with the origin and nature of ideas." A functional definition is further maintained later in the entry as "a systematic scheme of ideas, usually relating to politics, economics, or society and forming the basis of action or policy; a set of beliefs governing conduct" (OED).

Not long after Destutt de Tracy's coinage, Napoleon Bonaparte used the terminology to attack proponents of democracy who "misled the people by elevating them to a sovereignty they were incapable of exercising" (cited in Williams, 1983, p. 154). This negative connotation persists today, particularly in political discourse. The negative sense was given greater weight by Marx and Engels in *The German Ideology,* written between 1845 and 1847, in which they described ideology as false consciousness: "In all ideology men and their circumstances appear upside down as in a *camera obscura*" (cited in Williams, 1983, p. 155, emphasis original).

Later writers sought to retrieve the more neutral conception of ideology (as reflected in the OED functional definition) as a set of beliefs governing conduct. Mannheim (1955) argues for a broadening of the concept to recognize that a whole group's thought was formed by its social position and the context in which it was created. For Geertz (1973b), ideology is a cultural system, a set of symbolic structures for making sense of the world – positively, which he terms "interest," or negatively, which he terms "strain" (p. 201). The symbols can either be "cognitive," i.e. explanatory, or "expressive," i.e. emotive (Geertz, 1973b, p. 281).

A more contemporary understanding, which best represents the Worldbuilding perspective, is the imaginary. Although the term has been used as early as the mid-twentieth century (see Sartre, 2010), its use in Unit III derives from Taylor (2003), who devised the term "modern social imaginaries" to describe the way a given people imagine their collective social life. Taylor in turn took his inspiration from Anderson (1994), who developed the term "imagined communities" to trace the historical causes of nationalism. Anderson is relevant for design due to the connection he establishes between the invention of the printing press as a technology of cultural dissemination and the emergence of the political consciousness that underpins national identity. Also taking inspiration from Anderson is Steger (2008), who coined the term "global imaginary" to refer to the global consciousness that has emerged in recent decades with the rapid rise of communications technologies. The Worldbuilding Curriculum proposes that the term "planetary" be substituted for "global," reflecting Chakrabarty's (2021) assertion of the need to decenter the human in the face of the crises of the Anthropocene.

Conclusion

This proposal is an outline of a theoretical foundation that develops a planetary imaginary, one that recognizes the deep history of the earth and broad patterns of change, of which human agents are only a small part. It seeks to offer a theoretical perspective that prompts designers to develop new ways of thinking, and thus designing, in that light. Following Chakrabarty (2021), it contrasts the planetary with the global, understanding that the latter is the constructed object of human history whereas the former is the province of evolutionary processes beyond human control and under which humans must adapt (which is to say, design in accordance with) rather than seek to dominate.

There is much work needed to realize the curriculum as a truly planetary imaginary. First is the fact that the literature surveyed herein is entirely in English, originally or in translation, the language of Western empire and those who have the cultural and social capital to engage in the conversation. How space might be opened for others to enter the conversation needs further research, especially with an eye toward heretofore marginalized voices (Escobar, 2017; Santos, 2016). A particular emphasis needs to be placed on Indigenous voices in that regard.

Another facet is the need to expand the conversation across disciplines. An attempt has been made in this proposal to incorporate scientific knowledge along with that of the humanities and the social sciences. It is vital that the conversation continue as the stakes are high. To quote the Dane: "To be or not to be? That is question." Never has that been truer for humankind than at this moment.

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RADICAL INTERDEPENDENCE ON A NEIGHBORHOOD SCALE: RAISING AWARENESS AMONG CHILDREN ABOUT HUMAN AND MORE-THAN-HUMAN ENTANGLEMENTS

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Abstract
The massive environmental and social emergency we are experiencing in recent years is deeply rooted in an anthropocentric and Western vision of the world which does not consider the other agents that compose our planet. This multi-level crisis sheds an even brighter light on the relationship between human and more-than-human agents and is particularly evident in those urban contexts in which human processes – clashing with more-than-human ecosystems – try to reduce the latter to energetic, health, and aesthetic factors. While anthropologists and philosophers are searching for new paradigms, designers must explore these theoretical thoughts and translate them into action. Designing ways of adapting in this ever-changing world is a forced choice we can no longer postpone.

In this framework, there is an emerging need to investigate the urban context and its features to imagine new practices and solutions to go beyond the Anthropocene. Neighborhood communities are peculiar ecosystems inhabited by different actors (both human and more-than-human) with whom we must co-design from a bottom-up perspective. This is the case with Nolo, a neighborhood in the city of Milan characterized by a proactive community that has been fostered by the Polimi DESIS Lab – the research lab the authors belong to – to imagine social cohesion and innovative interventions triggered by tailor-made participatory design (PD) activities. PD here plays an important role in activating, sustaining, and orienting practices and processes of change, with the aim of disarticulating polarizations and co-designing shared solutions for social and environmental issues.

In this research, currently ongoing, specific attention is paid to addressing various points of view from the marginalized communities in the neighborhood such as immigrants, the elderly, citizens with physical and cognitive impairments, and children, but also agents from the more-than-human realm like plants, insects, and others. In this framework, the paper provides both the theoretical background that supports the project and a broad

description of one of the activities developed to include children's point of view. By referring to the concept of *citizen scientists*, the authors designed an interactive and transmedia storytelling activity to involve children from the neighborhood in an awareness-raising workshop to highlight the current social and environmental emergencies, generate a process of empowerment/community infrastructuring, and foster "radical interdependence" (Escobar, 2018) by caring for the human/more-than-human entanglements.

Author Keywords
Participatory design; inclusiveness; care; awareness; more-than-human; post-Anthropocene.

Introduction

Over the past decades, the social and environmental emergency we are currently experiencing has been fundamental in triggering new ways of thinking about the bond between the human and the more-than-human (here intended as "living entities" such as plants and animals), reframing the dichotomy between what is thought of as "artificial" and "natural." In the field of anthropology, but also philosophy and political theory, the need to think of human and more-than-human entities as an *assemblage* – that is, a fluid and open-ended relationship between vibrant materials (humans and non-humans) of all sorts (Bennett, 2010; DeLanda, 2016; Deleuze & Guattari, 1988; Latour, 2007; Steele et al., 2019; Tsing, 2015; Tsing et al., 2017) – is increasingly marked. The French philosopher and anthropologist Bruno Latour (2018) proposes this combination of different agents by identifying the *terrestrial* as a new political actor, aware of contemporary challenges and able to recognize himself or herself as a being on a large living entity (Gaia).[1] The terrestrial is an attractive force that contrasts modern humans who are too mentally closed towards a dichotomy between global (or the world as a disastrous project of modernization supported by globalization) and the more primordial idea of local (identified as soil and connected to bottom-up practices developed by new local communities). The terrestrial can be seen as an interdependent collective – based on mutual help and care (de la Bellacasa, 2017; Tronto, 1993) – in which communities of people are committed to maintaining and repairing the planet and all its entanglements with other forms of living (and non-living) beings. After all, the ability of communities of people to safeguard the resources of the planet has been widely explored by the American economist Elinor Ostrom (1990) with the theory of the commons.

Ostrom (1990) identified citizens as essential to managing the most fragile, shared, and unregulated common goods such as natural resources (forests, fishing, atmosphere, air, water). Empirical studies on the commons demonstrate that, despite various social problems, communities of people can effectively manage and support natural resources through collective actions and practices, thus identifying other forms of organization besides the market, governments, and private associations (Marttila et al., 2014; Wall, 2005). Even if the theory of the commons is useful to describe the commitment of citizens to managing other forms of living (and non-living) beings composing the ecosystem, here the word "resources" has to be intended as "more-than-human agents," that is, something not to be extracted and widely used but preserved and included in the community. This ability of communities to manage the commons is also useful to foster the citizen science model: the "general public engagement in scientific research activities where citizens actively contribute to science either with their intellectual effort, or surrounding knowledge, or their tools and resources"[2] (European Commission, 2013). Citizen science activities –

mainly developed in the natural sciences field – include the monitoring of fauna and flora, the collection of different types of data, and collaboration in the various phases of research projects. The objectives of citizen science are not only to support academic research, but also to increase the interest and knowledge of the population on the scientific topics of the research in which they participate.

Designing for the Post-Anthropocene

In this framework, design – both as a discipline and as practice – can be effective in fostering the resilience of communities and triggering new ways of acting to intertwine the needs of human and more-than-human agents, with the aim of mutual benefit, to obtain shared and more pervasive solutions (Bastian et al., 2016; Pitt, 2018; Roudavski, 2020). In fact, departing from anthropocentric, human-centered design can be a way to investigate a more complex system with the aim of bringing to light what may be the common interests between the different agents (Forlano, 2017; Plumwood, 2002; Rice, 2018). The role of design is essential to reach the interdependence (Bennett, 2010; Carson, 2002; Coulton & Lindley, 2019; Escobar, 2018; Fry, 2009) of the different agents who – according to the objectives of the research project presented here – are called to spread "the need to reconnect with each other and with the nonhuman world" in neighborhood communities (Escobar, 2018, p. 151).

The field of design is also dealing with sensitivities coming from other disciplinary fields – such as philosophy and anthropology – towards its re-evaluation as a virtue not only associated with the human being. Driven by an ethical reassessment of human actions in the Anthropocene,[3] especially related to Western behaviors, academics and practitioners are questioning those issues that occur daily in society through decolonizing practices (Descola, 2013; Escobar, 2018; Haraway, 2016; Heise, 2008; Ingold, 2011, 2015). Also linked to those issues are themes such as Indigenous knowledge (Descola & Pálsson, 1996) and matristic cultures (Maturana & Verden-Zöller, 2008), which open up to different ontologies and let emerge the need to see, live, and design the world from different points of view. From this perspective, the human being emerges as one of many design agents – not the only one – as he or she is constantly designed back from the surrounding world (Willis, 2006). This "double movement" (Escobar, 2018) of design calls designers to a re-evaluation of their own role and practice, opening up the ability to design to other agents as well. This theoretical framework led the authors to think about the theme of "radical interdependence" (Escobar, 2018) in urban contexts as seen from the point of view of neighborhood communities, where "communities" means "assemblages" of both human and more-than-human agents. The project presented in the paper is framed within an ongoing experimentation of Polimi DESIS Lab within the city of Milan and developed in the urban living lab Off Campus Nolo,[4] hosted in the local municipal market of Viale Monza, 54.

Neighborhoods as "Assemblages"

Neighborhoods are complex systems of agents – both human and more-than-human – that interact daily within specific spaces and infrastructures. Their heterogeneity – and the related social and environmental complexities – makes it difficult to find solutions for the well-being of the community. Indeed, neighborhood "voices" – intended as ideas and points – are rich and different and include those points of views that are normally unheard, such as those belonging to fragile communities that tend to be excluded or marginalized (foreigners, elderly, children, people with physical or mental disabilities), but even those belonging to more-than-human agents such as plants and animals. Putting these different "voices" into dialog is a way to create a shared neighborhood culture, not only to counter social polarizations but also to imagine possible future actions that take common interests into consideration. This means laying the foundation for a more inclusive and ecosystemic bottom-up approach, aimed at making the neighborhood more sustainable, innovative, and resilient.

Nolo Neighborhood and Off Campus Nolo

The experimentation presented in this paper was conducted in the context of Nolo, a semi-peripheral neighborhood of the city of Milan which represents a peculiar case of urban fabric in transformation, supported by a vibrant and proactive neighborhood community. The area in which Nolo is located has historically been the site of various migratory flows – both national and international – creating a rich context in terms of a variety of cultures, traditions, and behaviors. Today, newcomers with different cultural backgrounds represent over 34% of the local population (made up of about 25,000 inhabitants), compared to an average figure of 19% throughout the city of Milan. However, over the years, this diversity has not always been considered a positive aspect and has often been related to episodes of degradation (social and spatial) – as well as other phenomena known to the news – that contributed to the perception of the neighborhood as dangerous and poor. These phenomena have not discouraged the inhabitants of Nolo from trying to imagine solutions for the sake of their neighborhood, helping to strengthen its social cohesion through spontaneous aggregations of different sorts. In the context of Nolo, a group of inhabitants – here defined as a creative community (Meroni, 2007) – have already fostered over the years a process of urban and social transformation that includes not only the opening of new citizen-centered services, but also the spontaneous aggregation of the inhabitants around different initiatives, activated both online and offline. These initiatives have taken up both formal and informal forms of association such as the "Nolo Social District," a "social street"[5] managed by the inhabitants themselves through a Facebook group with more than 12,000 members, helping the socialization process between neighbors. This process of "beautification" (Fassi & Vergani, 2022) was intercepted by the Polimi DESIS Lab of the Politecnico di Milano – the research lab the authors belong to – which initially started teaching and research activities onsite and subsequently managed to open a living lab in the historical covered market of the neighborhood. Off Campus Nolo not only hosts research projects and community-making practices, but also events and meetings organized by the neighborhood's citizens as well as volunteer activities.

The "Situated Vocabulary"

One of the research projects launched with the opening of Off Campus Nolo (and still ongoing) is the Nolo "Situated Vocabulary," a neighborhood vocabulary that since its first steps helped the community of Nolo to map the area's spatial and social features by embracing its wide network of "situated stakeholders" (citizens, shopkeepers, and neighborhood associations as well as local administrators and the Municipality) (Fassi & Vergani, 2022). The vocabulary is managed by the off-campusers (mostly professors, researchers, PhD candidates, and interns of the Polimi DESIS Lab who become curators, content creators, and volunteers when working at Off Campus Nolo) (Fassi & Vergani, 2022) who are currently exploring ways to generate conversations around key concepts chosen by its inhabitants. The founding idea of the project is that the vocabulary starts as a physical prompt and then becomes an agonistic space – a platform – in which to dis-articulate and re-articulate points of view, illuminating unexpected similarities and revealing possible divergences to develop a cultural discourse on the neighborhood developed by the same neighborhood. Specific attention is paid to the vocabulary's potential to include (ontologically) different voices, bringing them in dialog to envision common matters of concern and new courses of transformative actions.

The "Situated Vocabulary" also promotes a more ecosystemic design dimension by listening to and integrating the voices of scientists representing agents from the natural world, such as plants, animals, and other organisms that populate the neighborhood. This collection of "voices" takes place during co-design activities, workshops, and interviews triggered both in the physical space of Off Campus Nolo and on online platforms and social media. The "voices" of the inhabitants, as well as those of writers, linguists, artists, designers, local activists, scientists, and others, are collected in the vocabulary and then spread in the community of Nolo in the form of a podcast – "In Poche Parole" (literally, "in few words") – developed in collaboration with Radio Nolo, the neighborhood radio created and supported voluntarily by local citizens, based in the Off Campus Nolo space. The vocabulary is made of nine keywords (*public space, degradation, common good, sense of belonging, memory, change, fun, commitment, Nolo,* and *heritage*) chosen by a group of members of the "Nolo Social District" Facebook group as hot topics experienced daily by the inhabitants. Every couple of months, a keyword chosen by the citizens is addressed as a red thread to provoke new thinking about what could happen in the neighborhood related to that specific topic. During this period, Off Campus Nolo hosts co-design sessions in its (physical and digital) space with passers-by and specific focus groups and showcases the diverse ideas emerging from these encounters. In this way, the market becomes a physical "agorà" (Huybrechts et al., 2018) in which reflections on the words can be shared, conversations can take place, and new courses of action can be envisioned.

Objectives

The work presented here is specifically connected to an activity enacted for *sense of belonging* that included the points of view of a group of children from the neighborhood. By referring to the concept of *citizen science*, the authors designed an interactive and transmedia storytelling activity to involve children from the neighborhood in an awareness-raising workshop to highlight the current social and environmental emergencies, generate a process of empowerment/community infrastructuring, and foster "radical interdependence" by caring for the human/more-than-human entanglements. Starting from the insights collected through the "Situated Vocabulary" research project during previous activities based on the words *public space* and *degradation*, the main objectives of the workshop with children were to:

- Foster the engagement of the neighborhood from a different point of view;
- Empathize with more-than-human agents and understand the concepts of multispecies cohabitation and radical interdependence;
- Encourage the children living in Nolo to be active citizens aware of the importance of human beings' footprints and behaviors towards the ecosystem and its inhabitants; and
- Test participatory design in creating new forms of democracy, inclusion, and activism even in young participants such as the children involved.

Methodology

The tailor-made research activity was supported by a hybrid methodology adopting methods and tools from transmedia storytelling using a participatory design approach. The activity – specifically designed for the phrase *sense of belonging* from the Nolo "Situated Vocabulary" research framework – benefited from the work previously done with co-design sessions, individual and group interviews with situated stakeholders (Fassi & Vergani, 2022) (citizens, shopkeepers, neighborhood associations, informal groups, and others), and workshops conducted both online and in the spaces of Off Campus Nolo. From the data collected, the research group gathered insights to work on to envision – with the help of the community of Nolo – future scenarios to be implemented in the neighborhood. Paying particular attention to addressing the various points of view of the marginalized community of the neighborhood, for *sense of belonging* the research group decided to focus on children as the most suitable and open to including more-than-human agents (in this case mostly plants and insects) in a participatory design approach (Akama et al., 2020). With the aim of understanding extremely important themes, the group decided to opt for an activity – supported by a specifically designed narrative world and storytelling – that would help children to participate and enjoy the experience.

The Transmedia Design Framework: Gaia's Club

To build the storytelling behind the experience of the activity with children, the research team used the transmedia design framework following the transmedia building model developed by Ciancia (2016). As stated by Jenkins (2003), "Transmedia Storytelling represents a process where integral elements of a fiction get dispersed systematically across multiple delivery channels to the purpose of creating a unified and coordinated entertainment experience [where] each medium makes its own unique contribution to the unfolding of the story." In the activity presented, transmedia storytelling consisted of a particular challenge named "Gaia's Club" where Gaia – envisioned as Mother Earth (the same one addressed by Latour) or a mysterious entity protecting the balance of all the ecosystems in the world – seems to have asked for the help of the children living in Nolo to solve important tasks for the well-being of the planet. As stated by Pinardi & De Angelis (2008), telling a story means "to open a window on a world" (p. 7) and it is a process that requires the presence of a structure following seven generative elements defining the storyworld (Altan, 1999; Pinardi & De Angelis, 2008):

- EPOS: Historical memory, the common memory of past events, the celebration of one's origins;
- ETHOS: The shared values, the rules of coexistence that regulate relationships, civil, and religious life;
- LOGOS: The common language;
- GENOS: The relationships of kinship and lineage;
- TOPOS: The territory;
- TELOS: Community aims, the goals for the collective good; and
- CHRONOS: The time.

Following the identification of the main storyworld and its themes, the seven generative elements were imagined as follows:

- EPOS: The history of the Nolo neighborhood – its transformation over time, from a countryside area to an industrialized urban neighborhood thanks to a regeneration process;
- ETHOS: Nolo as a neighborhood with a strong identity, full of the values of inclusion, multiculturalism, and care;
- LOGOS: The language of Nolo as a mixture of Italian, the Milanese dialect and other Italian accents as well as Arabic, Chinese, Spanish, English, and other languages from all over the world;
- GENOS: Besides blood family relationships, the neighborhood is characterized by the presence of a strong sense of belonging, community, and identity, even though the community is divided into various sub-communities and groups who sometimes may find it hard to mix with others;
- TOPOS: The location in which the storylines take place is the whole neighborhood of Nolo or the upper world, which includes aspects relating to society, nation, state, continent, nature, and planet (Pinardi, & De Angelis, 2006) and Parco Trotter, a park that is also a diffused school, situated inside the neighborhood. Parco Trotter represents the underworld; that is, the space including professional, artistic, scientific, religious, political, and affective environments (Pinardi & De Angelis, 2006);
- TELOS: The aim of the residents of the neighborhood is to improve the spaces and the sociability of the neighborhood. However, the presence of a large number of people makes it difficult to combine the will of the various social groups that inhabit the neighborhood and avoid fragmentation; and
- CHRONOS: The storytelling takes place nowadays. The time in the neighborhood is hectic; a lot of things happen at the same time and the process of change is quick.

After the identification of the storyworld, the main characters and the storylines supporting the transmedia project were developed as follows:

PRIMARY CHARACTERS:

- *Gaia*: A mysterious figure who has the duty to protect the balance of all ecosystems in the world;
- *The explorers*: Curious and adventurous children living in Nolo who answer Gaia's call to action and decide to take the lead and explore the Parco Totter to solve the tasks given;
- *The more-than-human agents*: Empathic and passionate children playing the role of plants, animals, and insects living in the ecosystem of Parco Trotter.

SECONDARY CHARACTERS:

- *Gaia's helpers*: Adults selected by Gaia to be her helpers and messengers to communicate with the children (the research team and other volunteers).

STORYTELLING:
The storytelling consisted of Gaia worrying about humans behaving badly towards other agents on the planet since humans consider themselves at the top of the ecosystem. It was then that she decided to involve the children in finding new solutions for the well-being of the planet as adults did not seem to be willing to listen to and collaborate with her. So, she decided to enroll some children and found a club – Gaia's Club – to give them tasks to be completed and personifying some human and more-than-human agents of the Nolo ecosystem.

The Activity
As reported in Figure 1, Gaia's Club is made of four main activities that took place in October 2021 at Parco Trotter (Milan). The four main activities were anticipated by a pre-activity: a preparatory assignment to be completed at home in which the participants could enter the storyworld and learn about the background story through a toolkit sent via e-mail and followed by an after-life step. The whole activity was structured to follow a conceptual path that aims to raise children's awareness about "radical interdependence" and more-than-human agents by using a playful and interactive method to foster teamwork and cooperation. All activities were supported and supervised by adults (Gaia's helpers), and each moment between the different steps of the activity was designed to have smooth changes between topics and different narrative sections. The activities involved 15 children from 5 to 9 years old with different backgrounds, all living in the neighborhood. As previously described, they were divided into two groups: the explorers and the more-than-human agents inhabiting the park (such as the frog, the oak, the daisy flower, the mole, the owl, the bee).

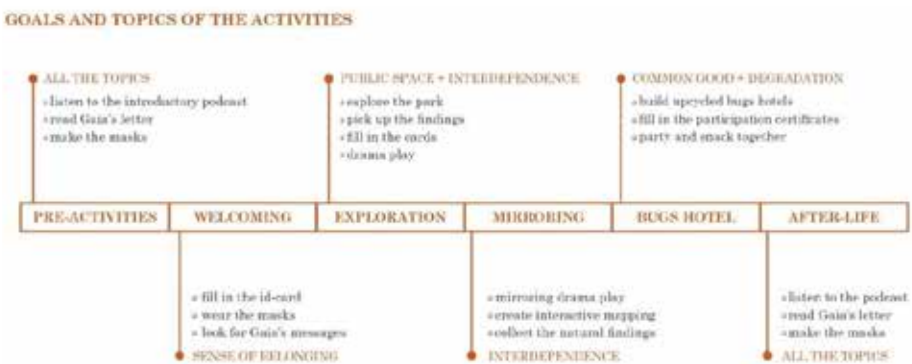

Figure 1. Scheme of the goals and topics of the activity pack

1. **Pre-activity:** In the preparatory phase, children were introduced to the experience thanks to a toolkit received via email consisting of a podcast (in which Gaia's helpers introduced the participants to the background story) and a letter signed by Gaia with the call to action. In the call to action, the children were encouraged to take part in the challenge to help Gaia build a stronger bond between human and more-than-human agents. The message included the time and location for the meeting to discover the activities and the other members of the Club.

2. **Welcoming:** During the in-person welcome, the children received another toolkit to start the activity and dress as explorers or more-than-human agents. The welcome toolkit (Figure 2) included a small compass, a paper bag to collect natural features found in the park, notebooks and pens, an interactive map of the park with exercises to be filled in, pins depicting elements of nature or exploration, ID/membership card for Gaia's Club, and low-tech costumes to help the children assume their new characters's shoes and feel like part of the group.
3. **Exploration:** The first task given by Gaia was the exploration of the park (Figure 3). The exploration was meant to collect natural objects to be used in the subsequent activities and to discover the park as an ecosystem inhabited not only by humans but also by more-than-human agents. This phase was intended to transmit the knowledge described in the introduction to the children in an easy and funny way, discovering the entanglements between plants, animals, and other agents.
4. **Mapping and mirroring:** In the second task, children were asked to mark on a map the places seen during the exploration and the corresponding findings about the more-than-human species observed (Figure 4). Then the children were involved in a drama game – a mirroring exercise (copying in sync the actions of those in front) – to create a "chain" and learn about the "radical interdependence" between the different agents. The "chain" made the children sit on top of each other to create a physical demonstration of how an ecosystem works.

Figure 2. Welcome kit.

Figure 3. Exploration of the park.

Figure 4. Interactive mapping.

Figure 5. Children building the bugs' hotels with natural findings and waste materials.

5. **Bugs' Hotel:** In the final task assigned by Gaia, the focus was to join forces for the construction of something useful for the more-than-human realm: a bug hotel (Figure 5). Children were equipped with some waste materials (wood and cotton) and used the natural objects collected during the exploration phase to build boxes where bugs and insects could live and prosper.
6. After the end of the activity, the toolkit was made easily downloadable to be used by the community of Nolo and to reach other children in the neighborhood. The aim is that Gaia's Club could become an open tool for the community to spread the main topics highlighted in the introduction and trigger both adults and children in thinking about the issues addressed.

Results

The activities had a positive impact both on the families and the children who participated and were successful in collaborating while playing in a positive and proactive way. Both introverted and extroverted children responded positively to the proposed stimuli and activities, although this was not a sure outcome, especially because the activities required quite a long period of focus and commitment. The storytelling seemed to work and was an important element to both entertain and motivate children in following the activities with curiosity and empathy, identifying easily with the proposed characters and storylines; in fact, they never questioned the existence of Gaia or the storyworld in general during the activities. This was particularly useful to understand that children – already aware of environmental issues – have a greater sensitivity in imagining themselves as active citizens interested in designing solutions for cohabitation with more-than-human agents. In particular, activity 4 (mapping and mirroring), although initially not fully understood, was useful to explain the concept of "radical interdependence" and the correlations between all the different agents. The idea of embodying and playing more-than-human agents as fundamental building blocks for the construction of the chain (the ecosystem) has created a playful but effective moment of cooperation that helped the children understand the need to act for coexistence. This idea of continuous support and help has been effectively implemented in activity 5 (bug hotel) where children – driven by a genuine willingness to help – worked hard to provide insects with a place to hide and live.

All the theoretical concepts explored (environmental issues, multispecies cohabitation, radical interdependence, being active citizens, and inclusion) were easily absorbed by the participants thanks to the transmedia design framework that mixed practical activities with storytelling. However, while it can be argued that building a narrative world can be useful for creating engagement and facilitating the management and implementation of participatory activities, some limitations may occur. For example, a limitation could be encountered in the case of online activities that have been applied in the context since, normally, transmedia design framework refers to digital media products to be enjoyed independently. As for the case presented here, a difficulty encountered was that of not having a complex background made of different media resources (such as short films, blogs, or social networks on which to spread the narrative) that could have helped the immersion of the children in the topics explored even more. This is mainly due, on the one hand, to the type of target chosen (which does not benefit from this type of media independently) and the will to create activities to be carried out offline collectively and in a public space, and on the other hand to making the experience accessible, inclusive, and not too complex.

As future improvements, potential changes may be to:

- Devote more time and specific attention to how to build a bugs' hotel with specific advice from some experts: in fact, even if the adults tried to explain how to build it to be really useful for insects, the children were very enthusiastic and creative, and they tended to build it following their personal touch;
- Give more time to the "mapping and mirroring" exercise (activity 4) after the exploration (activity 3) and provide more props;
- Divide the activities over several days to create a sense of continuity regarding the challenges children have to face in helping the (wider) neighborhood community; and
- Add a final exercise to let the children imagine (and design) some future scenarios for the neighborhood urban space according to all the new knowledge acquired.

Conclusions

The Gaia's Club workshop seems to have succeeded in combining the practice of transmedia storytelling with participatory design from a social innovation perspective. Thanks to the support of a strong narrative built around participatory activities, the involvement of participants before, during, and after the activities was very satisfying. The activities during the workshop were successful in involving children in a light and fun way, while conveying at the same time some basic knowledge on the main topics around which the storytelling was built. Simultaneously, the different challenges raised awareness of the issues addressed (radical interdependence between agents, the call for environmental and social emergency, the need to care for others, etc.) and fostered positive feedback from parents and relatives in attendance.

As for the Situated Vocabulary, the experiment proved to be useful for collecting unheard voices, such as those of children. Gaia's Club represented a milestone for Off Campus Nolo in developing a participatory, inclusive, and ecosystem-based neighborhood culture – this time from the point of view of children, intended also as a bridge to bring such concepts into the world of adults. As for the toolkit used during the workshop, all the props and storytelling for the co-design sessions were given to the Nolo community with the hope of being expanded and disseminated by the community of citizens itself, becoming a pilot project to validate other processes of social innovation and urban regeneration. In this framework, participatory design (PD) emerged as an optimal approach for the co-design of social elements in the public sphere. The PD approach succeeded in triggering inclusive projects and dialogs by entering a complex public social dimension made up of a plurality of actors (Manzini, 2015). In any case, it can be said that the combination of the two main approaches adopted here, PD and transmedia storytelling, can open interesting perspectives and scenarios to make participation and awareness more accessible and inclusive than that currently offered by the two approaches adopted separately, especially with such a young target. Regarding a broader perspective of the impact on the neighborhood scale, the results in the Nolo community are not immediately observable as the project does not aim to produce immediate tangible effects but rather a cultural change. This means that Off Campus Nolo will constantly monitor the impact of the project and, if needed, design new activities to be executed with the community and its agents.

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1. *Gaia as the Mother Earth goddess*. Gaia theory proposes that living organisms interact with their inorganic surroundings on Earth to form a synergistic and self-regulating complex system that helps to maintain and perpetuate the conditions for life on the planet (Lovelock & Margulis, 1974).

2. European Commission (2013). *Green Paper on Citizen Science*.

3. The Anthropocene is a proposed geological epoch dating from the commencement of significant human impact on Earth's geology and ecosystems, including but not limited to anthropogenic climate change (Braidotti & Hlavajova, 2018; Edwards, 1993; Ellis & Ellis, 2018).

4. Off Campus Nolo is an initiative promoted by Polisocial with the aim of strengthening the presence of Politecnico di Milano inside the city of Milan, following the principle of a university that is more responsible, open, and aware of social challenges and closer to the community. OFF CAMPUS, Il Cantiere per le Periferie. Retrieved March 22, 2022 from http://www.polisocial.polimi.it/it/off-campus/

5. "Social streets" are a typically Italian phenomenon that derives from the deeply rooted cultural tradition of living neighborhood public areas as social places that foster neighborhood relations.

REDEFINITION OF FASHION: INTERPRETATION AND SUSTAINABLE RECONSTRUCTION OF FASHION DESIGN IN THE METAVERSE

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Abstract
With the development of digital technology and the expansion of virtual scenarios in the post-pandemic era, the metaverse – as a maturing mechanism of cultural production and subject organization – is redefining many industries, including fashion. Fashion design, as an important element in the metaverse world, needs to be reexamined in terms of its composition and boundaries. This study focuses on the new definition and characteristics of fashion design in the metaverse through literature research, case studies, categorization and comparative analysis. This study uses an adaptive design paradigm to comprehensively optimize the economic and environmental benefits in the life cycle of the fashion design industry. It then analyzes the value and necessity of fashion design in the metaverse from three dimensions: user, function and value. The principles (environmental relevance principle, consistency principle), methods (parametric design method, perceptual design method, experience design method, new mimetic design method), techniques (blockchain technique, digital twins' technique, enhanced intelligence technique) and development processes of fashion design based on the metaverse concept are then proposed. Finally, it is validated and optimized through design practice, aiming to provide theoretical support and practical reference for fashion design in the metaverse era.

Author Keywords
Fashion design; metaverse; design method; innovative design; adaptable design; sustainable.

Introduction
The creation of the metaverse world opens new possibilities for the future development of metaverse fashion design (L. H. Lee et al., 2021). The metaverse can be extended to digital fashion, social media, augmented reality (AR), virtual stores, video games and non-fungible tokens (NFTs) (Kemp & Livingstone, 2006). The creation of the metaverse solves the problems caused by the separation of time and space in online design, such as the lack of product-user immersion, decreased desire to share, small social scope and lack of experience (Dionisio et al., 2013). In addition, it constructs a fashion design space-time that is parallel to the physical fashion space and integrated with the virtual and real environment

which can promote the development of higher-order thinking (Sayem, 2022). The social environment, blockchain-based trust mechanism and hi-fi fashion design environment in the metaverse can effectively solve the problems encountered by the fashion industry (Terdiman, 2007), including obvious environmental distortion, difficult reflection of user-centric features, difficult integration of three-dimensional space and lack of immersion in user experience. With the advent of the metaverse era, the new infrastructure of the global fashion industry, the cultivation of new thinking in fashion design and the development of fashion design in the future are facing new opportunities (J. Y. Lee, 2021). Based on the metaverse's development history, outstanding features and logical relationship that empowers fashion, the influence of the metaverse on fashion design is explored, and a forward-looking analysis of the new development of fashion design in the metaverse era is carried out (Johnson, 2016).

According to Park and Kim (2022), the current metaverse is based on the social values of Gen Z. With the development of deep learning's high-precision recognition model and natural generation model technology, the metaverse's core technology has gradually improved, from mobile device-based, always-on access to virtual currency-based connection to reality (Idrees et al., 2020). Bolger (2021) regards the metaverse as a universal expression of tech culture with global influence. The metaverse digitally connects all entities around the world through knowledge, social, geospatial and artificial intelligence (AI) technologies and creates a 3D information experience layer (Duan et al., 2021). The research by Annamma et al. (2022) suggests that leading luxury brands reinvent their brand image and consumer experience through core technology in the metaverse. The fashion design industry is undergoing a historic transformation due to the continuous development of emerging technologies such as blockchain and NFTs as well as impactful technologies such as AI, machine learning (ML) and virtual reality (VR) (Luchev et al., 2013). At present, some scholars have carried out the exploration of the metaverse. However, in-depth research on fashion design in the metaverse is lacking. This paper focuses on the interpretation and sustainable refactoring of fashion design in the metaverse.

Basic Connotation and Characteristics of Metaverse

Metaverse consists of two roots, meta and verse (Eichenlaub et al., 2014). Meta comes from the Greek "beyond," which also means "after" in pragmatics. Verse evolved from "universe" and means the universe or the world (J. Y. Lee, 2021). The metaverse therefore means a recognized new kingdom formed through reality (Rogers et al., 2012). The term "metaverse" was first coined by science fiction writer Neal Stephenson in the novel *Avalanche*. Subsequent sci-fi films such as *Ready Player One*, *Westworld*, and *The Matrix* provided more realistic depictions of the basic idea of the "metaverse" (Sacham et al., 2010). Additionally, Roblox's listing prospectus explicitly mentioned the metaverse. Facebook founder MarkZuckerberg visualized the unique social picture of the metaverse through video, and the interpretation of the basic connotation of the metaverse began to diversify.

In recent years, the technical system of the metaverse has gradually matured. Among them, six supporting technologies, namely blockchain, human interaction, virtual games, network computing, AI and the internet of things (IoT), have achieved theoretical construction and technological breakthroughs. As more and more large technology companies enter the field, the related economy is booming. 2021, also known as the "first year" of the metaverse, is considered to be the tipping point for the virtualization of human society (Zhou et al., 2012). In the meantime, the metaverse is a concept that is constantly enriched, improved and developed by expelling the old and accepting the new, indicating the dynamic evolution process of digital survival. In March 2021, Roblox became the first metaverse company in the world to go public (Zheng et al., 2018). However, in just six months, there were more than five hundred public companies involved in the metaverse business worldwide. According to forecasts by some international consulting firms, the metaverse economy will reach $800 billion to $1.5 trillion by 2024 (Monrat et al., 2019). With the involvement of various types of enterprises, an industrial chain – with the metaverse as the core – is rapidly built. Enterprise layout for the metaverse includes various types such as technology development, investment, fashion, education, logistics and medical care, which covers multiple businesses such as capital supply and scene design. With the continuous spread and extension of the metaverse, a multi-domain integration trend is formed.

On the one hand, there are different interpretations of the metaverse. On the other hand, there are some common features between them, such as deep immersion, social ecological civilization, virtual and real space interaction and integration and free creation. This paper assumes that the metaverse is a parallel and independent nature-society of the real world and a virtual-real fusion of ecological civilization space based on technologies such as digital twins, AI, human-computer interaction, the IoT, high-speed communication to meet people's needs for deep immersion, cross-domain social entertainment and surreal creation. As an ecological civilization space where nature and society blend, the metaverse is a transcendence of the embodiment network metaverse view proposed by Zuckerberg. Alternatively, it interprets the essential features of the metaverse from a separate systematic view across the metaverse that blends virtual and real.

Interpretation of Fashion Design in the Metaverse

Basic Connotation of Fashion Design in Metaverse

Fashion design in metaverse is the next generation of internet applications and a new form of virtual social fashion generated under the integration of various new technologies (Wang et al., 2021). Based on extended reality technology and digital twins, spatio-temporal expansion is realized (L. H. Lee et al., 2021). Based on AI and the IoT, the human-computer fusion of virtual human, natural human and robot is realized (Rospigliosi, 2022). Based on blockchain, web 3.0, and digital collections/NFTs, economic value-added can be realized (J. Y. Lee, 2021). Through virtual and real symbiosis in social systems, production systems and economic systems, each user is allowed to create fashion content and own fashion digital assets.

Core Technology of Fashion Design in Metaverse

The sequence of player usage scenarios and corresponding characteristics of the metaverse can be roughly divided into five categories: 1) access: immersive experience is emphasized, with AR, VR and extended reality as the main technology group. 2) Interaction: hi-fi interaction is emphasized, including 3D engines, real-time rendering, digital twins and other technologies. 3) Concurrent use of digital content: creation of virtual objects or spaces is required. 4) Rules and identity: based on blockchain technology, different users in the virtual world are supported to identify and interact with each other among entities. 5) Large-scale continuous online use: in order to ensure the continuous operation and real-time feedback of the virtual world like in the real world, massive and high-speed computing and information transmission capabilities are required, mainly cloud computing, supercomputing and wireless communication (5G and 6G). AI algorithms underpin most of these technologies.

Fashion Design in the Metaverse: Self-Growth and External Expansion
According to Maurice Merleau-Ponty, “For the normal human being, the tactile and visual experiences are not separate. Various perceptions are fused together with impossibly determinable weights” (Mystakidis, 2022). It can be seen that the complete cognition of the virtual world requires the participation of all senses, not only the brain.

VR Endogenous in Fashion Design
VR technology mainly provides immersion through computer simulation of virtual environments (Ning et al., 2021). The metaverse creates a new stylish virtual world with virtual people, objects, environments and rules. On the one hand, this innovative world has all the elements of the real world. On the other hand, these innovative virtual humans, objects and environments have no counterparts in the real world. Therefore, we can use our imagination and creativity to create virtual and stylish people, objects and environments (as shown in Figure 1). For example, the VR glove in the Manus Prime II series is a top-level immersive virtual experience design. With extremely high finger tracking accuracy, it can precisely measure and synchronize finger stretch. In addition, the exclusive VR glasses jointly launched by Sony and Xperia mobile phones can achieve 4K HDR immersive experience.

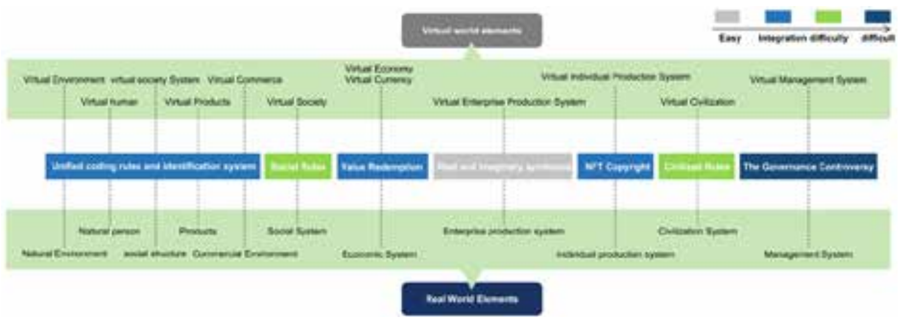

Figure 1. Fusion method of virtual world elements and real world elements.

AR Extension in Fashion Design
AR technology can skillfully integrate virtual information with the real world (Bourlakis et al., 2009). VR technology simulates virtual information such as text, images, 3D models, music, fashion design and video generated by computers and then applies it to the real world. With the addition of two kinds of information, an “enhancement” of the real world is achieved. The metaverse involves a virtual world that simulates the real world. AR technology is used to provide feedback to users with all the elements of the real world (including identity, business, fashion, social, civilization and governance) and the most important features (feelings) in the real world. The experience of mutual coexistence of virtual and real information facilitated by AR can significantly improve the insight into the real world (as shown in Figure 2). In November 2021, Niantic, the developer of AR games Ingress and Pokémon Go, completed a $300 million financing layout for the metaverse. The Lightship

developer platform launched by Niantic builds a "real world metaverse" based on "existing games + new applications + Lightship."

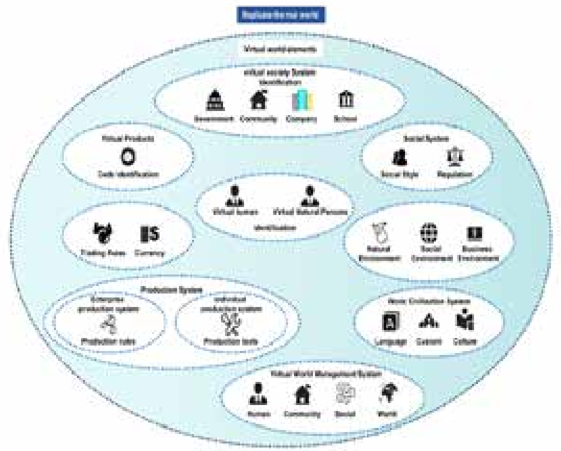

Figure 2. Elements of the virtual world replicating the real world.

Digital Value of Fashion Design in the Metaverse

A non-fungible token (NFT) is an encrypted digital proof of rights and interests based on blockchain technology that cannot be copied, tampered with or divided, which can be understood as a decentralized "digital ownership certificate for virtual assets or physical assets" (B. K. Lee, 2021). According to the application field and value logic, NFT can be subdivided into Art-NFT, Fi-NFT, GameNFT and IP-NFT. Art-NFT is mainly about the field of fashion art collection. With the gradual increase in the transaction price of fashion design products in the trading platform, Art-NFT is currently the most utilized NFT. On March 11, 2021, artist Beeple's *Everyday: The First 5000 Days* sold for $69,346,250 on Christie's website. This is currently the most expensive NFT artwork as well as the third highest auction price among living artists.

As consumers in the Z era advocate for environmental protection and sustainability, digital fashion with little impact on the environment is sought by young consumers. Therefore, fashion brands embrace digital technology. On the one hand, this has caught the attention of consumers who share a sustainable view. On the other hand, VR and AR technologies are used to change the online experience of consumers. As a result, increased communication and interaction with consumers and continued profitability are achieved.

Digital Added Value Creation of Fashion Design in the Metaverse

Experience Value

Experience value is the foundation of user engagement. Unlike the internet economy, the purpose of users entering the metaverse is not to obtain information. As a virtual human, users actively enter the scene with authenticity and social presence to express their emotions and participate in the production of economic activities.

Creative Value
In the metaverse, the creative creation of information plays an extremely important role. Creative value is the added value endogenous from a supply perspective. Different from technological innovation in the real economy, the metaverse values innovation and openness of ideas.

Communication Value
The metaverse reshapes the communication value to provide participants with a new scenario for knowledge transfer. In the process of product ownership transfer between creative parties and users, the transaction of traffic and communication power is realized. As a result, new market segments and added communication value are created.

Realizable Value
Users experience, create and communicate in the metaverse to achieve realizable value. The realizable added value in the metaverse is that user behavior can generate realizable substantial value based on specific mechanisms.

Capital Value
In the future metaverse, there will be more and more digital assets. Due to the demand for diversification of asset allocation, more traditional capital will be deployed in this field.

Development Bottleneck of Fashion Design in Metaverse

Core Technology
The current route into the metaverse is dominated by wearable devices and human-computer interaction. Technological breakthroughs are an urgent problem for the metaverse. Further discussion of the setting and application of the metaverse model requires a major technological breakthrough.

Digital Application
Currently, the main application areas of the metaverse include entertainment, social, gaming and NFT artwork. In contrast, the metaverse is not closely integrated with the manufacturing world. Some features of the metaverse have deep application prospects in manufacturing such as real-time permanence, digital twins and merged reality. Due to technical limitations, its potential has not been fully exploited.

Economic Driver
The metaverse is still in the high cost and low yield phase. In other words, the investment does not match the return. Under the wave of the metaverse, many enterprises poured into this field. However, there are still many risks and uncertainties in the metaverse industry. Excessive catering to the concept boom may lead to behaviors that deviate from the original technological development path, which in turn hinders the industrial pattern and economic development.

Environmental Protection
The metaverse has a complex operating mechanism which consumes a lot of network, storage and computing power resources. In addition, its stable operation is inseparable from the construction of new infrastructure. The current construction of 5G base stations, big data centers and super/intelligent computing power centers cannot meet the

requirements of the metaverse. Under the global trend of carbon neutrality, the environmental protection, construction and operation of infrastructure needs to be taken into consideration.

Element System Construction of Fashion Design in the Metaverse from a Sustainable Perspective

From a sustainable perspective, the focus group interview method is used to sort out and code the core and sub-core requirements of the future fashion design development in the metaverse by experts and fashion designers. Through the information weighting method, the element system of the metaverse in fashion design is finally obtained.

Element System Construction of Fashion Design in the Metaverse

There is currently no complete design theory and design practice for fashion design in the metaverse. Respondents are required to have a certain understanding and awareness of this research field. Therefore, the selected interviewees included five senior fashion design professors and five senior fashion designers. The researchers used focus group interviews. Through the guidance of the host, people in different fields can fully and comprehensively discuss the development of fashion design in the future metaverse.

The interviews were taped and consolidated with the consent of respondents. High-frequency words were openly sorted. The core coding of the element construction of fashion design in the future metaverse and its influencing factors are summarized below. Among them, initial concepts with word frequency repeated six times or more were entered. (The sub-core code was repeated six to nine times, and the core code was repeated ten times or more.) The results of the word frequency classification of fashion design in the metaverse in the focus group discussions are shown in Table 1. In open coding, phrases with word frequency less than six times were not input for analysis.

Primary elements	Word frequency / time	Number	Secondary elements	Word frequency / time	Enter or not	Weighted percentage (%)
Core technology	91	A1	Virtual native	9	Yes	9.89
		A2	Technology	4	No	/
		A3	NFT	16	Yes	17.58
		A4	Internet	5	No	/
		A5	Neural network	7	Yes	7.69
		A6	Digital twin	11	Yes	12.09
		A7	Deep learning	4	No	/
		A8	VR/AR	12	Yes	13.19
		A9	Combination of reality & imagination	8	Yes	8.79
		A10	Blockchain	6	Yes	6.59
		A11	Virtual & real symbiosis	9	Yes	9.89
Digital application	85	B1	Digital collection	12	Yes	14.12
		B2	Virtual idol	8	Yes	9.41
		B3	Robots	2	No	/
		B4	Virtual clothing	8	Yes	9.41
		B5	Virtual 3D design	12	Yes	14.12
		B6	Digital interaction	5	No	/
		B7	Digital design	10	Yes	11.76
		B8	Virtual fashion	15	Yes	17.65
		B9	Digital art	13	Yes	15.29
Economic value	40	C1	Collection value	7	Yes	17.50
		C2	Creators' economy	3	No	/
		C3	Circular economy	8	Yes	20.00
		C4	Intelligent manufacturing values	5	Yes	12.50
		C5	AR retailing	3	No	/
		C6	Digital currency	2	No	/
		C7	Trendy consumption	7	Yes	17.50
		C8	VR retailing	5	No	/
Environ-mental value	42	D1	Carbon emission	12	Yes	28.57
		D2	Carbon neutral	12	Yes	28.57
		D3	Climate change alert	5	No	/
		D4	Disaster alert	6	Yes	14.29
		D5	Pollution source detection	7	Yes	16.67

Table 1. Word frequency classification of fashion design in the metaverse.

According to Table 1, there are 33 secondary elements in total. In Table 1, the word frequencies related to fashion design element system construction in the metaverse repeated six times or more were extracted, totaling 23 words. 10 respondents' rated high-frequency words (as shown in Table 2). The information weighting method in SPSS was used to analyze the scoring weights of the 10 respondents (as shown in Table 3). By calculating the coefficient of variation and the weight coefficient, the final comprehensive evaluation score of the frequencies of the 23 words was obtained. The comprehensive evaluation score above 80 points signals a core high-frequency word, and a score below 80 points indicates a sub-core high-frequency word. There are 12 core high-frequency words and 11 sub-core high-frequency words in total. The analysis focused on high-frequency secondary elements under primary elements. From the perspective of fashion design, the metaverse's sustainable reconstruction strategies and solutions are proposed.

Number	Secondary elements	1	2	3	4	5	6	7	8	9	10	Evaluate score
A1	Virtual native	71	73	71	74	75	71	74	71	80	77	73.835
A3	NFT	77	83	92	80	91	79	81	92	95	80	86.805
A5	Neural network	66	71	69	70	77	74	70	72	83	72	72.966
A6	Digital twin	75	79	89	75	90	79	75	89	92	78	83.999
A8	VR/AR	73	80	88	79	91	80	81	88	91	78	84.326
A9	Combination of reality & imagination	65	74	72	73	75	74	72	70	81	70	72.838
A10	Blockchain	78	70	90	81	88	76	75	88	88	74	82.749
A11	Virtual & real symbiosis	79	71	86	77	87	77	75	89	90	76	82.636
B1	Digital collection	81	81	91	80	93	80	80	92	94	80	87.036
B2	Virtual idol	80	76	86	78	85	73	74	85	86	74	81.281
B4	Virtual clothing	76	71	75	70	76	71	70	71	71	69	72.383
B5	Virtual 3D design	69	70	73	71	72	73	66	73	73	67	71.141
B7	Digital design	70	71	75	71	73	72	71	72	70	66	71.351
B8	Virtual fashion	65	73	79	73	74	70	75	74	81	67	73.900
B9	Digital art	62	70	80	72	72	71	71	74	70	70	71.624
C1	Collection value	77	78	93	81	89	81	80	93	90	75	85.481
C3	Circular economy	73	75	88	80	85	76	80	92	92	80	83.857
C4	Intelligent manufacturing values	75	71	85	77	89	77	76	88	87	78	81.996
C7	Trendy consumption	66	70	83	72	72	75	69	71	75	72	72.988
D1	Carbon emission	73	73	91	78	89	79	80	90	91	79	84.160
D2	Carbon neutral	71	70	90	78	84	77	80	90	90	77	82.559
D4	Disaster alert	65	69	68	69	70	70	76	72	65	69	68.994
D5	Pollution source detection	61	70	65	70	69	70	74	69	66	68	67.681

Table 2. Scores of respondents and comprehensive evaluation scores.

Information weight calculation results				
Respondent	**Average value**	**Standard deviation**	**CV factor**	**Weights**
1	71.652	5.913	8.25%	10.26%
2	73.435	4.121	5.61%	6.98%
3	81.696	8.89	10.88%	13.53%
4	75.174	4.086	5.44%	6.76%
5	81.13	8.193	10.10%	12.55%
6	75	3.631	4.84%	6.02%
7	75	4.317	5.76%	7.16%
8	81.087	9.366	11.55%	14.36%
9	82.652	9.595	11.61%	14.43%
10	73.739	4.721	6.40%	7.96%

Table 3. Weight coefficients of respondents' scores.

Element Data Analysis

Through the information weighting method, the final evaluation scores of the 10 interviewees on word frequency were stunned. As can be seen in Table 3, for fashion design in the metaverse, core technology mainly includes NFTs, digital twins, VR/AR technology, blockchain and virtual and real symbiosis; digital application mainly includes digital collection and virtual fashion; economic driver mainly includes collection value and circulation economy; and environmental protection mainly includes carbon emissions and carbon neutrality.

Fashion design in the metaverse is a new virtual and real symbiosis fashion ecology generated by integrating a variety of new technologies. Based on extended reality technology and digital twin technology, space-time expansion is realized. Based on AI and the IoT, the human-computer fusion of virtual human, natural human and robot can be realized. Based on blockchain, Web 3.0 and digital collection/NFTs, economic value-added can be realized. In the social system, production system and economic system, there is virtual and real symbiosis.

Fashion Design Upgrade Path Under the Sustainable Metaverse System

In the metaverse era, the objects in fashion design are separated from the external manifestation of materialization. The traditional product value that has material value and is carried by objective objects is replaced. Products can resist the influence of time and space and become more permanent and diverse.

Establish Fashion Design Industry Based on Core Technology

The development of fashion design in the metaverse is inseparable from the support of digital technology. Driven by the metaverse, the "fashionable consumerism" that emphasized the high-end of materials since the Industrial Revolution developed to "non-homogenization." The fashion design industry in the metaverse adopts the model of "NFTs + blockchain + digital twins + virtual and real symbiosis + VR/AR," thus integrating spiritual elements, ideological elements, fashion elements and design elements. These immaterial and non-homogenized elements have fundamentally changed the fashion design industry. As an important carrier connecting the real world and the virtual world, NFTs and blockchain technology are the only proof of ownership of rare digital art, which is an important way to make digital assets scarce. Consumers can buy NFT products with cryptocurrencies. It should be noted that each transaction of the NFT product will be recorded. For the product, this pattern ensures that it cannot be copied or tampered. For creators, they can benefit from each transaction, which protects their rights to a certain extent. More importantly, the uniqueness of NFTs and blockchain technology further highlights the importance of core technology in fashion design in the metaverse.

At present, the metaverse fashion design industry chain is still incomplete and full of shallow technologies. This will lead to industry risks and bubbles. The key to resisting industrial risks is to form a healthy industrial, ecological and value chain, so as to avoid the lack of link and the occurrence of “bottleneck” technical problems. Therefore, it is necessary to subvert the original development model of the fashion design industry. Through the deep integration of the new concept of metaverse fashion design, a new model of fashion industry development based on new technology is constructed, and an industrial digital intelligence platform is created. The supply chain channel in the fashion design industry is perfected to build a complete metaverse fashion design operating system.

Digital Application Scenarios in Multi-Dimensional Development Fashion Design
In the context of the metaverse, multiple industries have experienced or are undergoing digital transformation. Product production and operation use digital technology to realize the reconstruction of content, form and method. In particular, the digitization of fashion products is at the forefront of industry changes. The metaverse needs to reinvent the fashion design product scene. Through physical scene data collection and real-time synchronization, product manufacturing is fully restored, virtual factories synchronized with physical factories and virtual scenes that transcend physical laws are constructed and industrial manufacturing is empowered, holistically solving problems in research, development, production and management. Based on big data surveys and analysis of consumer preferences, product applicability and success rates are significantly improved. Product marketing achieves precise marketing, which not only reduces circulation time and marketing costs, but also improves product revenue. The virtualization of fashion and the personalized needs of fashion consumption are further met.

Layout the Economic Market of Metaverse Fashion Design in Advance
The metaverse is currently in the high-cost and low-yield phase. In other words, the investment does not match the return. Since metaverse-related technologies still need to be developed, it will take a long time for the industrialization and commercialization of metaverse fashion design to become profitable. Metaverse topics can add a market potential of $20 billion to the fashion industry. The NFT luxury business in the form of collectibles is worth as much as $25 billion. It is estimated that by 2030, metaverse games and NFTs may share 10% of the luxury market (worth €50 billion or approx. US$51.83 billion). It has to be admitted that the development and improvement of the virtual world will take many years. Therefore, the advanced layout of the fashion design industry has strategic significance for the long-term development of the luxury industry.

Actively Face the Sustainable Development of Metaverse Fashion Design
The metaverse provides a virtual world for all users to interact and share experiences in real time. In this virtual space, various behavioral activities of users will generate a large amount of rich and rapid data which requires AI applications to analyze. In general, data

processing work in central data centers, especially the delivery of AI technology, has huge environmental costs. It is necessary to encourage the fashion design industry to actively face the green development of the metaverse market. Fashion weeks may be replaced by virtual fashion shows as the fashion design industry enters the metaverse era. Fashion design products are gradually created and displayed in digital form. Online trade shows and summits can reduce the need for business travel, as well as the huge carbon footprint of transportation. In addition, the continuous development of core technologies such as blockchain and NFTs is conducive to a better understanding of the life cycle of physical clothing. Environmental protection popularization and charitable cooperation have more environmental protection value. Most importantly, the metaverse world can greatly reduce the production of physical fashion products, thereby avoiding waste of resources and pollution.

Conclusion

In the metaverse era, the previous fashion design industry faced great challenges and underwent significant changes. The transformation, development and sustainable reconstruction of fashion design in the metaverse era play an important role in the future direction of this industry. The core technology and value of the fashion design industry in the metaverse era were deeply sorted out and interpreted. In view of the problems in the development of metaverse fashion design, focus group interviews and SPSS were used for data statistics and analysis. From the perspectives of core technology, digital application, economic drivers and sustainable development, the theoretical significance and practical implications of the sustainable reconstruction of fashion design in the metaverse era are proposed.

The metaverse breaks down the limitations of the physical world and creates new interactive experiences, productions and lifestyles. According to Adam McBride (2021), the author of *NFT APE*,

> a community with a consensus on value and the need for ownership are the commonalities between the metaverse and the fashion design industry. In this sense, there is a natural relationship between the fashion design industry and the metaverse. The commonality, which will inevitably lead to deep integration.

From the perspective of the metaverse, the integration of fashion and technology, that is, the organic combination of fashion elements, concepts, contents and forms with the theories, methods, means and models of technology, will continue to give birth to new fashion methods, consumption, products and forms, thereby creating unprecedented value for consumer groups. It is looking forward to the metaverse fashion design to improve the quality of life through the integration of virtual and real worlds.

Admittedly, this paper has some limitations which need to be further improved in follow-up work. The respondents in the evaluation test are mainly university professors and senior fashion designers, which may have some influence on the comprehensiveness and objectivity of the evaluation results. Subsequent research can increase the number of interviewees and expand the sources, thereby increasing the reference value of the evaluation results.

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SHIFTING PERSPECTIVES: A SPECULATIVE ONTOGRAPHIC APPROACH

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Abstract
Whilst design has often sought to create smooth and simple experiences for "users" of a variety of products and services, this often means decoupling these experiences from the wider assemblages of things, both human and non-human, that they form part of. This consequently obfuscates any undesirable consequences of our interactions such as their carbon footprint or privacy concerns. Drawing from more-than-human design and alien phenomenology, we discuss how speculative ontography, or collections of ontological modalities showing the possible relationships things may take, can be used within a future-focused design practice to better consider what things are and do rather than the way they are presented for use. We illustrate this conceptualization through the design and implementation of an experiential futures platform housed in a caravan to illustrate how it can be used with design practice.

Author Keywords
More-than-human design; object oriented ontology (OOO); design futures.

Introduction
Originating from the field of cultural geography, the term more-than-human (Whatmore, 2006) is increasingly being used to promote a shift from largely anthropocentric perspectives to one that acknowledges our relationships within complex ecological assemblages. This challenge to anthropocentric practices has also emerged in design and while some have used it to explore our relationships with non-human organic actants (Galloway, 2020; Westerlaken, 2021), in this research we draw from Ian Bogost's (2012) proposition of alien phenomenology, which itself derives from Graham Harman's (2005) conception of object oriented ontology (OOO). This enables us to broaden the scope of the more-than-human to include a much wider range of perspectives whereby an actant could be almost anything within such assemblages, for instance humans, birds, soil, algorithms, infrastructures, regulations, business models, values, etc. Whilst this philosophy provides an alternate ontological perspective for considering complex assemblages of the human and non-human, as designers we primarily want to know how to utilise such a theory within our practice. In OOO, ontography is the examination of ontographs or collections of ontological modalities as possible relationships an object(s) may fill.

These ontographs provide a useful perceptual scaffold that enables designers to ask questions that go beyond the surface of a particular proposition and speculate on broader considerations. Such speculative ontography thus allows designers to practically shift perspectives from a largely one-world-world (Law, 2015) view towards enabling a world of many worlds in which adaptation by human and non-human actants could take many forms. This paper demonstrates the value of scaffolding technology futures research using speculative ontography, describing an interactive and experiential installation that permits users to explore their future relationships with artificial intelligence- (AI) and data-infused products and services. The installation is a mobile research platform that mimics a smart home setting but goes further to make tangible the ordinarily intentionally seamless and obscured interactions that users have with technology, thus the experience imbues users with agency and negotiability regarding their smart technology.

Speculative Ontography

The notion of speculative ontography forms part of our more-than-human design practice inspired by readings of contemporary object-oriented philosophies discussed by Graham Harman (2005), Timothy Morton (2013), and Ian Bogost (2012), among others. The component is the use of OOO, principally through its rejection of correlationism, to manifest the proposition that perspectives derived by human minds and bodies are not the only ones worth considering, which supports the shift towards more-than-human design in a variety of forms.

Beyond the prerequisite dismissal of correlationism, our particular interpretation of OOO is principally influenced by Ian Bogost (2012) and his proposition of alien phenomenology. While Bogost's construction of OOO builds on the work of others, his presentation is particularly accessible and relevant for design-led inquiry (perhaps due to his background as a game designer). Many facets of the portrayal resonate with design, for example, the concept of "tiny ontologies," or the idea of any given thing (or aspect of a thing) being a "tiny, private Universe [which] rattles" inside computational things and the notion that all these "things equally exist, yet they do not exist equally" (Bogost, 2012). Bogost (2012) illustrates this in terms of the video game *ET the Extra Terrestrial*. Examining what the game fundamentally "is," Bogost (2012) notes it is equally a physical game cartridge, the compiled digital code on the game cartridge, and a set of game rules and points schemas which become manifest when the cartridge is interpreted by the computer, displayed on screen, and explored by the player. The "object" we refer to as *ET the Extra Terrestrial* is all of these constituents, and yet if we focus on a single one of them, those not within our gaze become temporarily less relevant. All these facets exist, but they do not exist equally, and how depends on which aspect of the game object's own tiny universe we consider at any given moment. This enactment of OOO-inspired views facilitates the focusing and refocusing on related but independent objects that is, perhaps, the pragmatic invocation of John Law's (2004) concept of "mess," which itself is a guiding principle for how to apply "perfect" theory to an inherently imperfect world. Bogost (2012) coins a series of OOO-related neologisms that works to make legible tiny ontologies, one of which is the idea of ontography.

In OOO, ontography is the examination of ontographs or collections of ontological modalities as possible relationships an object(s) may have. Bogost (2012) suggests a perspective of ontography as a record of the "things within." This recording of objects can then be defined further by their "collocation" to not only the things within the ontograph, but also those around it (Bogost, 2012). Here, it is also useful to draw on Karen Barad's (2007) consideration of agency not as a property but as something which emerges from how entangled agencies relate to each other. In ontography, we attempt to map the ontologies of relationships between human and non-human actants and highlight their interdependent relationships which operate through their independent perspectives. For example, consider the example of last mile delivery proposed by tire manufacturer Continental, who worked with ANYbotics to present a speculative vision of last metre robotic package delivery by combining autonomous legged robots with self-driving shuttles at the Consumer Electronics Show in 2019.[1] Whilst a speculative vision, it was based on current and near-future technologies and presents a seamless vision of an efficient future. We can construct a possible ontograph of this system, shown in Figure 1, which enables us to ask questions that go beyond the surface of the user centred perspective (a more efficient way of delivering packages) and consider an alternate perspective such as embodied carbon of such a system with its environmental impact, energy use, consumption of natural resources, and logistics. Alternatively, it could reveal answers to questions such as what data does it collect, how is the data used, and who has access to the data? Thus, such speculative ontography provides an incredibly useful way of critically questioning the technological futures proposed for emergent technologies. Before we address how such constellations might be enacted in design practice, we first need to address how futures are produced.

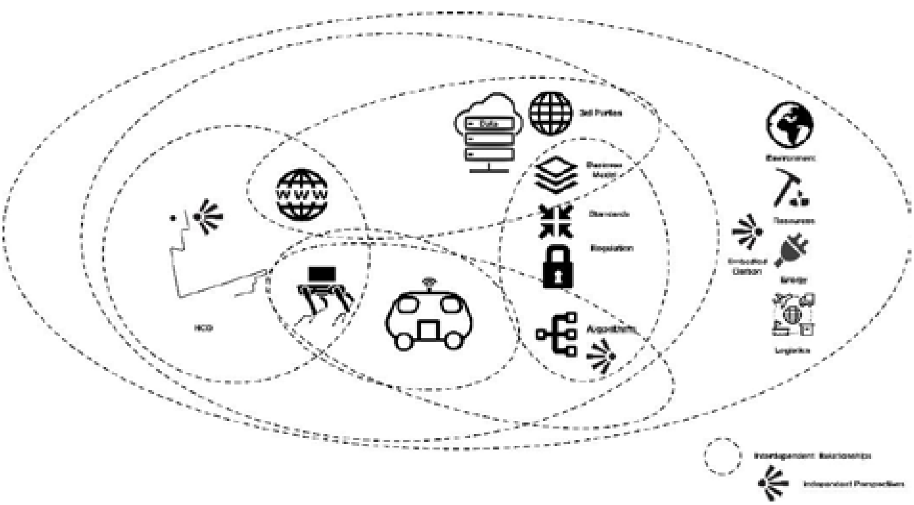

Figure 1. Alternate ontological perspectives of Dog Drone Delivery System.

The dominant approach when presenting potential futures is as scenarios based on proposed qualifiers – predominantly probable, plausible, possible, and in many cases, the addition of preferable. It is this framing which is most often presented through the much-hyped futures cone typically attributed to Joseph Voros (2003). As these qualifications are subjective, they are open to interpretation but could be considered as: possible – might happen; plausible – could happen; and probable – likely to happen. The notion of "preferable," which can occur within any of the qualifiers, has become increasingly contested as it is seen as often promoting the privileged vantages of the Global North (Martens, 2014). This is evident within the long history of design futures which arguably developed their prominence through events variously termed World Fairs, World Expositions, etc., that emerged in the nineteenth century and were used to present the technical prowess of particular Western countries to the rest of the world. These future visions are often developed through the auspices of technology corporations and are imbued with a rhetoric that these companies provide the gateway to efficient, desirable, and benign technology-driven futures (Coulton & Lindley, 2017). This type of corporate affirmative future has become even more prevalent in relation to digital technologies as evident from the rebranding of Facebook as Meta and their presentations relating to their ability to enable the so-called “metaverse.” These visions have been dubbed “vapourworlds” as an extension of notion of vapourware, a term commonly used to describe software and hardware that is announced, sometimes marketed, but is never actually produced. This leads us to posit that “preferable” should be a critical question the designers ask of themselves within the design activity rather than an aim of the design.

Another critique of the futures cone relates to its presentation in a way that suggests universal notions of the present or a one-world-world (Law, 2015), devoid of a relationship to influences drawn from history or acknowledgement of our tendency to incorporate elements of imagined possible futures from books, films, television shows, etc. within our world view (Gonzatto et al., 2013). We can also draw from the writing of Arturo Escobar (2018) in *Designs for the Pluriverse* to acknowledge the impact the different lived experiences of individuals and communities around the world will have on these factors, resulting in a requirement to consider a plurality of different perspectives on pasts, presents, and futures within our design processes.

“...transition from the hegemony of modernity’s one-world ontology to a pluriverse of socionatural configurations” (Escobar, 2018). Whilst design futures can help to highlight potential benefits of designing emerging technologies, it is important to acknowledge it also operates in tandem with defuturing. As previously highlighted, corporate visions regularly present futures which invoke a rhetoric that suggests that the products and services of the particular organisation are (or soon will be) the inevitable deliverers of particular futures. In his book *A New Design Philosophy: An Introduction to Defuturing*, Tony Fry (1999) stresses the active role that designers play in producing undesirable futures through the design and implementation of the products and services that we create. He argues we do this because “Fundamentally, we act to defuture because we do not understand how the values, knowledge, worlds and things we create go on designing after we have designed and made them” (Fry, 1999).

Fry’s observation embodies much of our argument towards moving to more-than-human design approaches as well as emphasising that designers should broaden their perspectives when considering a particular design challenge. To this end, Fry (1999) suggests designers should seek to “Disclose the bias and direction of that which is designed and how it is totally implicated in the world we conceptually constitute, materially produce, waste (rather than consume), occupy and use as an available material environment” (p. 10). Putting all these discussions together leads us to our alternative to the futures cone that forms the scaffold for our ontographic activities.

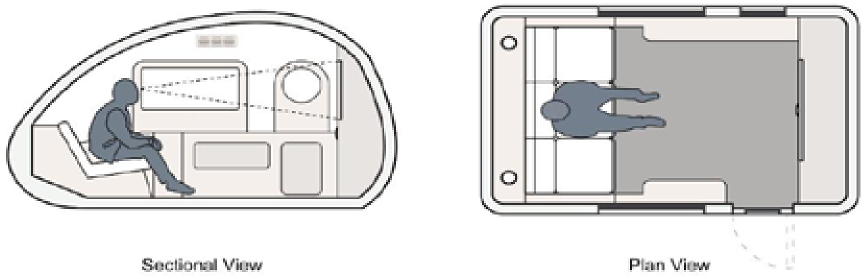

Figure 2. A rhetorical frame for pluriversal and more-than-human futuring (after Gonzatto et al., 2013).

Crafting and Experiential Future

To provide an example of both speculative ontography and a more pluriversal approach, we consider the crafting of the future mundane, which is an experiential future that allows people to directly experience potential futures of data- and AI-infused homes. This experiential future is also an example of the design fiction as worldbuilding approach (Coulton et al., 2017) which diegetically situates audiences directly within an artificial world in order to better explore and experience how today's emerging technologies may become tomorrow's mundane normality.

Whilst it would be possible to deploy such a mundane future experience in someone's actual home or simulate a home environment at a university or gallery, this would limit the potential audience with whom we could engage. We therefore decided to recreate a home environment as a mobile platform. This manifested as a teardrop caravan, shown in Figure 3, housing a familiar representation of a (U.K.) living room (i.e. a sofa, TV, lamps, etc.) along with integrated smart devices and support for monitoring and capturing the experiences in an unobtrusive manner.

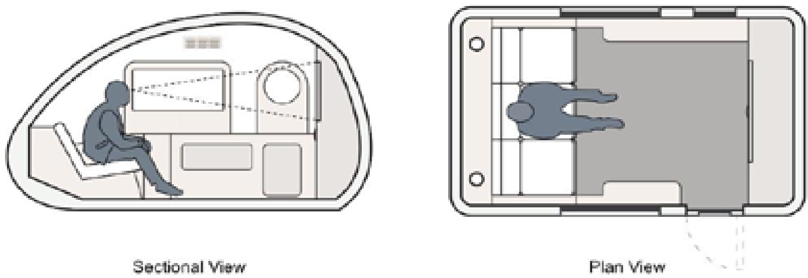

Figure 3. Cross section and plan view of the caravan, showing internal space and layout.

In terms of using speculative ontography to allow the consideration of varying relationships and perspectives, it is embodied within the design and fabrication decisions within the caravan. Experiences within the caravan are crafted from a variety of networked electronic devices which can be configured within a particular experience to explore differing tiny ontological relationships both between themselves and members of the audience. It is important however that devices do not disappear from view, as suggested by "ubiquitous computing," but rather, and in stark contrast, that their behaviour, particularly in relation to data, are made legible without being overtly creepy or intrusive.

An important factor for immersing the audience within the experience was to ensure they were placed in an appropriate and effective position that allowed us to craft an experience around them. As these experiences are largely audiovisual, the audience is positioned with an unobstructed view of the main screen. Despite the small form of the caravan, it is possible for three audience members to be seated at the rear, and each have an optimum viewing distance and viewing angle to the screen positioned directly opposite, as shown in Figure 3.

With the audience position decided, we could then begin to consider positioning for each of the additional interactive devices. Knowing that there would likely be additional upgrades and additions to this experience, the construction of the interior space was carefully considered to provide the maximum possible flexibility. The primary audio and visual devices are the 4K screen, active speaker system, and controllable RGB lighting. The speakers are positioned in a 5.1 configuration, with the centre speaker directly below the television and two additional speakers sitting either side of the screen. A further two are positioned behind the seating at the rear, with a subwoofer mounted below the central seat. This arrangement was chosen to provide an immersive soundscape and allow for experimentation with directional sound in future experiences. Controllable internet of things (IoT) lighting was installed along the rear panel behind the seating, underneath the seating, and along the top of the front panelling housing the screen. This not only provides lighting for the internal space, but also enables us to control the lighting colour and hue, acting as a visual display of the "networkification" (Pierce & DiSalvo, 2017) of devices and data in response to participant audience interactions.

With the positioning of the primary elements for this experience decided, the additional complementary devices could then be considered, using a corresponding process of defining their hierarchy of spatial needs to inform their optimum location within the space. The diagram shown in Figure 4 indicates the chosen locations for each of the additional devices. In effect, this is the base of our ondograph through which experiences are crafted using a version of Twine, an open-source tool for telling interactive, nonlinear stories. Twine has been enhanced to allow the sensors and actuators to be used and the subsequent experience can then be loaded onto the caravan platform, as shown in Figure 5. To illustrate what type of experiences can be created, we will describe one that was deployed at the Ethical Dilemma Café in April 2022 as part of Mozilla Festival.

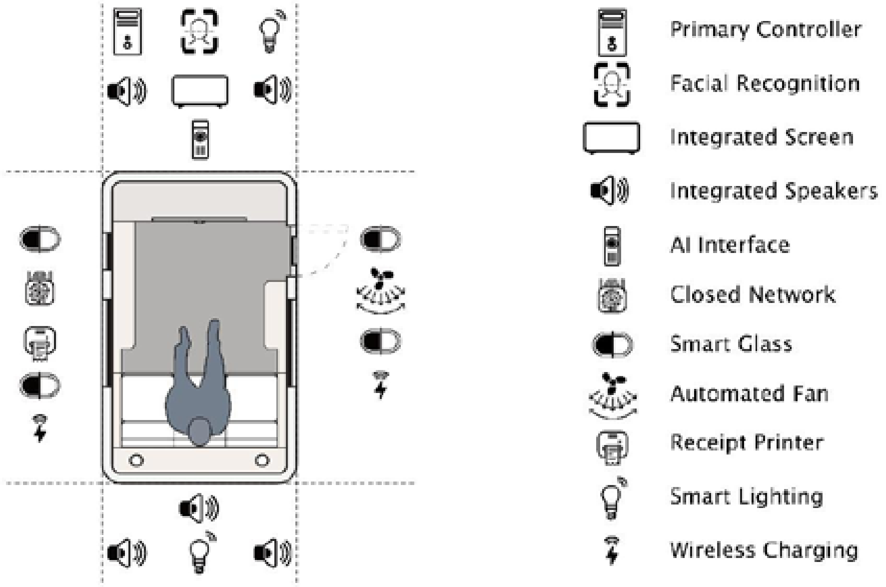

Figure 4. Diagram indicating the internal layout and positioning of all digital devices within the future mundane experience.

This particular experience within the Future Mundane was split into two main parts. To begin, the participants seat themselves on the sofa in front of the television screen and the experience is then introduced using a voice user interface which seeks to gain consent from users to collect, process, and store their data (the experience prints out a permission slip using the thermal printer which the audience must sign to proceed). In the second part of the experience, a short film is played based on a profile generated by the system. During this phase, various IoT objects in the room begin to contribute to the immersion. For example, the smart windows become opaque, and the room's lighting adapts to each scene (the system "knows" the outside weather and picks up a relevant colour gradient). When the lead character in the film is outdoors, the fan switches on, matching the wind blowing her hair. The music within the film is chosen dependent on the profile generated by the system, as is the chosen ending. The impact of particular data interactions which affect the film do not immediately affect the media objects, which means that while each experience was uniquely tailored to the audience, they would not necessarily be able to see why or how. Therefore, these are displayed as captions at the bottom of the screen when data is being collected and subsequently used.

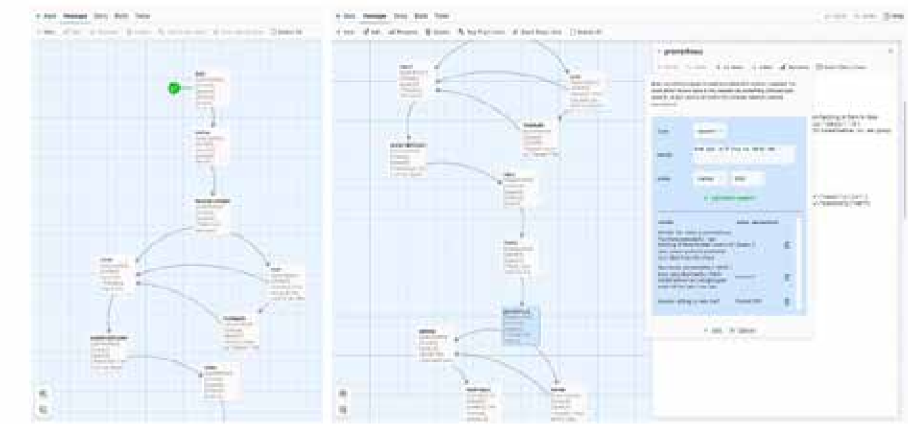

Figure 5. Screenshots of the Twine interface which has been used to create an authoring tool for the caravan, allowing new experiences to be produced and make use of all the integrated devices.

The consent procedure within the experience is designed to explore the differing ontological relationships of an AI- and data-infused environment through prototyping the proposed pillars of human data interaction, agency, legibility, and negotiability (Moriter et al., 2016).

Legibility recognises that the full extent of our interactions with data flows and data processes is generally opaque. We would distinguish the term from transparency, which is primarily related to providing open access to data and algorithms, which does not necessarily make it accessible to non-expert users. Legibility is primarily concerned with ensuring that the use, storage, and sharing of data and associated algorithms are made clear and understandable to users. For example, owners of Vizio smart televisions were unaware that 100 billion data points related to their viewing habits were being collected every day until it was made public in 2016.

Agency relates to how users of data-enabled systems are able to manage their data and who has access to it. Aside from the basic ability to opt-in or opt-out of data collection, agency also relates to how data is stored and used, including the ability to modify data and the inferences that may be ascribed from it. Consider the domestic smart energy meters that are currently being rolled out in the U.K. Users have little agency to optimise their tariffs or control who has access to the data, which reveals a great deal about the users' lives and has ultimately reduced their uptake.

Negotiability acknowledges the transactional nature of data collection, particularly in the context of trading functionality. Negotiation seeks to facilitate an ongoing engagement by users in data collection and use so that they can withdraw access completely or in part, and derive value from data collection themselves. For example, if you choose not to connect your Roomba to your wifi you lose some of the features offered through the mobile app such as remotely scheduled cleanings, customised cleaning features, and any voice control functionality provided by Amazon's Alexa or Google Assistant. In this instance, the trade-off for losing this functionality is increased certainty that your data is secure (as it is not leaving your house); however the negotiation is very one-sided. In the Roomba's case (as is frequently true) the terms equate to "give us your data or we do not provide functionality."

The consent procedure introduces each sensor in turn, starting with the face recognition system and at each point the audience is asked to indicate their willingness to have their data collected. As most "things" currently present within our home do not require us to negotiate their use, this specifically highlights the different perspectives in play when we add smart devices. Whilst the creators of these products and services may primarily be interested in collecting the data about our use, as users, we are primarily concerned with what the devices actually do. Whilst this process provided legibility, we purposefully did not always provide a choice other than "Yes" or "No." This was intended to highlight the lack of agency and negotiability that many consent systems actually provide in that we often must trade our data in order to access the functionality of a smart product or service. For example, when the audience in the experience said "no," the system would either say this would result in a lesser experience or say that this was a shame as they would miss out on the film, but they could exit through the gift shop. However, during the two days the experience ran, none of the 75 people who participated declined consent. This perhaps indicates it could be due to the setting in which the experience takes place or perhaps the beguiling nature of voice may present a problem for future IoT systems in that, if their security is compromised, voice may present nefarious hackers a highly effective means of phishing.

Conclusions

In this paper we have sought to provide practical approaches towards incorporating more-than-human perspectives into design practice using speculative ontography. Ontographs allow for the consideration of multiple perspectives, and unlike a systems-based approach which promotes the view that all things are connected and dependent on each other, it acknowledges that whilst certain attributes may make things interdependent, they may operate from highly independent perspectives. It is this tension, we argue, that design needs to foreground rather than obfuscate in the name of simplicity of experience, if we are to practically engage people in considering their relationships within the complexity of challenges such as climate change if we are to mitigate the deficit of opportunity we are creating for future generations.

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SYMMETRIC FUTURES: POSTHUMAN DESIGN AND ITS SHORTCOMINGS

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Abstract
There has been a growth of philosophical debates around posthumanism which are currently seeking their space among the design community. Design researchers and practitioners have started to tackle and work with some of the ideas that stem from these debates, such as the need to decenter the human, acknowledge and work with non-Western epistemologies and aesthetics, or question notions of power, justice and agency in design. In this sense, the hegemony of human-centered design seems to be challenged, opening space for experimental posthumanist design practices. This is shaping many conversations around design research and design practices which will be addressed in this paper. Walter Mignolo (2011), who has written extensively about colonial legacies, has clearly shown how the European Enlightenment and modernity have a darker side that needs to be challenged. European modernity was sustained by a very limited epistemological framework – a closed civilizational ideal – and defined a liberal notion of subject that has been called into question (Rivera Cusicanqui, 2018).

We see how these debates are present in the design research context, for example, in the many calls and ideas surrounding the need to decolonize design and redress modernist ideas and aesthetics that have been naturalized in design practices (Prado & Oliveira, 2014). In this line of work, we can see the contributions of Arturo Escobar (2018) who, under the notion of *pluriversal* design, opens a debate around the need to incorporate non-European perspectives and aesthetics in design. In this sense, humanist traditions are being challenged, and this is giving place to a new set of posthumanist design research practices such as ontological design, medium design or *pluriversal* design that will be addressed in the following paper. Our aim in this paper is to show how these epistemic systems, humanism and posthumanism, can appear as contradictions or give rise to epistemic conflicts that need to be analyzed and taken into account. These paradigms need to be tackled symmetrically, and the notion of the designer sustained on a strong idea of self needs to be evaluated in order to go beyond discursive tropes and provide space for posthuman design practices to emerge.

Author Keywords
Posthumanism; ontological design; anthropocentrism; interdependence; sustainable futures; epistemologies.

Introduction

In the following paper, we will argue that some contemporary design practices are getting entangled between two different discursive and epistemic regimes, humanism and posthumanism, which is giving rise to contradictions and conceptual mistakes that need to be addressed if we are willing to strengthen this discipline called design research. We will do so by engaging with different strands of design theories and practices that are currently trying to overcome or amend some of the worst aspects of the humanist legacy. Humanism is an epistemic and social system that has been recently challenged and put into question by different philosophical and analytical trends that can be identified as posthumanist. In recent years, these debates around posthumanism (Morton, 2017; Braidotti, 2013, 2019; Hayles, 1999) are finding their space among the design community.

In the following paper, we will explore how some design practices, such as human-centered design and contemporary design research conceived as a discipline and epistemic space deeply embedded in a humanist tradition, are dealing with and integrating some of these posthumanist ideas. Our aim in this paper is to show how these epistemic systems, humanism and posthumanism, can appear as contradictions, or give rise to epistemic conflicts that need to be analyzed and taken into account. We will do so by interrogating some contemporary tendencies such as transition design, ontological design and medium design, and try to flag-up some of their shortcomings.

As the philosopher and key proponent of posthumanism Rosi Braidotti (2013) has clearly argued, we need to re-evaluate the notions of human and humanism that were built during modernity and challenge the Eurocentric visions they embody. As she argues, "as a civilizational ideal, Humanism fueled the imperial destinies of nineteenth-century Germany, France and, supremely, Great Britain" (p. 15). Humanism and imperialism are inextricably intertwined. The supposed universalist claims to knowledge that serve as a basis for the Enlightenment have also been called into question (Haraway, 1988). Similarly, the idea of progress as a straight and consistent path to follow, so central to the modern project, or the idea of the world as an inexhaustible resource to cover human needs, has been seriously contested in the context of global warming (Morton, 2021). Since the late 1960s, modern taxonomies, binarisms and other classifying tools that have served humanist knowledge creation have been under scrutiny as a whole (Foucault, 2009). There is a growing discomfort with the modern legacy and with humanism as the set of knowledge and academic disciplines that has validated and sustained many of these assumptions (Camps, 2020). In this sense, there is a need to understand how these problems should be addressed in contemporary design or pedagogy. Many of these ideas can be attractive in purely discursive terms, but difficult to transform into specific projects and practices.

The European Enlightenment has traditionally been considered a historical moment in which certain feudal regimes were dismantled, royal privileges transformed into human rights, the power of the church was challenged and the appearance of scientific rationality helped to limit the power of mythical accounts of reality and superstition. As Kant famously put it: "Enlightenment is man's emergence from his self-imposed nonage." There is no doubt that this movement improved the living conditions of a great part of the peasant population of Europe, introduced medical advances that improved human life, started a process of democratization of education and triggered the appearance of European democracies. Secularism and humanism are the intellectual legacies of this era and still shape the ways we think and feel about the world (Taylor, 2018). But European Enlightenment also had a darker side that needs to be addressed.

Writing in the mid-twentieth century, scholars from the Frankfurt School started challenging the more optimistic views of the period, arguing we needed to take into account the negative effects it has had – mainly the growth of what they termed instrumental rationality (Adorno & Horkheimer, 2007). More recently Walter Mignolo (2011), who has written extensively about colonial legacies, has clearly shown how the European Enlightenment and modernity has a darker side that needs to be challenged. European modernity was sustained by a very limited epistemological framework – a closed civilizational ideal – and defined a liberal notion of the subject that has been called into question (Rivera Cusicanqui, 2018). Notions of development and progress have also been subjected to scrutiny (Braidotti, 2013) and a critique on how rationality has overwritten other epistemic regimes has also been established (Viveiros de Castro, 2010).

We see how these debates are present in the design research context, for example, in the many projects, calls and ideas surrounding the need to decolonize design and redress modernist ideas and aesthetics that have been naturalized in design practices (Prado & Oliveira, 2014). In this vein we can see the contributions of Arturo Escobar (2018) who, under the notion of pluriversal design, has opened a debate around the need to incorporate non-European perspectives and aesthetics in design. Transition design also has dealt with ideas of progress and evolution, looking at more subtle changes and ways design can trigger social transformation (Tonkinwise, 2015). These different debates and approaches are also finding their space in the academic context as conversations around the need to think and implement what has been called "Pluriversal Design Education" (Noel, 2020), or pedagogical experiments in which decolonial perspectives and non-Western epistemologies are taken into account (Mortensen & Tavares, 2021). There is also a questioning of how academic disciplines have shaped the expectations and aims of design research with a call to "undisciplined design" (Camps & Rowan, 2019) or to build experimental methodologies able to challenge modernist assumptions and entangle the creation of knowledge through design with different sensibilities and cosmovisions (Moscoso, 2021).

We can also see how these ideas are present in conversations around new materialisms and how to deal with material agencies in design practice and research (Rowan, 2016; Winner, 1986). The importance of non-human politics and ways of allowing the material agency of objects to speak is present in the works of Latour (1986) and Bennett (2010), opening a space also to discuss the morality of things and technology (Verbeek, 2011). Following Karen Barad's (2007) insights, this has opened a debate on how matter and meaning get entangled in design research projects. In this sense we could follow the

> Invitation to take part and be able to contribute to the creation of mutually constitutive entangled agencies, in which matter, discourse and bodies occupy unexpected positions. What we have called "entanglements of material meaning" are areas of potential engagements with theory/practice that can lead to and shape performances, drawings, paintings, constellations of objects, sound-based projects, movement and body languages, interactive outputs, etc. (Camps & Rowan, 2021, p. 4708)

Many of these debates are present in specific design projects, but more importantly, are shaping specific design research perspectives that need to be interrogated.

Ontological and Medium Design

Many of these conversations have shifted design from a practice aimed at dealing with briefings and providing solutions to specific problems to considering design as a world-making practice (de la Cadena & Blaser, 2018). With this displacement, we see that the weight is no longer placed on the semiotics of what is communicated, on the aesthetics of what is created or on the effectiveness of the results obtained, but rather the question arises as to which worlds are desirable to create. This idea occupies a central place in the article "Ontological Designing" in which Anne-Marie Willis (2006) proposes the need for and importance of approaching design as an ontological practice. With this, the author stresses that it is important to understand design as a material practice rooted in very specific socio-historical and material conditions, and "ontological designing is a way of characterizing the relation between human beings and lifeworld's" (Willis, 2006, p. 70). There is no design outside the world, that is to say that it necessarily always has consequences on the context in which it operates, but more importantly that it is always affected in turn by that same world. This introduces a posthumanist turn in design that forces us to rethink the centrality of the designer in design processes. These ideas have helped to shape some contemporary design practices such as transition design, which provides a conceptual and practical context in which design is considered a world-making practice. In this same context, we see design initiatives around design justice, pluriversal design or decolonial design practices becoming increasingly important to the field.

If we consider design as an ontological or world-making practice, we need to pay attention to the multiple agencies of the socio-material environment in which design operates. According to Willis (2006), "this adds up to a double movement – we design our world, while our world acts back on us and designs us" (p. 70). Those who design are also being designed. This challenges the idea of the designer being understood as a demiurge or god-like creator, and generates a context in which material and social agencies need to be taken into account in the design process. Understood from this perspective, and in line with design theorist Tony Fry (2010), design always has an implicit politics. Whoever designs must know and assume the consequences and impact of the artifacts introduced in the world that he or she is helping to create. Designers need to care about the worlds they are contributing to opening and establishing. Every design object put into the world opens a material future in which that object is going to operate. Every decision on shape, material, color or size will have consequences that sometimes go beyond a human time scale.

Another current perspective that tries to engage with many of these issues described before is the so-called "medium design," put forward by Keller Easterling (2021). As she suggests, "Rather than prescribing solutions, like buildings, master plans, or algorithms, medium design works with protocols of interplay – not things, but parameters for how things interact with each other" (Easterling, 2021, p. 20). In this sense, it connects with notions of relational ontology put forward by Haraway or Puig de la Bellacasa or it resonates with actor-network theories developed primarily by Bruno Latour (2008). Again, in this context, the designer is no longer a demiurge but a modulator of semiotic and material flows. As Easterling (2021) put it, in medium design "the designer is then temporarily manipulating the chemistries of assemblages and networks" (p. 11). In this sense there is a certain displacement, the designer's role is to reassemble, connect or cut short heterogeneous flows of ideas and materials. In the midst of complex social, economic or political problems, the designer is not so much a provider of solutions (as conceived in human-centered design), or a world-maker (as in ontological design), but an agent who taps and connects semiotic and material flows and rearticulates realities. In this sense, the medium designer is more of a broker than a demiurge.

With the shift towards relational ontologies, we see how certain ideas of the inherent existence of objects are called into question. Things are shaped and defined by the semiotic, energetic, material, political or aesthetic networks in which they become entangled. There is no being which is not part of a complex alliance of human and non-human elements. In this sense, "Medium designers move through the world constantly jostling its solids into more interdependent relationships" (Easterling, 2021, p. 39). This need to allow and shape connections and relationships resonates with the call for an "epistemic erotic," that is erotics understood as:

> a way to get entangled by the links and bonds that ensemble humans and non-humans, subjects with objects, persons and things. We could define these erotics as the materialization of the bonds that make us part of the world. Erotics signals the subject that is fascinated by another subject, or by another object. It engages in the power of attraction. It casts light on the broken links that modern epistemic modes have enforced on our understanding of the material reality of which we are a part. (Rowan, 2021, p. 4611)

Understanding design through these lenses or perspectives opens up the possibility of thinking of design as an act of composition more than a work of creation. Designers compose worlds by allowing certain connections to happen, certain material alliances to take place. In this sense, there is a will to displace the role of the designer, allowing non-human entities and agencies to have a stronger voice and presence in design practices.

These different perspectives – ontological design, decolonial design, medium design, etc. – have led to what we could provisionally call a posthumanist design approach, or ways in which we can conceive worlds in which humans are not the central actors and in which notions of time, agency or politics need to be re-evaluated. An issue that needs to be addressed in this context stems from the idea of design as a world-making practice. When we talk about understanding the consequences of design or the transformations that derive from it, we do so with human-centric temporalities which generally are not capable of understanding or engaging with the non-human temporalities such of metals, plastics or certain forms of organic matter (Barry, 2010). In this sense, the idea of the designer as a world-maker in such posthumanist approaches retains clear modernist undertones typical of the humanist conception of design. If we assume a posthumanist perspective, we must take into account the multitude of agencies that intervene in the consolidation of new design artifacts and the worlds that unfold around them. The human will (of the designer) is going to become entangled with socio-technical systems, infrastructures, regulations, cadences of use, diverse materialities, propensities, collective imaginations and economic criteria. Material and semiotic systems. Human and non-human time scales.

Arturo Escobar (2018) is aware of some of the modernist legacies which are still shaping contemporary design practices when he asks, "can design be extricated from its embeddedness in modernist unsustainable and defuturing practices and redirecting toward other ontological commitments, practices, narratives, and performances?" (p. 168). This focus on the ontological dimension of design also needs to be examined carefully. One of the most biased or problematic readings that could be derived from this idea of design as a world-making practice is to believe that individual action produces worlds. As the philosopher Timothy Morton reminds us, statistically there is no human action that has an impact of any kind when it comes to solving major problems such as the mass extinction of species due to global warming. No single person opens or transforms worlds. As feminist theories remind us (Serra et al., 2021), individual action does not create the conditions for the transformation of economic and power relations that have a structural nature. Humans can intervene and shape certain semiotic or material flows, but there is no individual design project that can change structural problems or inequalities. In this sense, we need to be able to evaluate whether effectively designing is a world-making practice; whether it contributes to changing power relations or by producing material artifacts, it helps to stabilize certain worldviews and the systems that sustain them.

The main contradiction to be addressed is the will to overcome humanist design traditions while still wanting to work from a strong notion of the importance of human agency and will. It appears that there is a will to discard humanism, but without discarding human privileges. Authors such as Timothy Morton (2018) have argued that the notion "human" should be, if not completely erased, at least faded down – this is a way to get out of "correlationism." As he argues:

> Extreme postmodern thought argues that nothing exists because everything is a construct. This idea, now known as correlationism, has been popular in Western philosophy for about two centuries. We just encountered it in our exploration of different kinds of "realizer." Again, the idea is that things in themselves don't exist until they have been "realized." (Morton, 2018, p. 13)

He argues that we must start "fading down" the sound of the human in order to start hearing other agents and non-human entities. But how could this idea affect design research and practices in which the idea and the agency of the designer is still so strong?

Human Supremacy or Interdependence?

Most of the cases seen above follow a humanist tradition in which the individual subject is always in a privileged position in relation to the community or non-human forms of life. This has been named as human supremacy or human exceptionalism, a term that "has been employed to designate those world-views or philosophies or systems of thought that characterize humanity as essentially and fundamentally different in kind from the rest of the natural order" (Tyler, 2021, p. 17). Therefore, it rests on the idea of an individual that exists above the world they inhabit. As Braidotti (2013) reminds us, "the humanistic ideal constituted, in fact the core of a liberal individualistic view of the subject, which defined perfectibility in terms of autonomy and self-determination" (p. 23). This autonomous subject, independent from other subjects and free to make decisions, seems to contradict the attempts to decenter the human in design as a very specific kind of human seems to be central to all these actions: the designer herself. We still operate under a paradigm that considers each human to have an inherent self that drives and shapes their destiny. But this idea is confronting growing opposition. "The self is inextricably intertwined with, a part of, or in some sense identical with the rest of the world. In recent interdisciplinary work, this general idea has been described as the 'oneness hypothesis'" (Ivanhoe et al., 2018).

We are shifting towards more complex or interdependent notions of the self; an expansive conception of the self that can include other human and non-human agents. In this sense, we are escaping from notions of the self that are "strongly individualistic" or what can be called "the hyper individualistic conception of the self" (Ivanhoe et al., 2018, p. 3). There are many social, cultural and religious traditions that call the notion of the self into question. Also, there are many non-Western traditions in which the autonomous self with inherent existence has been called into question. As Philip J. Ivanhoe et al. (2018) argue, "Buddhism, a complex, venerable, and influential global religion, is well known for its view that there is no separate and enduring self, and that the delusion that such an enduring self exists is the source of all suffering" (p. 3). The notion that there is no autonomous self is prevalent in other cultural and religious traditions; see for example Daoism, which equates certain notions of the self to holding selfish views of the world.

> Like Buddhists, Daoists do not deny the genuine and healthy everyday regard we have for our own interests; the object of their criticism is not so much a concern with the self but a mistaken conception of the self that leads to self-centeredness and even selfishness. (Ivanhoe et al., 2018, p. 4)

One of the key teachings of Buddhism is what is called emptiness, that is, the realization that "ourselves and all sentient beings and their suffering do not exist inherently, we are just designations" (Kelsang Gyatso, 2016, p. 94). In these spiritual and cultural traditions, meditating on emptiness allows the boundaries of the self to dissolve and generates an awareness of the interconnected nature of reality.

These cultural and religious traditions are far away from contemporary design debates but they help illustrate how in the claim to introduce non-European epistemic perspectives there is reluctance to endorse those who would challenge completely one of the central elements of the European Enlightenment: the individual and autonomous human subject. We need to ask ourselves if we can talk about posthuman design if we are unwilling to erase extremely strong notions of the self, subjectivity and the role of the designer as a world-maker. Are posthuman design practices just cherry-picking ideas and aesthetic tropes from non-European cultural traditions? Can we claim to be working on posthumanist design practices if we do not challenge the centrality of the Western ontology and its idea of being?

It is in this context that notions of interdependence have flourished, displacing the ontological question "what it is to be" with the question "with whom is being possible?" There is no autonomous disentangled self. No being can exist outside of a very specific material, semiotic, energetic or cultural entanglement. In this sense we need to understand and take into account the recognition that human beings are related in complex and intricate ways, not only to other humans, but also to other non-human beings as well – human and non-human networks and entanglements that make the idea of an individual self-redundant. This implies understanding interdependence as a deep ontological but also political space, avoiding the belief that subjects or objects pre-exist their relations (Haraway, 2003). As Kriti Sharma (2015) reminds us, "by and large, we think that interdependence just means 'independent objects interacting'" (p. 2), but instead this notion implies the impossibility of an independent or inherent existence. Nothing is, everything is being. Nobody opens new worlds, as worlds are always embedded in a deep entanglement of modes of being.

The questioning of the modern European notion of self is not only happening in non-Western thought traditions. Recently the unitary self with inherent existence has been challenged from Western scientific perspectives such as neuroscience (Mcgilchrist, 2019; Niebauer, 2019), cognitive sciences (Noë, 2010), philosophy (Metzinger, 2018) or even from a biological perspective (Weber, 2017). The notion of the human as a self-encapsulated being has been called into question as there is no being that exists outside an ecological context which he or she helps to produce (Maturana & Varela, 1987). More extremely, from a biological perspective the human being is not a being at all as it is considered a holobiont, a being of beings, living in a symbiotic relation with its gut bacteria (Yong, 2017). There is no human being which is not part of a complex energetic and material network; that is, there is no self which is not interdependent from other human and non-human selves. Biologically, the possibility of an independent and autonomous self is technically impossible. Culturally, there is no self which is not part of a complex network of words, gestures and shared beliefs. And whilst the proof that the central agent of humanism, the human, does not exist, we still struggle to acknowledge this absence in posthumanist design research and practices. There is still a strong need for social validation, authority and branding individual practices that clearly clash with the theoretical claims that underline some of these practices.

In this sense we see the emergence of non-symmetric relations between the discourses established and the practices performed. Bruno Latour (1986) argues that in the midst of an epistemic or conceptual conflict, we must be able to ask the same questions to all sides involved. We are very quick to dismiss humanism but still timid in looking at the ways modern notions are deeply embedded in posthumanism. We are happy to critique the role human agency has in humanism but are still unable to engage with posthumanist design practices that are not deeply mediated by subjective and human agencies. We see practices that argue for non-human agencies but still seem to have a strong authorial voice and position. In this sense we see forms of posthuman design practices that are happy to not let human privileges become questioned or challenged. We read about human and non-human interdependence in heavily branded and authored essays, exhibitions and design practices. One of the clearest shortcomings to be addressed is that whilst striving for a posthumanist design practice, humans seem to be unwilling to decenter their names, subjectivities and brands from their practices.

Conclusions

In this paper we have argued that some contemporary design practices are caught between two competing systems, two different ways of addressing and understanding design theories and practices. We have shown how these practices are currently diving into uncharted territories, that of posthumanist epistemologies and perspectives, although it still relies heavily on humanist conceptions and ways of doing. We aim to displace the human whilst publishing academic articles with clear human authors who claim to have original ideas; claiming to give voice to non-human agencies in design projects but becoming something more than a mere translator or mediator. Displacing the role of the human but re-centering the role of the designer.

Whilst challenging the modernist idea of the designer as a demiurge, the posthumanist notion of the designer as a world-maker retains clear modernist undertones typical of the humanist conception of design. These contradictions need to be explored and addressed if we are willing to displace humanist visions with posthumanist knowledge-producing practices, if we intend to replace modern epistemologies with world-making and agential approaches, or human concerns with more-than-human problems. For all these reasons, we maintain that design research needs to engage with these contradictions and acknowledge its role in reaffirming the world it wants to challenge.

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TEACHING FOR MORE-THAN-HUMAN PERSPECTIVES IN TECHNOLOGY DESIGN – TOWARDS A PEDAGOGICAL FRAMEWORK

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Abstract

This position paper presents the initial steps towards the development of a pedagogical framework for teaching for more-than-human perspectives in design, targeting teachers at technology design programmes and courses in higher education. We build on the methodology applied in the Value Sensitive Design in Higher Education (VASE) (2021a) project and the resulting VASE open educational resource (OER) (2021b). This continuation of the project focuses on developing teaching activities that address more-than-human perspectives when teaching the next generation of responsible technology designers. In recent years, there has been a growing awareness towards designing for more complex and holistic systems that include perspectives of nature and the more-than-human. As stated in the United Nations (UN) (2015) Sustainable Development Goals, to achieve sustainable development we need to address the three levels: people (society), profit (economy), and planet (biosphere) since they are all intertwined. Still, most of the design methods professionally practised and taught in technology design education are geared towards humans with a particular focus on users through, for example, human-centred design and user experience design. Thus, there is a gap between methods taught to designers and the methods needed to solve problems related to environmental and social sustainability while also addressing planetary perspectives. This paper puts forward the importance of challenging the dominant paradigm of technology design practices that primarily focus on people and profit by also including planetary and more-than-human perspectives. Examples of existing practices and approaches for including and listening to more-than-human perspectives are presented. By building on the experiences gained from the VASE (2021a) project, we present a path towards a pedagogical approach for how practices of designing for more-than-human perspectives can be turned into teaching activities in technology design education. In doing so, teachers become agents of

change by creating conditions for students to grow into responsible designers of future technologies and play a role in driving adaptation towards a more sustainable future.

Author Keywords
More-than-human; technology design education; open educational resource (OER); UN Sustainable Development Goals (SDGs); cultural education; pluriversal.

Introduction

Designing for/with the More-Than-Human

In recent years, there has been a growing awareness of designing for more complex and holistic systems that include perspectives of nature and the more-than-human (Borthwick et al., 2021; Wakkary, 2021). Still, most of the technology design methods both professionally practised and taught in technology design education are geared towards human stakeholders as in, for example, human-centred design and user experience design. However, with the current climate crisis, it is not enough to just consider the needs of individual users. Attention must also be paid to more-than-human stakeholders and their values. A new kind of framing is needed in which humans share the centre stage with the non-humans with whom we are inherently interconnected (Haraway, 2016; Wakkary, 2021). How can we learn to listen to the voices of our more-than-human companions, and all the species and parts of nature that cannot speak for themselves, but still are affected by or affect our actions and design choices? What if forests and trees, birds and bees were treated as stakeholders – or even a virus, which is probably one of the most prominent stakeholders in 2020-2022?

As stated in the UN (2015) Sustainable Development Goals (SDGs), to achieve sustainable development we need to address the three levels – people (society), profit (economy), and planet (biosphere) – since they are all intertwined. A more-than-human design approach encompasses planetary perspectives where our shared planet and all the living organisms and communities that depend on it are put at the centre of the design process. As highlighted in previous research and by design professionals, there is an identified need to extend the repertoire of technology design methods to fulfil the SDGs (UN, 2015) where all three levels are addressed (Borthwick et al., 2021). Up to now, the technology design community, including design education, has tended to incorporate the perspectives of people and profit, but not enough attention has been given to planetary perspectives and, in particular, the more-than-human perspectives. The neoliberal economic system contributes to framing the ways in which technology designers envision their designs having an impact (Friedman, 2019). Thus, there is a gap between the human-centred design methods taught in technology design education and the need for alternative methods to solve problems related to environmental and social sustainability by also addressing planetary perspectives.

In this position paper, we argue for the importance of challenging the dominant paradigm of technology design practices primarily focusing on people and profit by also including planetary and more-than-human perspectives. Further on, we introduce a few examples of existing practices and approaches and a few educational initiatives where more-than-human perspectives are addressed. By building on the experiences gained from the Value Sensitive Design in Higher Education (VASE) (2021) project, we present a pedagogical approach for how practices of designing for more-than-human perspectives can be turned into teaching resources published as open educational resources (OERs). The OERs target teachers at technology design programmes and courses in higher education. Finally, we discuss the potential impact and effects of sharing teaching resources about critical societal issues, such as addressing more-than-human perspectives, as an OER and how this initiative can give teachers across the globe access to knowledge and teaching resources to create conditions for students to grow into responsible designers of future technologies. In doing so, teachers become agents of change and play a role in driving adaptation towards a more sustainable future.

Background

Challenging the Dominant Paradigm of Technology Design Practices and Teaching

Technology designers have great responsibility since their designs feed the capitalist market economy and the resulting unsustainable use of resources (Borthwick et al., 2018). As Monteiro (2019) argued, "design is a political act. What we choose to design is a political act." Thus, today's technology designers – such as interaction designers, product designers, and engineers – need to become aware of how humans affect the environment and incorporate such an awareness into their designs so that future products, systems, and services contribute to the sustainability transition.

Recently, the field of human computer interaction (HCI) has taken on its fourth wave and is slowly turning away from human-centred design to engage with posthuman theories (Frauenberger, 2019). In particular, we see strong potential in participatory design (PD) (Bødker et al., 2022) and value sensitive design (VSD) (Friedman & Hendry, 2019) for embracing more-than-human perspectives. PD methods have the potential to contribute to the sustainability transition since they address larger contexts with multiple stakeholders and thus can contribute to social change. In addition to PD, VSD (Friedman & Hendry, 2019) focuses on incorporating human values into products, systems, and services. Importantly, Friedman and Hendry (2019) broaden the view of stakeholders to include large groups of people, past and future generations, mountains, and rivers. Through the VSD approach, there is potential to go beyond human values to balance them with values related to nature and investigate how these values might interact.

The challenge of many of today's technology designs is that they mainly target users as individuals. The vast majority of technology designers work with user-centred design methods and design process models such as the Double Diamond design process (Design Council, 2021) where the focus is on objects and tools that support individual needs. Relatively little attention has been paid to empowering people to act together and orientate themselves towards revitalising and maintaining shared resources, including natural resources. Furthermore, technology designs often happen within the hegemony of Western knowledge systems, where underlying concepts like ownership and individual property have strong implications for new technology designs. As we enter more severe stages of global warming, technology designers should not just be concerned about humans and their everyday lives in urban environments. They should start focusing on establishing and evolving human connections with nature. Haraway (2016) explores the idea of kinship – the development of "diverse practices and knowledges for conjoined human and other-than-human becoming and exchange" (p. 153). How might technology designers develop products, systems, and services that enable humans to live sustainably with each other and beyond, with the more-than-human?

An important step towards answering this question is to overcome the myths of modernity (Leitao, 2018). One myth is the belief in techno-solutions to universal problems that have no critical reflections on the impact such solutions might have on diverse human and more-than-human relations established through cultural practices. Leitao (2018) criticises Cartesian rationality that leads to "mechanistic reductionist science" (p. 5). We need to go beyond this mindset to include cultural education and related community practices that guide how humans might live together with the more-than-human in respectful ways where the more-than-human is not just seen as raw material that can be manufactured into material goods. Leitao argues for a redefinition of what well-being is and emphasises that we are all capable designers of our own well-being: new designs should allow everybody – not just a small elite that creates technological products – to design new ways of life. The idea that there inherently is a desire for new technological development that supports civilisation is too narrow and resembles an idea of a "one-world world" (Escobar, 2020). Other kinds of developments that might not fit the Western understanding of "development" or "civilisation" need to be rendered visible to technology designers to learn how to interact with nature in regenerative ways.

Ingold (2013) suggests a shift in the conceptual thinking around the role of the designers in relation to consumer markets and cultures, for example, from "form-giving" to "form-keeping." There needs to be a change in the designer's perception of whom they design for/with: if not merely consumers, who else might they design for or in partnership with? For example, if a group of people have shared responsibility for resources assembled in products, how might they negotiate the endurance of a product in (shared) use (Rosner & Ames, 2014)? How might technology designers spot design openings where they focus on designing for collectives of humans and other species, e.g., through ways in which community practices emerge from products, systems, and services that enable humans to act and change unsustainable behaviours collectively? Technology designers need to not only consider what Mankoff et al. (2007) define as sustainability in design (if it is a sustainable product) but also sustainability *through* design (if the design supports sustainable lifestyles, actions, and decision making).

State of the Art – Practices for Listening to the Voices of the More-Than-Human

In contemporary technology design research and practice, there is a growing awareness of the limits of our resources. The Computing within Limits conference (LIMITS, 2022) is one such example. In addition, we see a spark of interest in expanding the worlds of design by embracing more-than-human (even cosmological) perspectives in the time of planetary crisis (Behzad et al., 2022; Borthwick et al., 2021; Giaccardi & Redström, 2020; Tomitsch et al., 2021; Wakkary, 2021). Inspired by scholars such as Escobar (2018, 2020), Haraway (2016), Bellacasa (2017), and Scharmer (2018), we may develop a more-than-human approach that not only includes the internet of things (IoT) and pervasive computing, but also attends to the great potential of more-than-human participation (Coulton & Lindley, 2019; Clarke et al., 2019). This is achieved by carefully considering "entanglements between human and non-human worlds" (Clarke et al., 2019, p. 60), for example, animal computer interaction (ACI) and cultural and spiritual dimensions of human lives that have evolved to maintain survival as part of a diverse array of ecosystems.

Clarke et al. (2019) draw attention to how design processes can show that "making-with and growing-with have the potential for alternative forms of participation in fabricated multispecies worlds" (p. 61). Thus, more-than-human approaches to technology designs should go beyond technology centrism and, for example, put emphasis on a) historically and culturally situated knowledge, b) matters of care in eco-social contexts, c) companionship with other species, and d) compassionate approaches to the generation of new economic systems, transforming from ego- into eco-awareness (Scharmer, 2018).

Wakkary's (2021) *designing-with* is a posthuman approach that attends to more-than-human participants in the design process by inviting a broad network of humans and more-than-humans related to a design project. The network is called a constituency and refers to the act of inviting and gathering all stakeholders, including the non-humans, to a design and making process. The process is mobilised through a repertoire of methods and techniques that create conditions for the non-humans to become participants in creative design processes. Explorations conducted as part of the projects Morse Things and Sympathy of Things (Behzad et al., 2022), a repertoire of methods for *feeling-with*, enable "non-human designers to take part, lead, and generate new design iterations in the process of making, as they find sympathy within and between one another" (p. 4).

Tomitsch et al. (2021) have developed a framework for involving more-than-humans in the design process consisting of four steps: 1) identifying non-human stakeholders; 2) creating non-human personas; 3) forming coalitions through middle-out engagement; and 4) employing non-human personas and their coalitions. When creating non-human personas, common guides for human personas are used, but with adapted categories: type/species, age/lifespan, local population, needs/motivation, food/food sources, challenges/stressors, "interacts with," and habitat. The third step consists of assessing whether the non-human persona developed accurately represents the non-human stakeholders that were identified in the first step. To achieve this, a middle-out engagement approach is applied "for forming a coalition that can speak on behalf of the non-human species that are impacted by design decisions" (Tomitsch et al., 2021, p. 102). The approach combines the collective knowledge from the top (government agencies, the industry) to the bottom (local communities, NGOs, Indigenous peoples). The final step is to use the non-human personas in the design process alongside and in the same way as human personas.

Pluriversal Ideas About the More-Than-Human

The above-mentioned state of the art examples reflect an integration of *many ways of seeing*. In *Designs for the Pluriverse*, Escobar (2018) calls for multicultural perspectives of design, some of which are more focused on caring for nature and do not see humans in opposition to nature. He points to the bifurcation of the following as a problem:

> Human and non-human, live (life/organic) and inert (matter/inorganic), reason and emotion, ideas, and feelings, the real and its representations, the secular and the sacred or spiritual, what is alive and what is dead, the individual and the collective, science (rationality, universality) and non-science (belief, faith, irrationality, culturally specific knowledge), facts and values, form and content, developed and underdeveloped. (Escobar, 2018, p. 95)

In the Western world, value systems are based on this bifurcation because they emerged from philosophies that generated this bifurcation in the first place (Lent, 2017). If technology designers can, through education, reach an understanding where the above are integrated, then technology designers might be better equipped to shape how people care for, restore, and revitalise the ecosystems that they are part of. By embracing different cultures, we can imagine different ways in which people relate to each other and the more-than-human. According to Nisbett (2003), integrating Eastern and Western ways of knowing will expand the intelligence with which we perceive, understand, and act. Lent (2017) argues for a critical review of our multi-cultural history and that we carefully consider the value systems that we, sometimes blindly, rely on. When highlighting some of the influential thought systems that have shaped the ways in which we live and relate to nature, he emphasises the need to engage with underlying assumptions about how things should be, and thus how we might envision a future where we do not act in destructive ways. This calls for an integration of, for example, Indigenous research methods (Wilson, 2008) with design processes where the central value of *relational accountability* is considered throughout the design process as well as in the roles that a new technology design might play.

One of the most crucial things to take into consideration are the Rights of Nature. In 2008, the constitution of Ecuador recognised the inherent rights of nature (Boyd, 2017). Since then, the Rights of Nature movement has influenced lawmaking around the world. How might Rights of Nature influence technology designers to think differently about their designs? And who can speak on behalf of nature in design processes and through a product, system, or service? How might design students learn to take these voices into account? And are there other movements, theories, and ways of thinking that can become more prominent inspirational sources for technology designers, so that it is not only the individual human being – the "user" (understood as a consumer) – who is the focus of a design process? Design researchers are probably already familiar with Latour's (2005) actor-network theory (ANT) that focuses on the study of how objects in our environments influence the ways we act and think, and our ways of being and relating to each other and nature.

By paying attention to how more-than-human entities shape the ways in which we interact with one another in different societies and cultures, future technology designers have an opportunity to consider what roles their products, systems, and services might play in shaping human lives and societies. What if, for example, signs of nature were made visible in urban contexts that are otherwise removed from nature? How might that influence the ways in which citizens commit to protecting nature? Until recently, academia has regarded cultural and spiritual ways of knowing as "alternative knowledge systems." How might designers re-discover how social and cultural practices and their corresponding spiritual and value systems have an impact on how communities of humans orientate themselves towards natural environments and resources?

Teaching for More-Than-Human Perspectives

Educating Technology Designers to Focus on the More-Than-Human

Despite the international design research community's growing interest in the more-than-human approach to design (Behzad et al., 2022; Borthwick et al., 2021; Giaccardi & Redström, 2020; Tomitsch et al., 2021; Wakkary, 2021), to the best of our knowledge, there are still few examples of educational initiatives where more-than-human perspectives are being foregrounded in technology design education.

One initiative with educational ambitions is the network "Design + Posthumanism" (n.d.) which engages in design practice, education, and research. The network consists of designers and scholars based in northern Europe who all share the common view that designers should learn to pay better attention to the more-than-human. Through their design practices, they explore how design, education, and research can thrive in contact with posthumanism but also contribute to the field. Another example, which is not purely a design school but still a relevant initiative, is the Oslo School of Environmental Humanities (OSEH) (n.d.). By partaking in collaborative lectures, experimental seminars, and field excursions, students learn to better understand and address environmental issues and challenges. An emphasis is put on building an understanding of how different approaches and trans-disciplinary thinking are essential for critically engaging with the challenges of the Anthropocene epoch; that is, the age of the human.

A third example is the company NHCD (n.d.), which has developed a non-human centred design method that is taught to students at design schools such as the Sustainable Design School Nice, HKU Design Utrecht, and Köln International School of Design. In their teaching, they challenge the students to change their design perspective to that of a non-human, and to explore a design context from the point of view of someone or something else. Design challenges explored by the students involve non-human stakeholders such as birds, seals, corals and pose questions such as "How to make a building that doesn't kill birds?"

What has become apparent from the few examples brought forward is that there is a growing interest in the field of design education to include more-than-human perspectives and introduce students to methods and approaches for doing so. Most of the examples that we have learned about so far are small scale, local initiatives, and are not made accessible to other teachers to learn from and be inspired by. To provide more teachers with teaching resources that enable and encourage them to educate students on this topic, we have initiated a pedagogical project that aims to turn practices of designing for/ with the more-than-human into teaching resources included in a pedagogical framework. By utilising the teaching resources, teachers can create conditions for students to grow into responsible designers of future products, systems, and services and play a role in driving adaptation towards a more sustainable future.

Extending the VASE Pedagogical Framework on Teaching for (Human) Values in Design to the More-Than-Human

The new pedagogical framework on the more-than-human builds on the pedagogical approach developed by the VASE (2021) project. Similar to VASE, the more-than-human pedagogical framework will be published as an open educational resource (OER) offering teaching resources that teachers can download and adapt according to their own educational contexts and aims. However, as the VASE pedagogical framework primarily addresses human values from a Western epistemology, more work is needed to extend it with more-than-human perspectives.

Thus, the more-than-human pedagogical framework is an extension of the VASE pedagogical framework (Figure 1) that intends to encompass the following components:

- **Three pillars** that cover the competency domains found to be central when educating responsible designers. The VASE pillars "Ethics and Values," "Designers and Stakeholders," and "Design and Technology" will be extended to also include 1) Ethics and More-than-Human Values, 2) Designers and More-than-Human Stakeholders, and 3) More-than-Human Design and Technology.
- **Learning objectives** that guide teachers for teaching more-than-human perspectives in design.
- **A curriculum compass** containing specific learning outcomes spanning the three pillars and the SOLO taxonomy (Biggs, 1982) that can help facilitate students' progression from simple to more complex understandings. The learning outcomes will be linked directly to the concrete teaching activities developed throughout the project.
- **Teaching activities** that materialise, concretise, and integrate the contents of the pillars, overarching learning objectives, and specific learning outcomes into step-by-step activities for teaching more-than-human perspectives in design.
- **Assessment activities** that link back to specific teaching activities to support teachers in checking whether the learning outcomes of the teaching activities were achieved by the students.

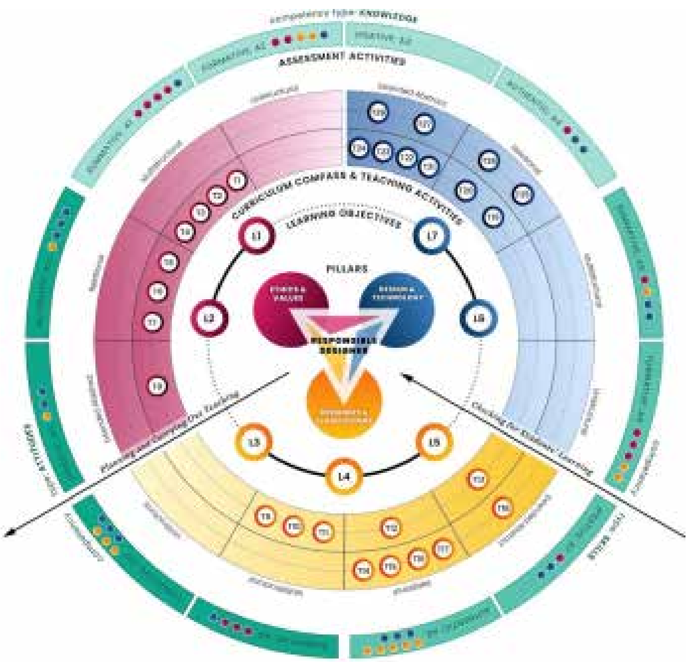

Figure 1. The VASE pedagogical framework model visualises the different components included in the VASE OER (VASE, 2021b), and acts as an inspiration for the more-than-human pedagogical framework.

The more-than-human pedagogical framework aims to provide a concrete and practical tool for teachers to navigate through a wide range of teaching resources to identify specific and concrete teaching and assessment activities that fit their educational contexts and pedagogical aims. The goal is *not* to provide a full curriculum or courses on more-than-human perspectives in design, but rather an inspirational repository of various resources for teachers to explore, experiment with, and integrate into their teaching.

In developing the more-than-human pedagogical framework, we will use a modification of the pedagogical design pattern method (Goodyear, 2005; Nørgård et al., 2019; Nørgård, 2022; Köppe et al., 2018; Laurillard, 2012). By connecting scientific, social, and cultural knowledge fields that address more-than-human perspectives and the field of educational design, we will translate theories and "best practices" into teaching resources. The new teaching resources are expected to provide a constructive proposal on how to include more holistic and planetary perspectives in technology design education to achieve the main learning goal: to educate responsible technology designers.

Discussion

The proposed more-than-human pedagogical framework will not only invite a multiplicity of perspectives on the more-than-human. It will also ask for a critical reflection on the dominant paradigms behind technology designs that are rooted in Western epistemologies. This invitation is not unproblematic – especially when it comes from researchers in the field of design that have inherited educational frameworks that support the development of products, systems, and services that mainly target Western societies and neo-capitalist market systems. Thus, careful work needs to be done to ensure that cultural dialogues and exchanges happen in respectful ways.

When developing a pedagogical framework with corresponding teaching activities that address the UN (2015) Sustainable Development Goals (SDGs), we hope to guide teachers and students in technology design learning environments on how to apply a new repertoire of design methods in a time where multiple societal systems and structures will undergo radical changes because of the consequences of climate change. By gathering ways of knowing that contribute to implementation of more-than-human perspectives in technology designs, we are part of a momentum that contributes to bridging gaps between cultures, facilitating dialogue, and learning to make change. This kind of mutual learning is also apparent in movements like the Pachamama Alliance (2022).

There are at least three issues that we need to pay attention to when developing the pedagogical framework for teaching for more-than-human perspectives in design. The first one is: *how might we listen to the more-than-human and define what more-than-human values are?* The breadth of sources that we listen to need to address the hierarchy of information and knowledge and, in particular, pay critical attention to the hegemony of Western scientific practices where data and "facts" are automatically considered to be at the top of this hierarchy. Learning how to listen to diverse sources of knowledge outside the Western scientific knowledge system might be a challenge, since they have not always been regarded as "scientifically valid." Yet, non-Western philosophies and Indigenous ways of knowing that have evolved throughout history as strategies for survival in specific natural environments might be even more relevant in these times. They guide ways in which humans can relate to each other and the more-than-human; for example, wisdom practices where intuitive, embodied, community-based, and spiritual relations to the more-than-human are at the centre.

The second issue is thus related to the first one: *how might we learn from each other across cultures?* The problem of cultural appropriation is obvious in this regard, and we can only learn through respectful exchanges that offer justice to the peoples who decide to share their knowledge and benefit from this sharing in return. It would be quite problematic if we extracted information from sources in the fields of anthropology and ethnography where Indigenous peoples have been exposed to the gaze of "experts" from coloniser and settler nations (Wilson, 2008; Russell, 2005). Even worse is when documentation comes from colonial systems where descriptions of Indigenous cultures and practices can be distressing (Wilson, 2008; Russell, 2005.)

The third issue relates back to our criticism of technology designs for individual users – designs that are often owned by corporate businesses intent on making a profit: *how might we create teaching resources that encourage upcoming technology designers to design for/with collectives of humans who live in networks with the more-than-human?* With the modern understanding of individual freedom, property, and intellectual property rights, it might be challenging to address taken-for-granted rationales behind how designers should operate, what kinds of products, systems, and services they should create, and why.

Future Work

In our work with the pedagogical framework on more-than-human perspectives in design, we will 1) build an understanding of the current state of innovative and best practices on designing for more-than-human perspectives; 2) provide teachers at technology design programmes in higher education with innovative teaching resources for teaching students and future practitioners to address more-than-human perspectives; 3) make educational resources on teaching for more-than-human perspectives in design available as an online educational resource; and 4) disseminate the results of our work to professional networks to foster cross-cultural dialogues and increased capacity to teach for more-than-human perspectives in technology design education. The potential impact and large-scale effects of this work as envisioned in VASE (2021a) could be to upgrade curriculums in technology design educations so that students learn to listen to and work with human and more-than-human stakeholders and take their perspectives into consideration, balance value tensions in constructive ways, and envision long-term societal and environmental effects of a design, including negative effects (e.g., Williams, 2019). They will also learn to critically evaluate features of a new design by consulting with diverse ways of knowing, performing expectation management, and dealing with resistance to more-than-human approaches to design upon entering the job market.

Conclusion

In recent years there has been a growing awareness in the design research communities of the need to design for more complex and holistic systems that include more-than-human perspectives. We need to move away from focusing on individual users and towards focusing on humans who live in sustainable ways as part of ecosystems that include the more-than-human. Yet there is a lack of concrete ways in which teachers in higher education can include more-than-human perspectives in their technology design instruction. In the present article, we propose how we might further develop the VASE (2021a) pedagogical framework for teaching values in design to also include teaching resources that can, in concrete ways, support technology design students in engaging with more-than-human perspectives. We gave examples of more-than human design approaches, theories, and methods that can serve as inspirational sources for the creation of teaching resources, and we discussed the potential impact and effects of teachings that address the UN (2015) Sustainable Development Goals (SDGs). With this paper, we hope to engage in the discussion about how to address the three levels – people (society), profit (economy), planet (biosphere) – in technology design education in ways that educate responsible designers who see new opportunities for design and are ready to position themselves as game changers.

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THE *PROMETHEUS TERMINAL:* WORLDING GAMES FOR THE ADOPTION OF SUSTAINABLE DATAFICATION AND CYBERSECURITY PRACTICES

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Abstract

Edge computing is being promoted as a more secure, private, and increasingly better sustainable option for data generation and processing. Nevertheless, the rapid surge in the number of internet of things (IoT) devices being integrated into networks and accompanying edge computing devices to process data closer to the source creates more opportunities and entry points for cyber-attacks. These attacks are labour intensive, with energy consumption increasing two-fold, contributing to climate change. Catalysing the situation further is the current illegibility and illiteracy of sustainable datafication and cybersecurity practices when using IoT devices and, to a more significant extent, the "networkification" (Pierce & DiSalvo, 2017) of connected devices.

To respond to these emergent issues and to make legible the domain for users' sustainable and secured adoption of edge and IoT systems, this paper describes a research-through-design process for the design of a digital "choose your own adventure" game, portraying a hacker's voyage through a perceptible world of computer networks and sustainable data practices. In addition to attempting to disambiguate the network ecology of IoT and edge computing, we describe our "worlding" method used to create the game's narrative to illustrate the various edge and IoT operations, how their systems are impacted by security threats, and how these technologies could be operated more sustainably. We conclude by showcasing the final physical-digital game console – the *Prometheus Terminal* – and gameplayers' response to it. We also take the opportunity to discuss the next phase of this research, which focuses on project impact through the design of an immersive experience, providing the opportunity to gather and reiterate research back to users concerning the legibility, negotiability, and agency within edge and IoT systems for the adoption of sustainable and secure practices within a network ecology.

Author Keywords

Sustainable datafication; edge computing; cybersecurity; legibility; adoption; worlding.

Introduction

The pervasiveness of internet of things (IoT), edge computing (EC), fog computing (FC), and cloud computing (CC) is affording end-users more significant levels of connectivity, convenience, and personalisation across society as well as providing opportunities for new enterprise and innovation (Brous et al., 2020; Sulieman et al., 2022). However, the legibility and user awareness of the outlined network assemblage and the associated socio-technical impacts on users is minimally known, due to the technologies' radical development and adoption, resulting in no universally accepted definition of EC and FC among experts (Caprolu et al., 2019). Adding to the perplexity: these computing paradigms are often used interchangeably for the other, as frequently evidenced in both academic and industry literature, with one archetype often being considered the sum total of the network endeavour (c.f. Cisco, 2015; Fan et al., 2018; Maia et al., 2019; Wen et al., 2017). Critically, experts' understanding of the technologies is constantly evolving while already in use and integrated into operational systems, leading to problems occurring in the "wild" with detrimental implications to users. The state of affairs also leads to a lack of general user knowledge, impacting agency and negotiability of the technology (Mortier et al., 2014), and compromising user security and adoption of sustainable practices (Stead et al., 2020).

Nevertheless, EC is promoted as a more secure and private method for data generation and processing in lieu of the cloud (Shi et al., 2016). A problem arises, however, in the increased use of IoT and EC technology, forming unwittingly insecure networks, creating opportunities for external actors (human and machine) to carry out cyber-attacks upon devices and systems, such as denial-of-service and ransomware attacks (Alrowaily & Lu, 2018; Fan et al., 2018). These incursions are "labour-intensive," requiring more processing power, where energy consumption can increase twofold during an attack (Kepçeoğlu et al., 2019), directly contributing to climate change (Morley et al., 2018). These environmental impacts are further compounded by the copious amounts of data generated by IoT systems, as almost half of the total data created globally originates from these systems (Reinsel et al., 2018).

To begin to respond to these outlined issues and to improve the legibility of the domain for users' secure and overall sustainable adoption of edge and IoT systems, this paper describes a research-through-design process (Durrant et al., 2017; Gaver, 2012) for the design of an interactive digital "choose your own adventure" game, housed in a specially designed terminal, whereupon the gameplay is of a hacker's voyage through a perceptible world of computer networks and sustainable and cybersecurity data practices.

To situate the context of the game, we will first unpack the ontology of EC, FC, and CC systems, noting their challenges and differences and establishing our rationale for focusing primarily on EC for this research. Secondly, we summarise a series of online workshops we held with computer science and sustainability experts. Thirdly, we describe our "worlding" method utilised to support creating the game's narrative and to visually communicate the various edge and IoT systems operations to everyday users of these technologies. As will be discussed, our worlding approach is a combination of chiefly design fiction as world-building approach (DFasWB) (Coulton et al., 2017; Pilling et al., 2021), flavoured with the novel practice of more-than human centered design (MTHCD) and "worlding" emanating from the likes of Donna Haraway (2011, 2016), who turns our attention to certain experiences of non-human things for a deeper look at human-world relations. Crucially, our worlding approach is used to disseminate our key research workshop findings and expand knowledge of IoT and EC sustainable practices and security issues through gameplay. We conclude by showcasing the final physical-digital game console – the *Prometheus Terminal* – and gameplayers' response to it, while also framing future research stemming from this work.

Network Ontology & Challenges

Before discussing EC and FC, it is essential to understand CC (Figure 1). CC is focused on data storage and operates as an online delivery of computer services (including databases, software, intelligence, and servers) offered to users by technological companies to operate their proprietary IoT devices and services. According to Statista (2021), by 2026, the number of IoT devices connected to the internet and cloud services is expected to double and reach 21.5 billion active connections. With IoT flourishing daily and the increased development of digital services, CC has transpired, despite its widespread success, as not being a one-size-fits-all solution owing to its centralised computing paradigm. This inflexibility has resulted in an amplified separation between users' devices and their clouds processing operational data that, across the spectrum of billions of active devices and services, are collectively and progressively demanding higher volume, variety, and velocity rates from data. This results in, to list a few consequences: low latency and jitter impacting time-sensitive applications (Caprolu et al., 2019); diminished context awareness and support (Roman et al., 2018); increased consumption and energy use of network bandwidth; a larger expanse of cyber-attack continuum; and decreased reliability of IoT devices operating as expected or as advertised (Cisco, 2015).

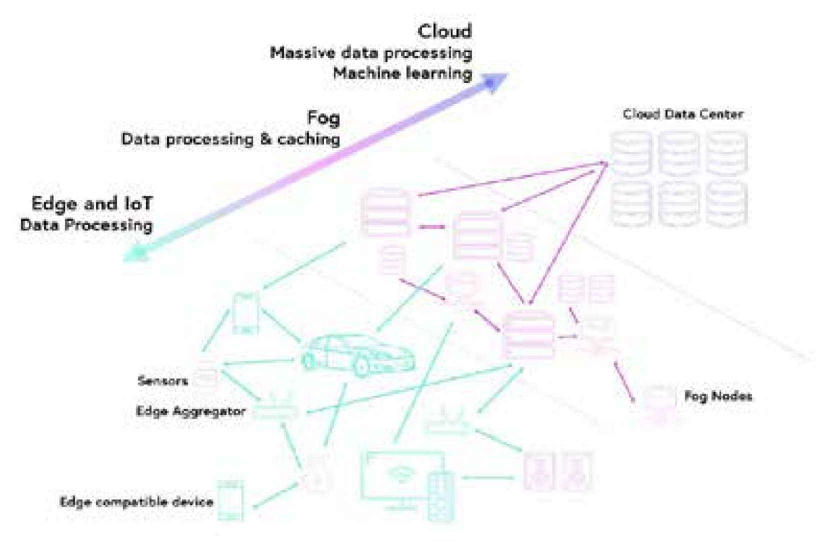

Figure 1. This diagram maps and traces the ontology of a typical network assemblage (Stead et al., 2022).

EC and FC share many similarities; specifically, they enable data traffic to the cloud and process operational data in closer proximity to devices. Nevertheless, to make a distinction between the two paradigms, EC is a distributed computing program constituting a network topology operating at the "edge" of a network, allowing IoT data to be gathered, processed, and distributed closer to the IoT devices themselves, rather than sending data out to a fog or globally dispersed cloud network (Shi & Dustdar, 2016). Based on the previous passage, one can assume a distinction between EC and IoT; however, it is a common misconception that IoT is synonymous with EC. Though at risk of confusing the characterisation, some IoT devices are edge compatible, with the capability to form edge networks and process data (also partially) within themselves or ping data to another edge device in the same network – such as mobile phones, wearables, and open-source single-board computers (Raspberry Pi) and constrained devices (Arduinos) (Caprolu et al., 2019).[1] In summary: it is not currently legible which IoT products aid in forming an edge network, a feature that is also addressed in the game by highlighting which devices are more likely to be part of the edge configuration. Our research will predominantly focus its attention on the sustainability and security implications of EC networks, as typically these are more easily adaptable or unwittingly formed by users through their adoption of edge-compatible IoT devices.

FC, however, is a network paradigm characteristically made up of servers outside of a user's network but geographically closer to the origin of the data, acting as a mediator between the edge and cloud. Some experts describe FC as extending the cloud via servers, as certain data packets commanded through programming not ordained for the cloud stay at the fog level, and are processed and cached here, with relevant data distributed to the cloud or back to the edge with excess data disposed of (Wen et al., 2017). As a result, both EC and FC are reshaping the operational computation of data-driven technologies. Therefore, the distribution of logic to different network nodes introduces new challenges such as dynamic scalability (Maia et al., 2019), specialised security mechanisms, and user acceptability to perform maintenance in the event of a cyber-attack (Zhang et al., 2018).

The Workshops: Methodology

To gather progressive and forefront information about the three themes of EC, cybersecurity, and sustainability, we designed and facilitated three "guided discussion workshops" with a mixed focus group of twenty experts from the fields (Hennink et al., 2020, p. 139). The workshops were staged and captured online using a combination of Zoom and the interactive whiteboard application Miro. Data was taken by recording the sessions with ethics approval and participant consent and transcribed for analysis, with the material used as context for worlding the "choose your own adventure" narrative. Participants were also encouraged to note prominent feedback directly on the interactive whiteboard, although advised that the conversation was the primary source of data collection.

An initial template of probing questions and discussion points was designed to initiate and pilot conversations, which reflected our preliminary research. The questions were also designed to be semi-improvised, flexible, and responsive to effectively follow topics as they were spontaneously raised or followed through by experts (Hennessy, 2015; Hennink et al., 2020, p. 174). As the workshops progressed, our qualitative methodology enabled us to adapt talking points with the knowledge gained from the previous workshops. Regarding the discussion template and group interaction, participants were able to synthesise speculations on sustainable edge computing. As Morgan (1997) states, the "hallmark of focus groups is their explicit use of group interaction to produce data and insights that would be less accessible without the interaction found in a group" (p. 2).

The structure of the guided discussions was broken into the three primary themes (EC, cybersecurity, and sustainability), with each theme being carried through to the next theme's discussion point. The first focus was EC, thus situating, familiarising, and probing the technology in question. Challenges and developments concerning cybersecurity at the edge followed, with the distinctive theme of sustainability concentrated on at the end. However, general enquiries into the sustainability facet were also queried at the close of each succeeding theme to increase the prospects of considering how sustainability translated into a digital context.

As we suspected, because of the uncharted territory of sustainable edge computing and experts' tendency to know a lot about their area of knowledge, it proved challenging to ground the conversations in practical, fleshed-out examples. Consequently, the last workshop task had a speculative emphasis which started with a demonstration and an example of the design fiction approach to lead participants into a speculative discussion, with an opportunity for them to create design fiction narratives, focusing on sustainable edge futures (Figure 2). As an example, a workshop participant speculated on a localised solar panel server farm that would cast an extensive edge network for neighbouring houses with a scheduled network activation, theorising a complete change in user behaviour and a more significant network field to secure.[2] A high-level thematic analysis was conducted after the workshops to identify and analyse the themes that materialised (Braun & Clarke, 2006). The following section will detail the analysis of the results of the motifs and contexts we employed for worlding the interactive game.

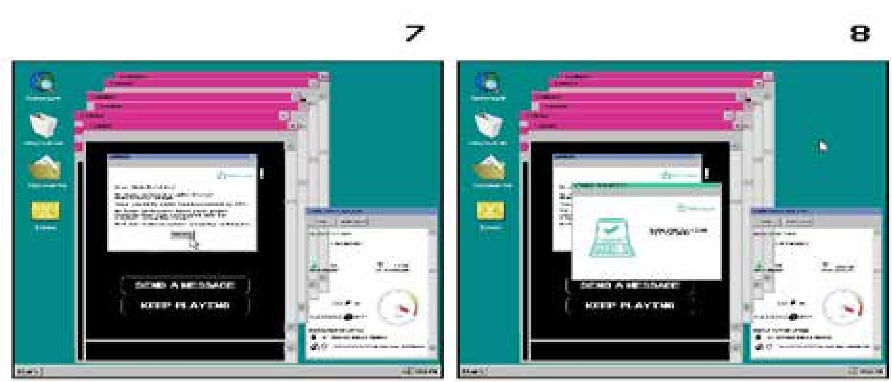

Figure 2. A design fiction showing a hack that can be identified through the energy widget, which reacts to the energy surge caused by the attack (Stead et al., 2022).

Workshop Results: Game Thematics for Worlding

During the workshops, we confirmed via the experts' knowledge that despite its cybersecurity issues, EC's inherent potential for reducing data traffic and thus mitigating energy usage and carbon emissions signifies the technology as a possible solution for developing more sustainable computing models (Stead et al., 2020). EC also creates opportunities to implement additional sustainable technology within its systems. An example of this is for the design and execution of machine learning software to reduce the duplication of data processed at the edge (Kim & Wu, 2020).

However, as we established during the workshops, the fact remains that the security applied to an edge network has to contend with the dynamic nature of virtual networks that the EC forms, with traditional firewalls – designed for a static network topology – not flexible or adaptive enough to contend with the dynamic nature of an EC network. This system, therefore, also comes with escalated maintenance required by users to keep services up to date for the subsequent payoff of better user experiences seen in faster response times to real-world stimuli through local processing/computations and data buffering.

Moreover, during the workshops, a cybersecurity expert revealed that due to the ease, accessibility, and customisation afforded to users to create edge networks via their adoption of edge-compatible IoT devices, EC can result in creating "backdoors" into personal data networks. The common culprit is default factory passwords left in operation by users on their various IoT devices. Furthermore, the peculiar hack of a Las Vegas casino's smart fish tank (Schiffer, 2017) also highlighted that hackers can find a "backdoor" through a wide variety of mundane IoT devices that do not form the edge network, yet are part of it. Consequently, the fish tank "permitted" access to the casino's edge network for hackers to steal data. In contrast, in a CC scenario, this data would have been routed and stored in the cloud with a different method of entry and perhaps with more robust security protocols imposed by online security systems.

As a result of the thematic analysis, the cybersecurity themes along with the different reasons why attacks occur (ethical, financial, cyberwarfare[3]), the various types of possible attacks that happen at the edge (ransomware, denial of service, data tampering, trojan, account hacking, network communication tampering (Caprolu et al., 2019; Martin et al., 2018)), and finally the numerous routes to enter the edge network (service provider, devices, evil-twin wifi) gave us sufficient material for worlding and developing a cybersecurity thread of the narrative.

The sustainability element of EC and IoT networks is the next theme to be addressed. As previously noted, cyber-attacks do trigger an energy surge; however, as discussed at great length in one workshop in particular, keeping a network secure also requires plenty of energy, even though "it's difficult to quantify the energy rate used over time as it doesn't necessarily spike like an attack does" (workshop participant). Keeping users' data secure is one of the significant challenges emerging since all components on a network are communicating and exchanging significant amounts of data through symmetric encryption, decryption, and authentication processes, again resulting in high energy usage (Sulieman et al., 2022).

Evaluating sustainability practices with (and perhaps over) security protocols is a challenging proposition, yet, debatably, keeping one's data safe can mitigate personal and immediate harm, especially when there are other potential avenues to execute sustainable datafication and edge practices. The key sustainable EC practices that emerged from the workshop included:

- Artificial intelligence (AI)-assisted streamlining of storage would avoid the build-up of so-called "data swamps" and limit opportunities for clandestine data mining and surveillance by platforms and providers, as well as reduce bait for hackers.
- The right to repair edge and IoT devices (Perzanowski, 2022; Stead et al., 2020), as their manufacture, materials mining, and global distribution consume vast amounts of energy and generate massive CO_2 emissions.
- Technological and data legibility can be applied to many modes and levels of user interaction. For instance, it is little-known that a user of the streaming service Netflix can adjust the streaming resolution in settings – the platform automatically streams in 4K resolution, yet many users watch on devices that are not 4K compatible.

Derived from the workshop data, the legibility factor can be rated high in the taxonomy of users' adoption of sustainable edge data practices, as it empowers user negotiability and agency across technological interactions. Improved user awareness and knowledge of technology is a faster call for change than technological advances or governance alone can offer sustainability efforts; however, it goes without saying that these sectors need to be cultivated simultaneously. Therefore, the game's narrative is principally grounded in the here and now. It also includes speculative elements pointing to near-future technological advancements, such as how hackers could theoretically cause a disturbance, triggering energy spikes and stealing data. The following section details our approach to worlding the game via a brief outline of the design fiction and MTHCD worlding approach, which will situate the practice by which we developed the game's narrative.

Discussion: Worlding a Game About Sustainable and Secure Datafication

For the narrative context of the *Prometheus* game, the player takes on the persona of a hacker, aiming to steal or encrypt data for a ransom. Using the hacker as the protagonist opened up the "worlding narrative arch" for a deeper perception of what happens in a cyberattack, uncustomarily enabling the player to learn from both viewpoints. The game does not teach someone how to hack; however, it is designed to be an abstract illustration of the motive, waypoints, and decisions that go into hacking and encountering defence mechanisms from applied security. Therefore, from a "typical" user's point of view, one can appreciate real-world hacking processes and apply the appropriate security. In addition to the goal of securing the most loot, a player also wins through the use of less energy for the hack. This principle is not highlighted in the onboarding of the game, as it has been designed to be deciphered by players via a CO_2 contribution readout on the player's in-game status bar (Figure 3) that monitors and quantifies the sustainability of the narrative choices they make, with each narrative option realistically programmed in the backend to have a high, medium, or low energy output revealed on the status bar. Game designers regularly use this "elusive" game mechanism to entice players' curiosity, and once a covert element is realised by players, they often place significant meaning and value on it as it has been a product of their perception, which we hoped would extend out into real-world practices (Salen & Zimmerman, 2003). The mechanism also served as a way to reflect the obfuscation of whether an action is sustainable or not across an edge network, grounding an immaterial practice in a measurable and perceptual narrative for players to encapsulate the problem and take information from the game and apply it to real-world situations.

Turning to the approach of worlding the gameplay, the science fiction author Bruce Sterling (2005) coined the term *design fiction* while describing the influence design thinking had on his writing, noting that, "[D]esign fiction reads a great deal like science fiction; in fact, it would never occur to a normal reader to separate the two" (p. 30). Sterling went on to describe the practice as "the deliberate use of diegetic prototypes to suspend disbelief about change" (Sterling quoted in Bosch, 2012, para 3). For reference, a diegetic prototype is an artefact not limited to a specific materiality that presents an interior view of a fictional world in status; the designer James Auger (2013) explains that the core motivation of design fiction and the creation of diegetic prototypes is to shift the discussions of technology beyond the field of experts (p. 11).

Sterling also wrote that design fiction "tells worlds rather than stories" (Sterling quoted in Bosch, 2012, para 3), inspiring the approach of DFasWB which can be summarised as the collection of diegetic prototypes that, when viewed together, build a fictional world (Coulton et al., 2017). Additionally, we would argue that "telling a world" is an act of narration whereby we narrate using the game player's avatar embodying a hacker's point of view, the diegetic prototypes, the construction of the world, and waypoints through the game. These worlds are therefore narrated with a "rhetorical intentionality" (Coulton et al., 2017, p. 167) using "educated guesswork" by their designers for the creation of rhetoric within a world (Bogost, 2012, p. 30), which enables those engaging or playing within the world to explore that rhetoric rather than being forced down a prescribed path (Coulton et al., 2016). For clarity, the game plays out as a non-linear narrative; therefore, players can make strategic choices about the sustainability of their hack. The collection of diegetic prototypes used in the game are the elective choices, as each represents a contextual element or digital artefact in the narrative and provides an entry point into the hacker's "fictional" world. Each element is displayed using graphical symbology and a textual description to flesh out the elements' diegesis. Hence the game itself can be considered to encompass many layers of entry points for players, much like how the earth is divided into four layers – crust, mantle, outer core, and inner core – with each layer forming the world (Figure 3).

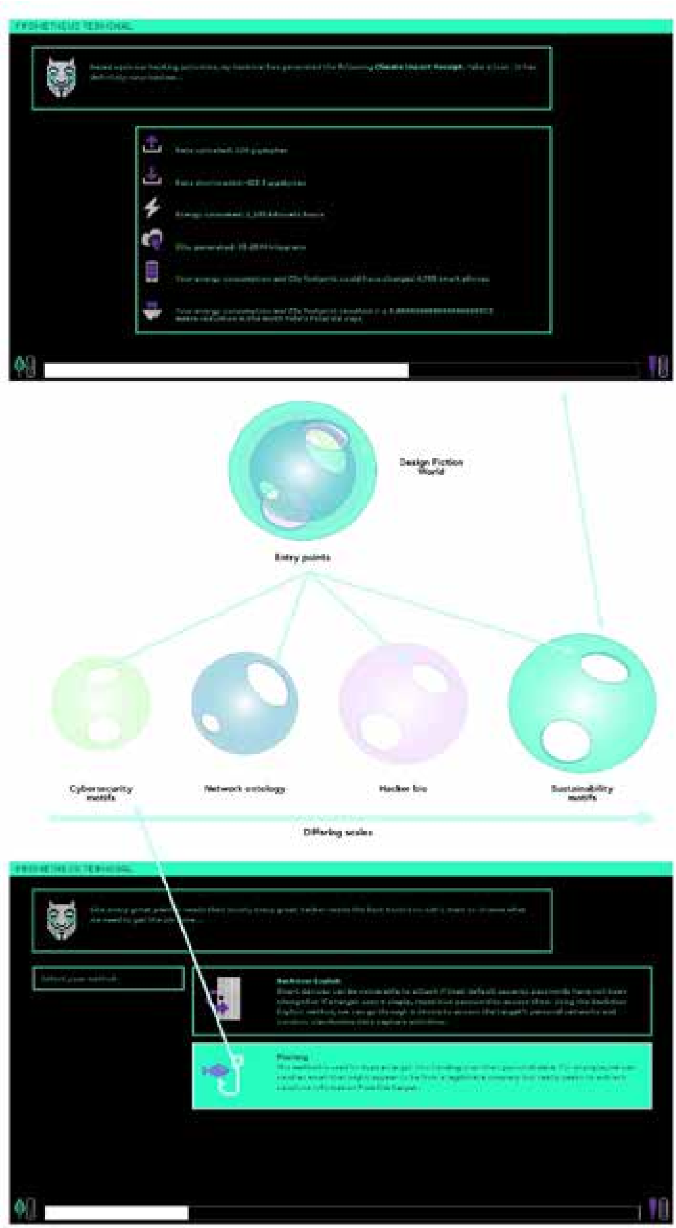

Figure 3. In the middle is a visual analogy for DFasWB, highlighting the entry points the diegetic prototypes form into the fictional world(s) and which the players enter through. The top and bottom of the diagram identifies some of the game's diegetic prototypes in operation via screenshots of the game (Pilling).

The MTHD approach (Coulton & Lindley, 2019; Wakkery, 2021), however small, did play a part in conceiving the diegetic prototypes that personified the digital ecology and things the players traverse. This particular more-than human approach is based on readings of the philosophical ideology of object-oriented ontology as promoted by Graham Harman (2018), Ian Bogost (2012), and Timothy Morton (2013, 2017), and Haraway's (2011, 2016) approach to articulate intertwined worlds of human and non-human ecologies. Expanding upon these in fine detail is beyond the scope of the paper;[4] however, OOO proposes that the perspectives derived from human beings are not the only ones worth considering and speculates that all things have a way of "being."

Within the confinement of more traditional design, approaches such as human centered design (HCD) – which promotes the human being as a central consideration – amount to HCD's core axiom of simplification in interaction through cutting out "excessive" information (Norman, 1998). Don Norman (2005), who notably founded HCD, has also argued against an anthropocentric view in his article titled *Human-Centred Design Considered Harmful*. In that paper, he criticised blind commitment and attention to users which, ironically, creates designs that lack cohesion, increases complexity, and obfuscates the functionality and operation of technology, thus hindering agency and negotiability in technology ultimately designed to be human conscientious. On the other hand, as designers forming a design fiction and a MTHCD worlding approach, we can trace, speculate on, and articulate digital beings through the practice of ontography, a taxonomy of being by speculatively mapping the many possible relations within a network assemblage between digital objects and humans, highlighting both interdependent relationships and independent perspectives. As Bogost (2012) writes, "ontograph involves cataloging things, but also drawing attention to the couplings of and chasms between them" (p. 50), whereas Stead et al. (2022) state, "revelation invites speculation." This approach exemplifies Haraway's (2016) embrace of "staying with the trouble" by reflecting the entangled ecology of all things human and non-human. Mapping the ontography of the network assemblage also translated into mapping the game's narrative and the different narrative branches players can elect (Figure 4).[5]

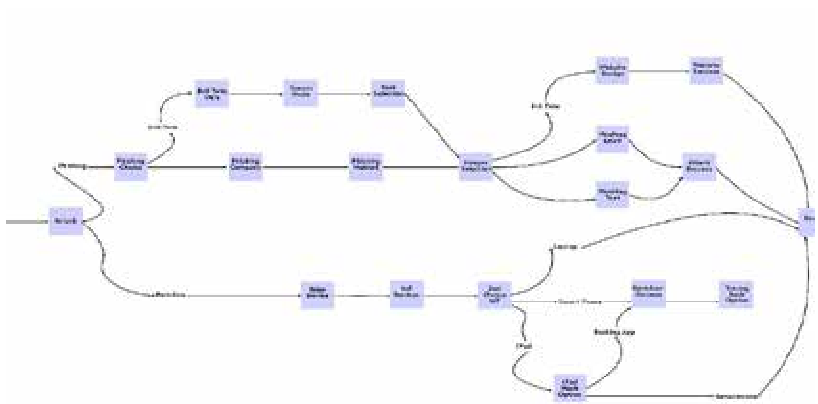

Figure 4. A snippet of the speculative and ontological mapping we did to produce narrative branches for the game.

After detailing the design approach of the game narrative, players set up what type of hacker they are, either acting in a group or as an individual and then select their motive for the hack – picking either an ethical, disruptor, or financial point of view. As a characteristic of “choose your own adventure” games, the options a player selects will guide players down a particular path of possibilities; while this does curb some narrative electives offered to the players, the game mechanic maintains a logical and realistic narrative. However, to ensure the game’s narrative was not restrictive, we provided sufficient alternative narrative branches to choose from that followed a similar configuration. For instance, after a player chooses their motivation, they progress to picking their method of a “way in” to a victim’s edge network, such as phishing, evil-twin wifi, or a backdoor exploit. Next, the player navigates their way through the edge network, jumping from one IoT device to the next, looking for data to either steal or to ransom through encryption software. Thereafter, the player encounters security protocols through AI-assisted and adaptable firewalls. Once a “hacker” has secured their spoils, a conclusive energy receipt is calculated of their hack that also quantifies the energy readings into tangible implications, such as the amount of energy consumed to charge X number of mobile phones (Figure 3). The game is played on a physical platform with a screen and navigational pad reminiscent of retro-computer terminals (Figure 5), a style that harmonises with the conventional 8-bit style of text-based games we were emulating.

Figure 5. The *Prometheus Terminal* being used at an event. Many players opted to play as a team to discuss strategy, the worlding of the game, and its underlying messages of sustainable and secure practices.

The Prometheus Terminal in Action and Future Research: Fostering the Adoption of Sustainable and Secure Computing Models

The aim of the Edge of Tomorrow project was twofold – to research and create design guidelines for sustainable and secure edge network practices (see Stead et al., 2022) and to embed these into an interactive platform for public dissemination, thus communicating and making legible computing paradigms for increased user agency and negotiation to adopt sustainable and secure networks and interactions. The second-mentioned aim was examined when we showcased the *Prometheus Terminal* at several public engagement events. The overall response to the game and its worlding was positive. Numerous gamers described the experience of playing the game as empowering them to understand a hacker's logistics while increasing their awareness about the network's ontology, IoT devices, and security measures and practices they could implement. However, the crucial finding for our research was that many players had not associated sustainability with datafication or considered the implications of their digital interactions on the environment, stressing the current lack of legibility concerning sustainability in a digital context, begging further research and public engagement.

Constructive criticism about the *Prometheus Terminal* concerned the delivery and gameplay via text, which took considerable time and effort for players to plough through the narrative branches, thereby affecting the project's overall aim for communicating a sustainable and secure approach to forming an edge network. Therefore, to improve the impact of the research project and players' experiences in future work, we are currently developing the second iteration of the game and its worlding by distilling them into an immersive game experience that involves visual, kinaesthetic, and auditory dimensions. The approach of the experience is to "dietetically situate" players directly into the same artificial world as the game (Pilling et al., 2022). In this sense, the player will enter the world and interact with the game in a physical setting. In effect, a player will enter a mundane set-up of a furnished physical living room complete with IoT devices. The player will be tasked to set up and form their edge network by considering and balancing their sustainable and security preferences. A disembodied AI assistant will take the player through this procedurally, acting as the overall game narrator and guide via voice interaction, evoking common household smart home assistants. The aim of the game for a player will be to stop a hacker from entering the edge network through strategic security measures.

In this interpretation, we have taken the worlding from the first iteration and flipped the perspective to suit the reimagining of the future mundane project, which researched the negotiability and agency of smart devices and their operations within our own homes (Pilling et al., 2022). As the research parameters of both projects are comparable, it served as an opportune instance to redesign and "load" an experience in an interactive and physical simulation that lent itself to being adapted through backend programming and interactive game design. As well as harnessing the embodied interaction, the other pivotal characteristic we are adopting from the game's reinterpretation is the unique execution of the experience being installed into a self-contained mobile research platform housed in a teardrop caravan. The pertinent aspect of being mobile is the opportunity to expand audience outreach beyond those who would usually frequent a university or gallery setting where research projects are typically showcased. The potential to increase project impact, as well as redesign the game interaction and develop the narrative through ontological research and worlding provides the opportunity to continue to focus on improving users' legibility of the unsustainable effects of smart devices' datafication, and create practical guidance towards sustainable data practices.

Conclusion

How data is created, processed, and stored is increasingly affecting the planet's natural environment and leading to cybersecurity issues. With that in mind, the adoption of edge networks will undoubtedly continue to increase due to the perceived benefits the technology brings as an alternative to contest issues associated with cloud scalability. Adoption will also increase because of EC's ability to facilitate better user experiences with respect to handling requests and processing "data exhausts" created by the proliferation of IoT devices, services, software, and associated networks. Nevertheless, whilst EC diminishes issues relating to latency management and some security and sustainability problems associated with cloud services, it is also starting to generate its own range of difficulties in terms of both data security and sustainability. To this end, our paper describes the exchange of issues from cloud computing for comparable ones at the edge, although unfurling unique challenges due to ontological differences between CC and EC. Through our research, we have sought to make the complex and obscured nature of edge networks and their data processes legible via a public engagement tool which imparts sustainable and secure data practices through play. Notably, the iterative designs described here only scratch the surface of the challenges we have outlined. However, we detail how worlding games can communicate the often imperceptible and entangled nature of new technologies (Murray-Rust et al., 2019) into tangible and situated experiences that users can easily understand.

The expansion of the research's themes and scope into a more experiential and interactive platform as part of our future work will offer the opportunity to identify and tease out further sustainability and security criteria arising from EC adoption. These points will be communicated to a much wider audience outside of academia and establish salient points of feedback for the industry – digital technology developers, service platforms, and data storage providers. Concerning the latter point, this project has been carried out in collaboration with BBC R&D, our project partner, who will utilise the findings and design guidelines (Stead et al., 2022) and embed these into the design of their future edge-based digital services and platforms, in addition to conveying findings to users in the form of technical guidance. Whilst this paper only explores a small niche in tackling climate change, it does begin to underscore the imperative for design research projects like this and transdisciplinary collaboration to make our computing practices more secure and sustainable.

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[1] Constrained devices are small devices with limited CPU, memory, and power resources which are often used as sensors and smart devices such as home automation, automotive, and surveillance devices.

[2] We have since found a similar example of this speculation for cloud computing in the online magazine *Branch* which is committed to designing a sustainable and just internet for all, originating from the Mozilla community (Brain et al., 2021).

[3] In addition to the devastating “ground” war in Ukraine, Russia has been sabotaging Ukrainian hardware through cyber-attacks, with officials calling it the first “hybrid war” (McLaughlin, 2022).

[4] For further detail on the adoption of OOO in design practice, see Lindley et al., 2020; Pilling et al., 2021; Pilling & Coulton, 2021.

[5] See also Coulton et al. (2017) for an example on ontographical storyboarding.

TOOLS FOR ADAPTATION IN DESIGN EDUCATION: RESEARCH ACTIONS IN THE CONVERGENCES BETWEEN RESPONSIBLE INNOVATION AND KNOWLEDGE DESIGN PROCESSES

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Abstract
Integrating responsible innovation (RI) into design practices is a complex process. It is often inhibited by limited knowledge of the issues and tools to support it. In order to bring awareness of these issues to future designers, a contemporary need emerges related to the integration of RI into university-level educational pathways. The research presented here aims to test new teaching and learning methodologies in which RI is integrated within the design teachings offered to students in courses in the Second Cycle Degree of Advanced Design programme at the University of Bologna. The field of investigation proposed to the designers was the city of Bologna through an activity called *Urban Data Sensification*.

In order to achieve this objective, this paper first presents three dimensions of adaptation, intended as a field of investigation and a methodology in educating designers. The convergence of these three perspectives leads to the presentation of a didactic experiment that demonstrates how to educate – in a holistic way – designers to be more adaptive, responsible and future-focused. With this in mind, this research aims to verify the triggering of RI sensibility in product and service design. In the conclusion, the authors present possible developments of the approach.

Author Keywords
Open responsible innovation; advanced design; multi-scale approach; design for change.

Adaptation as Object of Design Investigation: Responsible Innovation

The great challenges linked to climate change, scarcity of resources, digital and ecological transitions and the fight against inequalities have led to a review of the relationship between innovation, society, environment and technology, prompting the need to deepen reflections and experiment with approaches for the development of more inclusive, adaptive and sustainable economic-social-relational processes and knowledge access.

Starting from these pressures and emergencies, in 2011 the concept of responsible research and innovation (RRI) was introduced in the development policies of the European Communities (von Schomberg, 2011, 2013; European Commission, 2013), defined as a process capable of driving forms of inclusiveness and sustainable innovation through the synergy between different actors of the territorial ecosystem. This vision encompasses the concepts of collective and collaborative care for the future (Stilgoe et al., 2013), "right impacts" (von Schomberg, 2013, p. 56) and "meta-responsibility" (Stahl, 2013, p. 712).

Since 2014, the concept of RRI (Rome Declaration, 2014), also known as responsible innovation (RI), has been applied to Horizon 2020 projects, resulting in applied research at international, national and regional scales, up to being incorporated into bottom-up knowledge innovation processes within local policy, production, education and design disciplines.

The progressive "adoption" and experimentation of RI paradigms has gone along with another process investigated in the same period: the application of a "Quintuple Helix" knowledge innovation system, interpreted by Elias G. Carayannis et al. (2012) in an "ecologically sensitive" sense and by Christian Iaione and Elena De Nictolis (2016) as a form of co-constructed knowledge that grafts onto and extends the canonical vision of social innovation. These innovation systems have the same aim: to create a form of knowledge innovation in which institutions, citizens, productive and academic worlds hybridise their skills within the same environment.

The RRI/RI approach is characterised by six key areas – ethics, gender equality, open access, science education, public engagement and governance (European Union, 2014) – and four dimensions, defined by Jack Stilgoe et al. (2013) as anticipation, reflexivity, inclusion and responsiveness, embedded in an interactive system. When adopted in the design process, it underlines the need to consider territory-related characteristics, territorial capital (Franzato, 2009) and inclusive and fair co-creation and co-production.

Indeed, in recent years, design cultures have begun to take on the role of active drivers, capable of making RI operational within real contexts (Deserti et al., 2021). At the same time, design has also begun to investigate how RI can become a driver for transforming the role of professionals and their influence within territorial policies, leading to reflection on the responsibility of the designer in caring for the future and supporting ethical and inclusive systems in the development of new forms of environmental, economic and social sustainability (Salamanca et al., 2019; Bailey et al., 2016).

In both cases, knowledge becomes the fundamental resource (Lundvall, 1992) that must be adaptive, collaboratively created and generated from common values. The integration between a multiversal and non-hegemonic design approach (Escobar, 2018) and the dimensions of RI (anticipation, reflexivity, inclusion and responsiveness) leads to adaptive forms of design, according to the fluidity of change and the specificities of territorial identities in terms of communities, individuals, institutions and social and productive capital.

Starting from these reflections, the concept of RI has been taken as a primary observation point capable of including and, at the same time, supporting the adaptation of the designers' role within contemporary challenges. In particular, the pathway towards a possible transition was brought into academic design learning models, where design-driven RI adaptive processes (called advanced responsible design) were investigated and experimented.

Adaptation as Design Methodology: Innovating Learning Models

Over the last two decades, the quest of improving academic impact on society as a whole was at the centre of an animated debate in the Italian context (ANVUR, n.d.). Politically speaking, this was the climax of emerging rumours about an excess of power autonomy in terms of management and ambition which was affecting the whole university system, leading to a sort of isolation from practical aspects of societal responsibility.

Nowadays, the context is drastically changed and the university is even more required to become a constituting part of the societal "value chain" construction to guarantee a constant knowledge and technological transfer, framed within a newly established alliance between private entrepreneurial forces, politics and institutional subjects and citizens and the environment (Formia et al., 2021). A similar process has been practised since 2008 in Europe within specific research frameworks such as the Knowledge and Innovation Communities (KICs): partnerships made of universities, research centres and companies united by the common intention of pursuing a strategic agenda in specific scientific and technological fields through integrated higher education, research and innovation activities.[1] The design academic community is part of these partnerships with the aim of both transferring design-driven knowledge within the territorial ecosystem and contaminating skills within the university. This reflection is supported by the UK Design Council report (2021) that states that designers have "a limited conception of the tools and approaches necessary to design for sustainability and other important emerging issues" (p. 6). At the same time, the literature review reveals that there is an urgent need to renew and foster learning models with more attention towards transdisciplinarity, accessibility and inclusive multilevel collaboration, not only within the academic context but also interactions between all actors in the value chain. This leads to imagining new perspectives aimed at moving away from the use of codified and universal practices in order to redefine vocabularies on the one hand and on the other hand, ethical and adaptive design actions capable of taking into account the time and space in which communities operate and the impacts related to it.

In order to deepen this reflection on learning processes and models in the field of design, in 2016 the research group in the Advanced Design Unit at Unibo launched the *Future-DesignEd* project. This international symposium and research platform intends to share the roots, understand the current situation and propose models for the future in design schools and, more generally, in organisations interested in welcoming the innovative value of design (Bosco et al., 2021). Through the different symposium editions (2017, 2020, 2021), the platform activates international observers and experts committed to reporting and sharing experiences that relate to design-driven educational processes. As discussed in the book *Updating Values. Perspectives on Design Education* (Bosco & Gasparotto, 2021), the results of the surveys highlight many emerging trends, three of which are of particular interest for the present investigation:

1. **Future-Focused Education:** As a young discipline that lacks independent status, design has traditionally been able to draw from different fields of knowledge (humanities and the arts, engineering sciences and technology, economics and management) to enrich its corpus and build its own identity. In this process of continuous updating and opening up to new knowledge, future envisioning plays a pivotal role that starts from the need to anticipate tomorrow's systemic complexities (Celaschi et al., 2019). The keywords here are future-focused thinking, anticipation and speculative design. This requires the ability to interpret the subtle signals of our times and transform them into levers for change.
2. **The Realism of Challenge-Based Learning:** The degree of realistic engagement with the different contextual realities (people, systems, places, cultures, etc.) of the research, design and implementation process has significantly increased, almost eliminating simulation, and reducing the gap with professional experience. But the degree of realism is not the only evolutionary factor (Buchanan, 1992; Blackwell, 2008). Students learn by working on briefs that become "challenges," i.e. so-called wicked problems that have never been addressed before. "Challenge" projects are highly educational because they are not linear but evolutionary in the sense that they rarely have case histories to start from and they never have a predictable solution. Within this context, there is growing interest in the doing, using and interacting (DUI) pedagogical model based on tacit knowledge, informal learning processes and experience-based know-how.
3. **Social Purpose First: Ethics; Sustainability; Social Entrepreneurship; Service and Policy Design;** Social Innovation; International Development; Transition Design: Fifty-six years after the publication of the *First Things First Manifesto* by Ken Garland (1964) and forty-nine years after the publication of Victor Papanek's *Design for the Real World* (1971), the social impact of design today is acknowledged to be equal to that of its impact on economy and culture. A growing number of university programs have focused on the education of designers as catalysts of social, humanitarian and environmental good, and as stewards of a collective journey of change towards sustainable and inclusive development.

At the intersection of these three trends, it is possible to imagine a new field occupied by an investigation into whether and how RI can support forms of change within design learning processes. A few educational experiences show an emerging attention to methods, approaches, themes and models for anticipating social and environmental consequences within design practice.

The University of Illinois has initiated a Master of Fine Art (MFA) degree that applies a design for responsible innovation (DRI) framework, allowing a design theme to be approached through various levels of interaction, customising it according to the context or problem, focusing on the declination of what type of awareness to activate, what type of concern to address and what approaches and methods to use to solve it (Salamanca et al., 2019; Salamanca & Briggs, 2021). Similarly, Northumbria University has tested the transformational consequence mapping (TCM) approach within some design courses to increase awareness of the possible impacts of what is being designed in the preliminary stages of projects (Bentham, 2017).

In contrast, the University of Twenty through the Design Lab experiments with the responsible futuring approach based on a collaborative knowledge system that aims to get all participants to reflect on current emergencies and design new relationships in a socially and ethically responsible way.

The University of the Arts London and Loughborough School of Design and the Creative Arts are also redefining their educational models based on the concept of sustainable and responsible design with the intention of opening "the edges of traditional design disciplines with embedded and reflexive modes of learning" (Boehnert et al., 2022, p. 1).

The Advanced Design Unit (ADU) of the University of Bologna itself has experimented with an approach – design for/with responsible innovation (Succini et al., 2021) – within its design curricula, opening it up to interdisciplinary design projects such as the *Winter School: Design for Responsible Innovation*, which involved international universities in a path of learning, reflection and prototyping on the themes of RI applied in real contexts, on different scales, initiating a form of literacy in critical theoretical and practical responsibility and peer-to-peer collaboration.

The analysis and application of design-driven RI models within learning processes consolidate the initial reflection that the inclusion "in the design courses curricula [of] the concepts of Responsible Thinking and Responsible Education is the key to train[ing] responsible future designers, able to take a role in mixed groups of interest and power in a quintuple helix perspective" (Succini et al., 2021, p. 252).

This ever-changing phenomenon has led ADU to pursue experimentation with the RI design-driven educational model within some of the teaching activities of the Second Cycle Degree Programme in Advanced Products and Services Design at the University of Bologna. By linking the construction of sustainable, ecological and responsible critical thinking to an application field, it brings to the fore the social and environmental consequences of the relationship between people, technology and spaces. The contemporary city, its continuous mutations (Formia et al., 2021) and the relationship with data as an element that can be absorbed by urban spaces have become a tangible part of it.

Adaptation as a Field of Application Through Design: Urban Living Labs

Living Labs and Citizens as Privileged Contexts and Mediators for Experimentation

> In the next century, cities will no longer be able to depend on manufacturing and old industries to survive. Instead, they will need not only to develop creative and innovative industries and services, such as software, design and culture. They will also need to learn how to apply creative solutions to their myriad problems, ranging from crime to unemployment. (Landry & Bianchini, 1995)

If the framework described in the mid-1990s suggested a way out of the modern/nineteenth-century urban model, the 2007 financial crisis and the pandemic afterward accelerated the need to rethink systems, behaviours and relationships within the spaces in which we live, work and interact. The new priority is guaranteeing a sort of consortium within the city, assumed as a living lab, according to the European Union definition (Santonen et al., 2017) where associations, administration, entrepreneurs and research centres work together and collaborate with citizens in order to spread, as much as possible, socio-economic opportunities for being totally inclusive. "No one has to be left aside from the societal renaissance" is the new politically correct motto in which not only politics, activism and industry but also the education system (such as the university) are asked to play a crucial role in that respect. The concept is to consider the city as a living lab in which the five actors of the Quintuple Helix Model take part in a responsible way.

As defined by the European Network of Living Labs (ENoLL), living labs are real-life test and experimentation environments that foster co-creation and open innovation between the main actors of the territorial ecosystem. Among the objectives leading the urban living labs concept are citizen networking, reworking of open innovation environments, inclusive, green and digital transition and exploration of forms of adaptation in contexts ranging from the city to creative production, from education to policy.

This successful model for the development of innovations and adaptation has been confronted after the pandemic by a new challenge: to merge both real and digital actions, considering our emerging state of "onlife" living (Floridi, 2015). According to this interpretation, urban spaces are seen as places where the main socio-economic-cultural tensions can be found, where it is possible to experiment with an urban living lab that involves not only the university but a wide range of stakeholders who can learn and influence the construction of new systems for the city starting from data and a design-oriented learning model of RI.

Research Question

Integrating responsible innovation into design practices is a complex process. This is often inhibited by limited knowledge of the issues and tools to support it. In order to bring awareness about these issues into the skills of future designers, a contemporary need emerges related to the integration of RI into university-level educational pathways. The research presented here aims to test new teaching methodologies in which RI is integrated into the design issues presented to students of the Second Cycle Degree of Advanced Design courses. The field of investigation proposed to the designers was the city of Bologna. In this area, the university is at the centre of a connective network in which responsible innovation processes find an audience of interested and responsive stakeholders.

Urban Data Sensification

Previous analysis demonstrated that academic research finds that the urban context is one of the privileged fields of application for experimenting with forms of innovation of and through the design project. The city is a dynamic design field, articulated on multiple levels (social, spatial, digital, etc.), each of which is constantly changing. Moreover, the massive use of digital technologies has deeply impacted their configuration. Cities' spaces have become multidimensional places in which georeferenced digital information is layered moment by moment (Zannoni, 2018, p. 38). This digital information created by electronic devices scattered on the body and in space shows people's behaviours and acts in the complex process of collective memory (Formia & Zannoni, 2018). However, it is not manifested physically in a tangible way and it is only accessible through tables and graphs displayed on personal devices. These data almost never take on physical/chemical characteristics capable of establishing contacts with the human multisensory body. In their absence of sensoriality, they elude the human perceptual field.

Consequently, the necessity for designers to be able to turn their attention to the transduction of data emerged (Celaschi & Casoni, 2020) while at the same time referring physical space toward multisensory communicative modes, in order to value the whole system of data collection that the contemporary city is performing.

Very often, the focus of design attention is on how the city's data can be visualised on displays. It means that they mainly maintain the immaterial dimension of urban data, nurturing an informative role to design action. Less often, design acts on multiple sensory levels and the ways in which human behaviours can be changed by it. This kind of design is identified as *data sensification* (Hogan, 2018).

In the last years, we assisted in the development of projects of this type to the point that it is possible to trace them back to a specific field of research. One of the most widely used approaches is the sensory translation of semantic categories derived from social-network postings and referenced to places. An effective example of this design is the *Nefula* project[2] installed in 2014 at the Urban Center in Bologna.[3] Designers translate social network posts into emotional data through artificial intelligence (AI) semantic analysis. Referencing this data allows them to identify emotional clusters of the city that are immediately represented by the projection of colour areas on an urban scale model.

A similar approach can be found in *Futureform's Datagrove* project of 2012[4] or Invivia Studio's *Mimmi* project of 2013.[5] Here, the AI becomes a mediator and allows for the transformation of a semantic datum into a luminous chromatic feature that becomes part of the perceptual field of the community that traverses and experiences the urban space.

Moreover, different examples of designs that link digital data to physical space are those realised as outputs of the ideascape project *Porth Teigr,*[6] implemented in Porth Teigr in Cardiff Bay. The project was led by Igloo Studio[7] and the Welsh Government. In particular, it impacted the design of tools and physical and digital artefacts such as: a toolkit for citizens to book public spaces online; tourist binoculars that, through augmented reality, connect people with past and future data related to the space; an app that activates when you encounter geographically embedded audio tracks referring to a specific space; a talking object placed in the space that announces offers in limited quantities in certain spaces in the surrounding city; two telephone booths that connect with each other remotely; etc.

All these examples share a fundamental concept: the data used by a data sensification approach in urban space belongs to the communities that pertain to that space. These data represent the different stakeholders to which a data-aware RI design must respond. Therefore, the design of urban space elements through an urban data sensification approach fits the purposes of this research.

The Responsible Innovation Principles Embodied in Teaching and Learning Programs

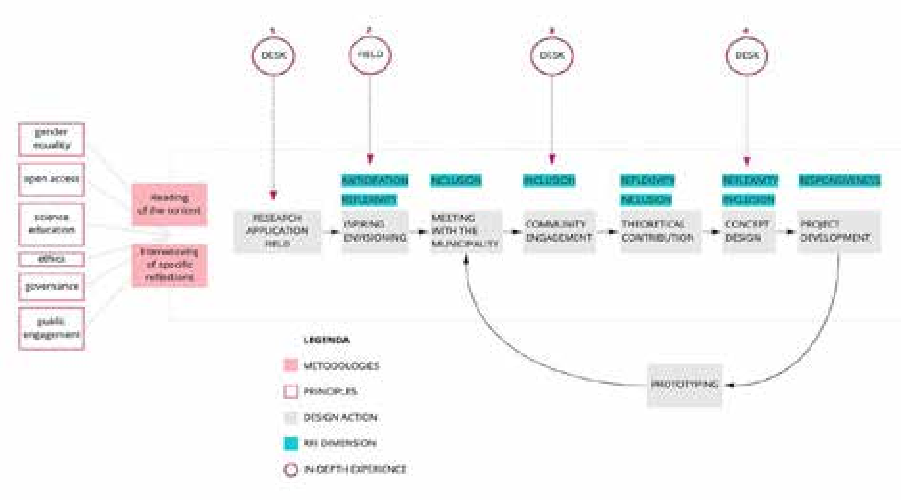

Table 1. Diagram of the model and design process applied.

The presented project was situated in the product design curriculum in the Second Cycle Degree Course in Advanced Product and Service Design with final-year master students. The didactic experience aimed to develop innovative knowledge, abilities and skills about how to integrate design and RRI principles, enabling students to be "responsible designers." The process involved a class of around sixty students and five members of the Advanced Design Unit of the University of Bologna as teaching staff.

The process (Table 1) was characterised by two sides: the side developed with classical "design action" (grey in the diagram) and the side dedicated to "in-depth experiences" (desk and field, marked with a purple circle in the diagram). The first has been focused on a specific field of application though the choice of the urban living lab model and the topic of data sensification. The second has been a transversal activity aimed at sharing methodological references to RI in order to infuse the design actions. The educational model experimented with focuses on teaching students how and when to apply a more critical and reflective design approach by considering impacts at all stages of the project. At the same time, they learn to use an anticipatory design process that is able to adapt design topics to rapid changes generated by the environment, people and emergencies.

The model integrated the RRI principles (gender equality, open access, science education, open governance, ethics and public engagement) and RI dimensions (anticipation, reflexivity, inclusion and responsiveness – see the first paragraph) with theoretical and practical tools and actions of design disciplines. Based on the experiences already carried out and the literature review, the model was based on two methodologies that were maintained during the developed process:

- First, reading the context of application through the RI lens, which supports reflection on impacts since the initial stages.
- Second, interweaving specific vertical reflections on RI dimensions into all the design activities of the course.

This combination leads the design process to be interactive, collaborative and open to the community, and increases the ability to adapt design thinking to change.

In the "Research Application Field" design action, the groups discussed the theme of urban data sensification with the aim of designing site-specific product design projects. The young designers, teachers and researchers worked in a specific urban area of the city of Bologna next to the city centre and marked by social housing called the "Malvasia quadrangle." The area is characterised by numerous social problems related to a population composed simultaneously of single-family households of advanced age, and very large households in undersized, rented apartments. At the time the design course was implemented, this area was undergoing a major regeneration by the municipality, both of buildings and common green areas.

The social urgency offers the working group a complex research application field. The designers were accompanied in the design reflection starting from the principles of RRI: gender equality, open access, science education, ethics, governance and public engagement. The "Malvasia quadrangle" is an evolving site and students designed objects and product-systems within future scenarios using both data already available in the area (Comune di Bologna, n.d.) and data that could potentially be collected.

The second action is called "Inspiring Envisioning." In this, the RI dimensions of anticipation and reflexivity were emphasised. At this time, designers were asked to work on visual elaborations representing clusters of digital data related to the city of Bologna. The work on representation allowed for common awareness with respect to possible design corridors that would systematise the available digital data within the city context.

Then, two close actions were organised: "Meeting with Municipality" and "Community Engagement." The first was done through a seminar with FIU, the foundation that monitors communities in the area on behalf of the municipality. This event allowed the groups to analyse the urban context on multiple levels of complexity. In the second, the "Community Walking" activity allowed the designers to relate the real space to the issues described by the associations acting in the area. These activities were conducted with strong appeal to the RI dimension of community inclusion.

In order to give a solid direction to the design of interactive artefacts intended for an urban space, during the "Theoretical Contribution" action, lectures were given by professors and invited guests in order to strengthen the students' design knowledge. The transmission of information related to the city and the management of interstitial space were interspersed with insights into the design of interactive products. In this activity, the RI dimensions of reflexivity and inclusion were highlighted.

At the end of this process, three classic design actions began: "Concept Design," "Project Development" and "Prototyping." Specifically, in the "Design Development" activity, the

RI dimension of responsiveness was developed. Included in the main body of the course were four in-depth experiences that allowed students to explore typical RI themes and modalities. These punctual actions were based on desk and field research methodologies. The theoretical and applicative in-depth study of RI concepts was thus embedded in the site-specific design process in order to propose a literacy process on themes, methods and approaches of the most advanced declinations of innovation (social innovation, responsible innovation, ecological innovation, etc.). In fact, the goal is to train a generation of MFA students capable of handling contemporary challenges with awareness of the opportunities that design has to act for the transformation of our environment through forms of adaptation socially, culturally and naturally. In this portion of the educational process, the main RI dimension activated was reflexivity. The design pills organised by the teaching group as in-depth exercises of two to three weeks each were:

1. **Research and Application Action (desk):** exploration of forms, dimensions and characteristics of innovation, defined according to the submission template of the *New European Bauhaus Prizes* 2022 that includes an out-of-the-mainstream approach: environmental sustainability, quality of experience/aesthetic/function and inclusion.
2. **Inspiring and Envisioning Action (field):** two short workshops (one day each) led by international experts on the concept of future literacy and scenario building.
3. **Community Engagement Action:** insight into citizen science through an applied experiment called "Citizens as Urban Sensors." This was a critical observation by the students of green areas in the city of Bologna to collect data in a participatory way, thanks to the app *NatureSpots*.
4. **Concept Design Action (desk):** application of the RRI Impacts Reading Matrix, a useful tool to consider economic, social, cultural and environmental impacts throughout both the products and services design generation phase.

The course concluded with the presentation of the design outputs at an open day with all the stakeholders involved during the course. On this day, moreover, a discussion activity was conducted by the researchers with the students to check the correspondence between the RI development lines and the goals achieved by the developed projects.

Conclusions

The Advanced Design Unit's design education and research models confirm the importance of introducing responsible innovation in a Quintuple Helix Mode, in which all systems and actors perform a pivotal function, influencing each other. In-field activities give the students a dedicated opportunity to apply the design for RI's methodology to the city, co-designing adaptive reuse solutions, testing forms of inclusiveness, sustainable innovation and care for the future.

The designers' outputs focused on three project categories that individually respond to the characteristics introduced by RI: showing tracks, activating relationships and dynamically guiding. The first group of projects worked on objects capable of showing the "invisible tracks" left in the city by people, plants, machines, etc. Each trace, when made manifest, bears witness to the community of a behaviour or action that has taken place or is taking place. In this manifestation of the invisible, the trace highlights and brings to the attention of others the information and the subject that generated it. The second cluster of projects involves urban objects that use data gleaned from space to guide users within that space. In these projects, objects interpret the user's needs and transform themselves by guiding them within the city and places that periodically have the qualities to meet their needs. Finally, the third group of projects dealt with developing solutions that used georeferenced data to activate specific behaviours. These projects in most cases aimed to relate sometimes distant and different users in the same space and time.

The educational model tested in the course produced results in line with expectations. The projects were designed with strong relations to the context, were open to the community and presented solutions in line with RI requirements. From a methodological perspective, there were some shortcomings with respect to community feedback both in the design phase and in the presentation phase.

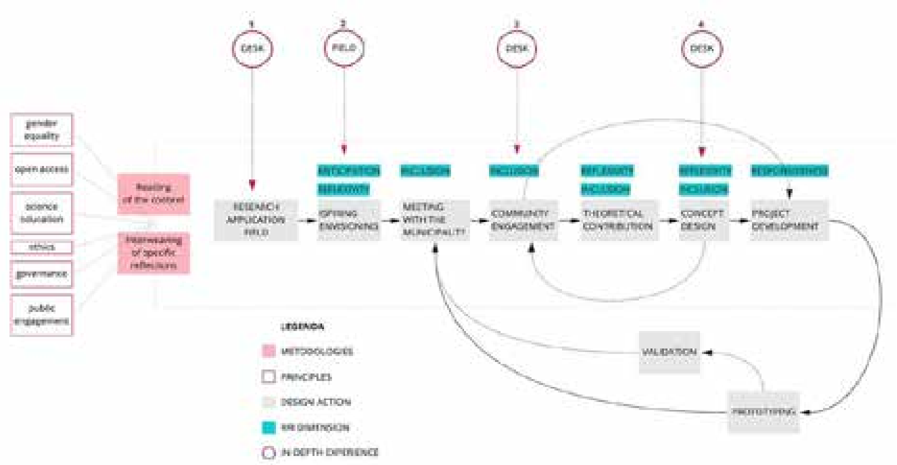

Table 2. Diagram of the model and design process implemented with new actions to improve community involvement.

We consider this didactic experiment the first step of a pathway towards the education of responsible designers able to consider adaptation as a field of investigation, a methodology and an application context. From an evolutionary perspective, this research on urban data sensification should be implemented through the active involvement of communities and citizens, not only in the design phase. Considering the city as the privileged field of application, the impacts of co-design actions should be analysed and tested by the community of citizens thanks to the mediation of public organisations. It is thus fundamental to deepen the study of the model, enriching it with activities such as prototyping and validation of the correspondence of RI-driven solutions and ideas in order to augment its responsiveness and iterability (as shown in the dotted arrows of the Table 2).

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TOWARDS SUSTAINABLE INTERNET OF THINGS: OBJECT DESIGN STRATEGIES FOR END-OF-LIFE

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Abstract
Digital technologies are a double-edged sword in the transition to a more sustainable society facing a climate emergency. This paper discusses how the internet of things (IoT) and associated technologies are resulting in a proliferation of manufactured objects with useful yet short lives. We explored this issue through designers' personal practice and relationships with objects and examined how designers, manufacturers, and users of the IoT can adapt to reduce objects' energy, resource, and climate impacts.

End-of-life IoT objects present challenges and opportunities for sustainable design. We use the term end-of-life to describe the point at which objects cease to be useful through damage, loss of support, user choice, and so on. The increasing volume of redundant IoT objects is driven by unsustainable, linear "take, make, dispose" (Moreno et al., 2016) principles: replacement over repair; hardware tied to software development; increasing energy demands; and virgin material extraction (Stahel, 2016; Unwin, 2020).

In this paper, we synthesise findings from a workshop with industry and academic designers that explored how design affects the end-of-life of IoT objects. We present two high-level strategies for more sustainable IoT design. Two key questions framed the issue and guided our discussions:

1. What values compel people to keep, re-use, or reimagine IoT objects after they are no longer functional?
2. What tactics can we use to design these values into IoT objects to encourage end-of-life upcycling, appropriation, and re-use?

Our workshop findings led us to two high-level design strategies to address sustainability and climate impacts of end-of-life IoT objects. Emerging from the tactics and values discussed, our two proposed strategies are Sustainable Caregiving for IoT Objects and Re-Imagining IoT Objects for Sustainability. The first strategy is to change people's relationships with their IoT objects, thus increasing their value and extending object lives for a world with finite resources. Our second strategy is to re-imagine existing objects creatively and facilitate circular lives through design.

We believe our workshop findings contribute to growing discourse in design research seeking to challenge prevailing modes of IoT design and manufacture and explore new

sustainable models. There is much work to be done to move IoT away from throwaway black boxes to anything resembling a sustainable technology ecosystem that supports our societal response to the climate emergency.

Author Keywords
Internet of things (IoT); circular economy; sustainable design; human computer interaction; electronic waste; spimes.

Introduction

Humans are acquiring and disposing of ever more manufactured objects, including electronic and connected products. Systemic approaches are required to address our unsustainable consumption and the resulting social and environmental impacts of object production and use. Internet of things (IoT) objects range from mass-produced smart watches and home assistants to niche objects with very specific purposes – e.g., the Good Night Lamp (2020) or Little Printer (Rickerby, 2019). However, many IoT objects are designed, manufactured, and disposed of in the same unsustainable ways as other mass-produced consumer products with major impacts on climate change and other environmental crises (Stead et al., 2019). Their complexity and material composition means greater care is required to address their sustainability impacts. Their reliance on software and internet connectivity makes them uniquely susceptible to losses in value (Lechelt et al., 2020). For example, frequent new model releases can make previous iterations appear obsolete. Broader sustainable design and consumption approaches need to be adapted for application to IoT objects and their unique characteristics.

Many niche IoT objects briefly fulfil a purpose then become obsolete as manufacturers change focus, are acquired by other companies, or disappear altogether along with their digital infrastructure. One of the shortest-lived examples is the Aether Cone smart speaker, whose unique internet-enabled features were removed only months after its launch as the company closed and the plug was pulled on the associated Rdio streaming service (Roettgers, 2015). Jibo, a social personal assistant robot, was released in November 2017 and was programmed to announce its own impending obsolescence a year later, when support and servers were taken offline (Carman, 2019). The Little Printer's first life was a little longer at two years (2012-2014) before the app was discontinued when the company disbanded (Dunne, 2019). There are countless more examples of IoT objects whose useful lives have been unsustainably short compared to their non-IoT equivalents.

Non-connected objects are often more resilient to loss of manufacturer support; however, both connected and nonconnected "dead" objects have been revived by communities of users and enthusiasts. The Little Printer was brought back to life by an independent tech consultancy after the original manufacturer discontinued its service (Nord Projects, 2021). The Aether speaker received an end-of-life firmware update to allow users to use it as a basic Bluetooth speaker, losing its unique capabilities but at least avoiding "brick" (dysfunctional, dead, wasted) status (Perlow, 2015). Whilst the original Jibo robots remain functionally redundant for end users, the device's intellectual property was acquired and a revival is planned as a robot for education and healthcare (NTT, 2020). Our research explores the short lifespans of IoT objects like these and approaches to mitigating the consequences of reaching end-of-life status.

The end-of-life of IoT objects presents challenges and opportunities for sustainable design that respond to the climate crisis. We use the term end-of-life to describe the point at which objects cease to be useful through damage, loss of support, user choice, and so on. The increasing volume of redundant IoT objects is driven by unsustainable, linear "take, make, dispose" (Moreno et al., 2016) principles, including: replacement over repair; hardware tied to software development; increasing energy demands; and virgin material extraction (Stahel, 2016; Unwin, 2020). In this paper, we synthesise findings from a two-day workshop that explored how design contributes to the end-of-life of IoT objects (Lechelt et al., 2020) and present two high-level strategies for the design of more sustainable IoT lifecycles. Our first proposed strategy is to re-imagine existing objects creatively and facilitate circular lives through design. Our second strategy is changing people's relationships with their objects, thus increasing their value and extending object lives.

Figure 1. IoT objects bricked through discontinued support. Sources: Roettgers 2015, Nord Projects 2021, Carman 2019.

Related Work

IoT objects are simultaneously data objects and material objects. In one of the earliest critical visionary works on sustainable IoT, Bruce Sterling applies the terms "material" and "immaterial instantiations" to describe his *spime* concept (Sterling, 2005). Spimes are speculative, infinitely recyclable, physical IoT objects that exist alongside their digital instantiations (Stead, 2016). This co-dependence of physical and digital means that loss of manufacturer support for the digital instantiation leads to material objects becoming bricked, leading to the question: what happens when an IoT object has reached end-of-life?

Regular (non-IoT) end-of-life objects are sometimes retained, repurposed, stripped for parts, and recycled but mostly landfilled or incinerated, depending on their design, supporting services, and residual value. The majority of IoT objects tend not to be designed for disassembly: too many parts are physically glued together, soldered, or force-fitted and made of hard-to-recycle plastics (Burgess et al., 2021; Stead et al., 2019). This is further compounded when proprietary, closed-source software is combined with non-modular hardware, making creative re-imagining and re-use difficult (Rickerby, 2019). Such objects inevitably become waste.

The waste from end-of-life IoT objects is both physical and digital, material and immaterial. Materially, exploitatively mined rare metals become an electronic/hazardous waste problem and environmental liability (Merchant, 2017; Terazono et al., 2006). Immaterial waste – data stored on devices or the cloud – becomes a digital liability, vulnerable to cybersecurity threats (Lin & Bergmann, 2016). Stead (2017) proposes a transparent future for IoT with greater manufacturer accountability and informed decision-making around purchase, use, and disposal. Their work highlights a sustainability gap between present-day IoT and Sterling's spimes. The data object is potential source material for design – a record of object performance data to inform re-design. Recent developments around digital twins and data-driven design show how this can be achieved (Gorkovenko et al., 2020). This paper builds on these concepts by examining existing end-of-life practices and participant speculations on future IoT.

Additionally, existing sustainable design principles may hold solutions for reducing the impacts of end-of-life IoT. The cradle-to-cradle philosophy promotes object designs where waste becomes the substrate for new objects (McDonough & Braungart, 2002). For example, the Sprout pencil can be planted when its useful life has expired, activating the seeds within (Sprout, 2021). Given the broad range of capabilities and resources in IoT devices, there are many possibilities for waste objects to be given second lives or become new objects. The workshop participants explored this philosophy in relation to end-of-life IoT practices.

Embedding emotional attachment is another established sustainable design strategy encouraging longer object-user relationships (Chapman, 2015; Norman, 2007). As IoT objects become embedded in our domestic lives, there is an opportunity to explore and harness emotional attachment for sustainable design and end-of-life practices. The social robot Jibo announced its own "death" when its servers were shut down, saying, "maybe someday, when robots are way more advanced than today, and everyone has them in their homes, you can tell yours that I said hello" (Jibo in Carman, 2019). Emotionally attached owners faced a dilemma with Jibo's corpse – should they keep it as a memorial, or bury it? (Carman, 2019; Krotoski, 2019)

Emotional attachment is one factor in influencing how we "care" for objects. Ackerman et al. (2021) define eight strategies for product design that encourage more sustainable behaviour through object care: informing, awareness, antecedents and consequences, social connections, enabling, appropriation, reflecting, and control. These existing product design strategies inform and align with the tactics and values emerging from our workshop. We are concerned with how IoT object design specifically can create attachment, enable care, and harness it for more sustainable consumption – why is one IoT object considered family and cared for, while others are dispensable and disposable?

Method

We ran our workshop – Designing for the End-of-Life of Internet of Things Objects (ELIoT) – during the Designing Interactive Systems (DIS2020) conference (Lechelt et al., 2020). We began with two key questions:

1. What values compel people to keep, re-use, or reimagine IoT objects after they are no longer functional?

2. What tactics can we use to design these values into IoT objects to encourage end-of-life upcycling, appropriation, and re-use?

The online workshop was attended by eleven academics (P1-P11) and two industry participants (P12 & P13). Participant backgrounds were diverse, spanning design, architecture, human computer interaction, and software engineering. Institutions from six countries were represented – Australia, Greece, Hungary, Netherlands, UK, and USA. In addition to the thirteen participants, a team of six researchers facilitated the event. The total duration of the workshop was six hours over two days.

Data Collection and Analysis

Day one was used to introduce and explore the workshop themes using a Miro board for recording ideas and discussion. First, attendees were asked to add their "favourite IoT objects" to a Miro board, which was followed by a show-and-tell discussion. Participants next gave four-minute paper presentations discussing their own work within the space of IoT sustainability, during which notes and ideas were gathered collaboratively. Attendees created a visual "cabinet of curiosities": a collection of their favourite or notable end-of-life objects and relevant context around the objects' life stories.

The Miro content was collectively discussed by the workshop organisers and participants in a thirty-minute clustering session. Our participants affinity-mapped (Nielsen Norman Group, 2018) notes and content into nine initial clusters in a collaborative process, identifying tactics and values that addressed our two research questions. Examples of these participant-generated clusters include: Alternative Lifecycles; The Old as New; Inclusive Re-imagining and Hacking: Internet of (Play)Things; Applying Metaphors of Living to IoT; and Ubiquity and Components of Things. A second round of affinity mapping led to identification of three overarching clusters – thematic areas for addressing unsustainability in IoT objects – and set the agenda for day two.

These three clusters were:

1. End-of-life practices
2. Inclusive re-imagining
3. Ubiquity and components

On day two, break-out groups were formed for each of the three clusters, with participants tasked with discussing their theme for sixty minutes and presenting their ideas. Participants chose break-out groups best aligned with their research or personal interests. Each group discussed their cluster with facilitator assistance and presented their visions. Presentations were given in a forty-five-minute plenary session, followed by a wrap-up discussion. The next section of this paper presents the three visions presented by the participants, followed by a discussion linking the findings with our research questions.

Findings

Our goal was to examine and rethink IoT object lifespans and how baked-in values influence end-of-life practices. We uncovered personal and professional practices and relevant expert opinions. Examining end-of-life objects through the lenses of performative and functional value enabled us to identify several tactics and values through which object lives can potentially be made more sustainable. Our findings and proposed strategies contribute insight for IoT design that have the potential to extend object lifespans and improve sustainability. The content from each workshop break-out group is summarised and discussed below, along with the tactics and values we identified and used to form our two design strategies.

End-of-Life Practices
Existing domestic end-of-life practices and the values these practices reveal were examined in the first break-out group. Alternative values were explored with metaphors of place and ownership applied to IoT objects. Participants revealed their own domestic practices with end-of-life IoT objects and electronic devices.

Domestic end-of-life practices were revealed and discussed. These were termed *cupboarding*, *toyboxing*, *framing*, *shelving*, *treasuring*, and *binning* by participants. These are linked practices; an object *cupboarded* or stored, once redundant, is later *toyboxed* or used for playful alternative purposes, then with age becomes a "vintage" or "retro" type object and is *shelved* or placed on display for aesthetic and nostalgic value where it gathers dust and is finally *binned*, where it leaves the home and enters a waste or recycling process (Figure 2). Participants discussed shifting relationships between values: "once in the cupboard, the price generally goes down – but does sentimental (value)?" (P12). Keeping sentimental value whilst releasing functional value was proposed: "What could you 'strip'/recycle from a device, such that you maintain the emotional value (for the shelf) but re-use materials/components. Just the shell?" (P1).

Human life stages and ageing as metaphors for objects were raised and explored. Participants proposed aligning human life stages with IoT objects, using terms like *second childhoods, middle-age*, *retirement*, and enabling "*graceful ageing*." P12 and P8 questioned how we design "things that age gracefully in a culture where ageing is shameful," where youth is considered more marketable than experience. These terms provide a human frame of reference that engender a sense of responsibility and care for objects.

Caring was explored as a key metaphor for ownership. Reframing ourselves as an object carer rather than consumer potentially leads to alternative approaches to ownership. Shared ownership models and the idea of being a temporary steward of objects were raised as more sustainable alternatives to present "take, make, and dispose" consumption. Sterling proposed the role of "spime wranglers" – people tasked with creating spimes and sustainably managing their data and object lives (Sterling, 2005). Stead (2017) reframed this "wrangler" role to include makers and the democratisation of innovation to counter commercial, proprietary, and closed-loop IoT devices and their unsustainable impacts. Discussions in the workshop included the empowerment of IoT users and enthusiasts, those willing to give up their time to care for objects, repair and maintain them, and find a suitable home for them at the end of their useful lives. This was seen as addressing the unsustainability of owning one of everything and the guilt of acquisition, redundancy, and disposal.

Nostalgia and rituals celebrating ageing, deterioration, and death were explored as ways of caring for and engaging with end-of-life objects. Rituals associated with living things – funerals, etc. – were proposed as engagement tools for IoT objects. Practices like *kintsukoroi*, a Japanese tradition whereby broken ceramics are repaired with gold leaf, were discussed with the potential for application to IoT. These practices embody graceful ageing and re-use, highlighting faults and life experience. Several participants presented their own work on creating such object rituals and practices on day one of the workshop (e.g., Cloke, 2020; Foster & Fricke, 2020). The digital/immaterial instantiations of IoT objects offer the potential to highlight, interpret, and engage with the history of the object.

These anthropomorphised and domestic practices suggest a future for IoT objects with a greater sense of care, value, and responsibility. Approaches to IoT design that allow for multiple life stages and graceful ageing are needed to move away from present short-lived IoT objects. The key values highlighted in the End-of-Life Practices discussion were *community*, *caring*, and *nostalgia*. The key tactics highlighted for embedding these values were *designing for life stages*, *attention-seeking*, *data souls and ghosts*, and *rituals*.

Figure 2. Domestic end-of-life practices for IoT objects, group presentation. Source: authors, incorporating workshop-generated Miro content.

Inclusive Re-Imagining
Inclusive re-imagining examines new roles of repair, open-source hardware and software, democratising design, and lifestyle choices around repair. The discussion focused on tools and infrastructure for repair/modification. Inspiration was drawn from "The Repair Shop," a TV series that follows restoration of dilapidated objects (BBC, 2021). Participants felt it effectively illustrated the sustainable re-imagining of objects. The show depicts owners of broken objects who lack the time and knowledge to fix them seeking expert advice in the absence of any manufacturer responsibility. This links with the values of caring, nostalgia, and responsibility explored in the End-of-Life Practices group, suggesting the need for a supporting infrastructure that enables more sustainable domestic practices with IoT objects.

An inclusive re-imagining system for IoT was mapped (Figure 3). Stakeholders included object owners (with the subsets DIYer, crafter, hacker, and consumer), repairers, crafts-people, designers, and manufacturers. The owner subset highlights disparities in agency, where a consumer has fewer options for an end-of-life object than an empowered hacker. A distributed "IoT Repair Shop" enabled by open-source design was proposed alongside accessible repair/modification information. The vision highlights opportunities for inter-vention and new services to support sustainable end-of-life practices.

Inclusive re-imagining suggests a future where stakeholders form new communities and infrastructure to support extended object lifespans and creative reuse, enabled by open, modular standards, and building on principles of transparency and right-to-repair. The key values highlighted in the Inclusive Reimagining discussion were *community*, *trans-parency*, *empowerment*, and *nostalgia*. The key tactics highlighted for embedding these values were *aesthetics*, *designing for life stages*, and *modularity*.

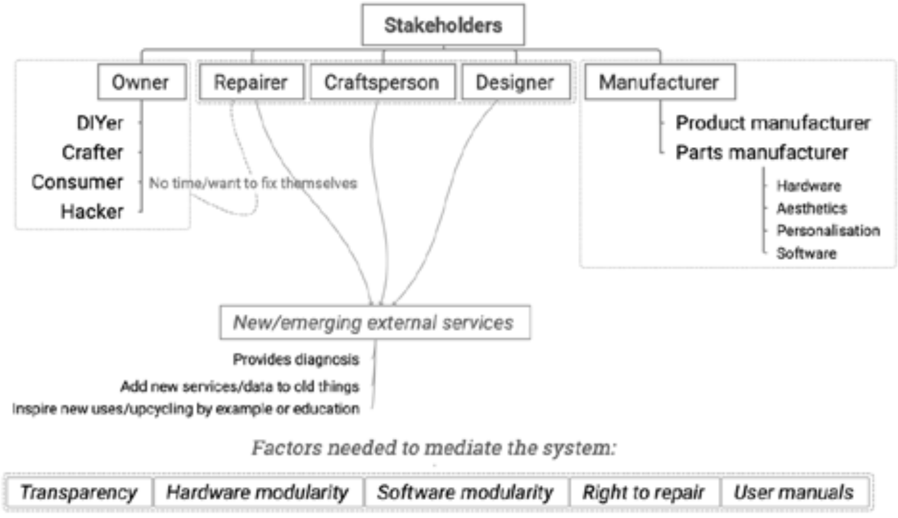

Figure 3. Inclusive re-imagining stakeholder map, group presentation. Source: authors, based on workshop-generated Miro content.

Ubiquity and Components

This group explored relationships between physical objects and cloud data, sustainable component management, and responsibility for end-of-life objects and data. The group discussed potential for the design of infinitely recyclable and trackable components. These components could be tracked in a spime-like IoT ecosystem, identifying when objects reach end-of-life and which components may be reused (Stead et al., 2019). Participants imagined IoT "graveyards" or "scrapyards," used as a repository of spares, available for new re-use, repair, and recycling services. IoT objects sometimes reach end-of-life through a single component failure (e.g., non-replaceable batteries), leaving behind functional components. Participants envisioned these cloud-enabled IoT scrapyards making components for repair as easily obtainable as new objects. Caution was voiced about cloud sustainability – "the cloud is just use of someone else's computer" (P10) – with new services increasing demand for data storage and energy use outside the user's view. Data centre energy consumption is projected to reach 8% of global electricity production by 2030 (Andrae & Edler in Jones, 2018), driven partly by IoT and cloud services.

Participants discussed the value of caring for objects and associated data. Caring was linked with notions of power and control and their division between users, manufacturers, and third parties. Ability to care for objects was seen as limited by power and control dynamics – for example, the monopolistic power corporations hold over end-user data (P6).

The key values highlighted in the Ubiquity and Components discussion are *caring*, *transparency*, *empowerment*, and *community*. The key tactics highlighted for embedding these values are *designing for life stages*, *data souls and ghosts*, and *modularity*.

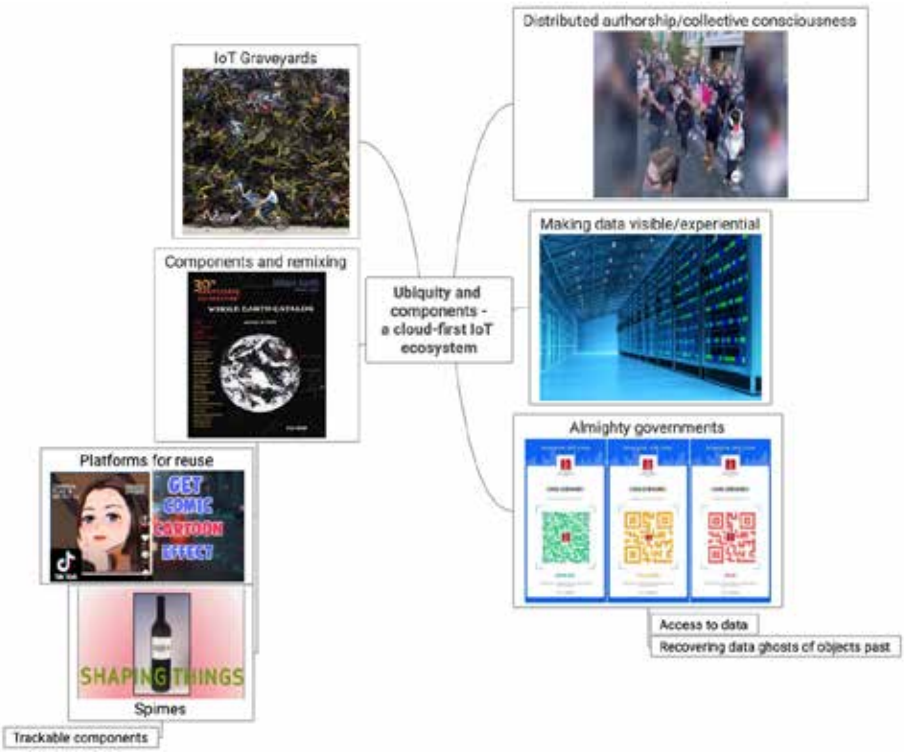

Figure 4. Ubiquity and components: cloud first ecosystem, group presentation. Source: authors, incorporating workshop-generated Miro content.

Discussion

Our workshop findings suggest two high-level design strategies to address the sustainability of end-of-life IoT objects, emerging from the tactics and values discussed across the three workshop groups. These strategies are Sustainable Caregiving for IoT Objects and Re-imagining IoT Objects for Sustainability. Figure 5 shows the tactics and values from the discussions that address our two original research questions. Figure 6 shows how these tactics and values combine to form our two proposed design strategies.

These strategies emerged from the mapping and clustering in the workshop itself, combined with the process of analysing and coding the data post-workshop. To synthesise and analyse the Miro data, two main coding strategies were employed. Firstly, a holistic coding was undertaken of the material from day one. The holistic codes used for the analysis of the workshop material are as follows:

- Design: issues relating to design broadly and participant involvement in design processes
- Lifestyle: objects and ideas that link with peoples' daily life, activities, hobbies, etc.
- Personal: direct involvement in the creation and/or design of an object

- Environmental sustainability: issues around energy, repair, and resource consumption
- Data: ideas around engagement with data, data-gathering, and ethical considerations
- Financial sustainability: costs associated with object ownership, production, and disposal

At the end of day one, a process of in-workshop, bottom-up clustering by the participants resulted in nine distinct clusters from the discussion and material generated so far. Given the time and number of participants, three overarching clusters were taken forward to day two: Inclusive Re-imagining; End-of-life Practices; and Ubiquity and Components. The second post-workshop coding strategy maintained the holistic codes from day one under the three participant-generated clusters. Our post-workshop analysis identified connected values and tactics relating to end-of-life IoT objects, from which the two design strategies were drawn (Figures 5 and 6).

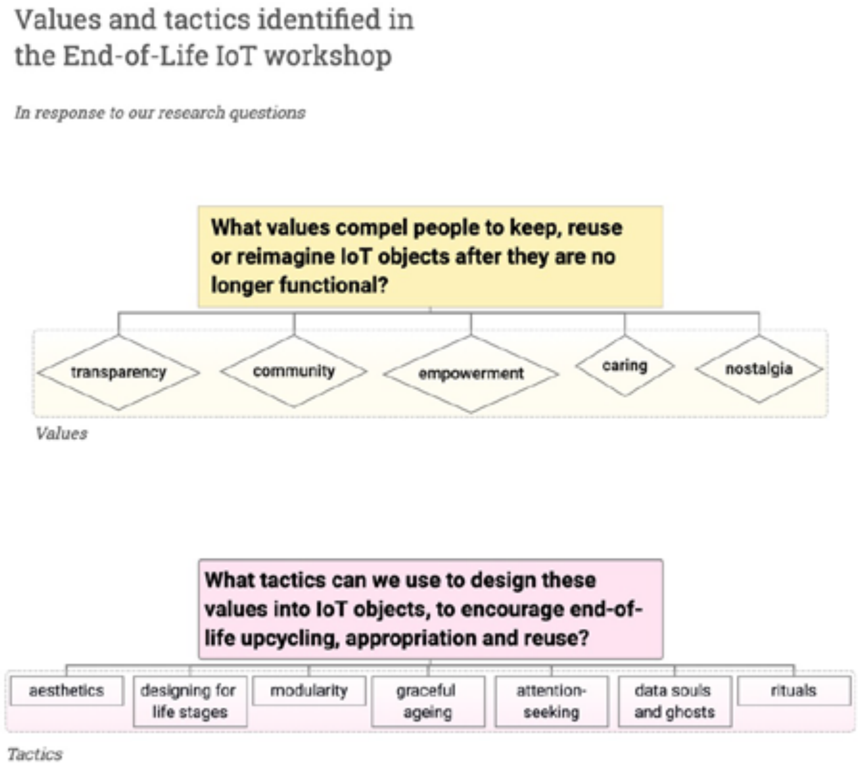

Figure 5. Our research questions and the values and tactics that emerged from our workshop. Source: authors.

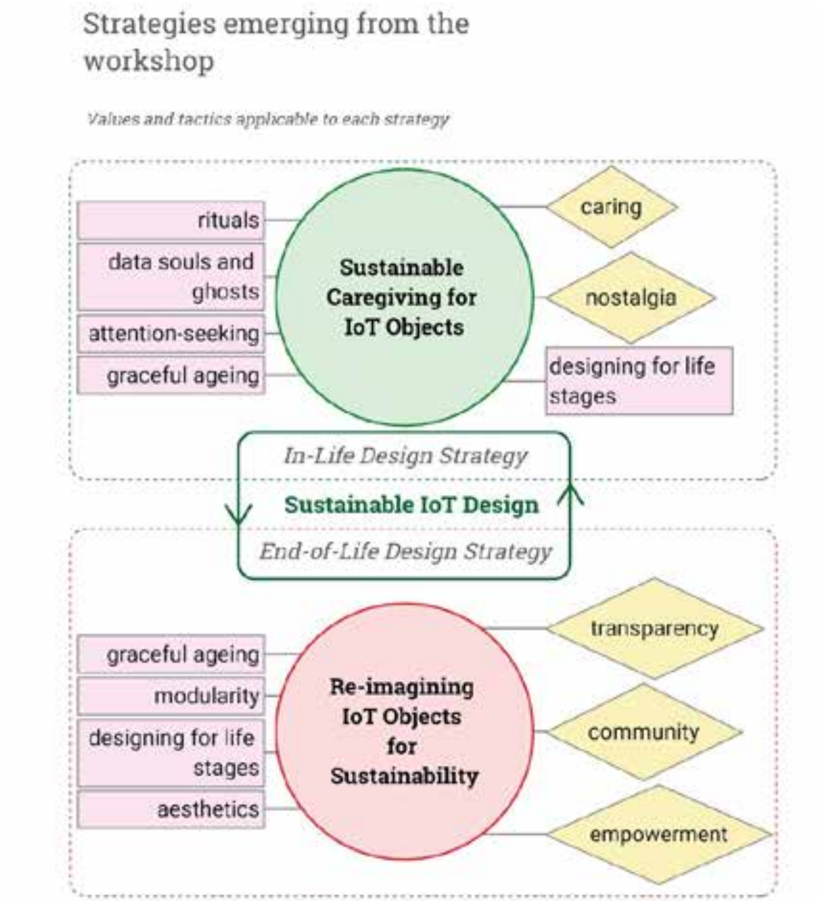

Figure 6. Values and tactics from the workshop aligned with our two proposed design strategies. Source: authors.

Re-Imagining IoT Objects for Sustainability
The workshop insights/data emphasise that IoT objects need to be designed for disassembly and modification, and users need to be empowered with the knowledge and ability to undertake re-imagining. Millions of manufactured objects are discarded every year, depleting copious amounts of useful resources: components, metals, and plastics. We propose that circular lives for objects are given greater consideration through repair, re-use, and hacking. Sustainable practices need to be made accessible to users with limited time and knowledge of repair and modification.

Manufacturers and service providers need to be transparent about hardware and software architecture in IoT objects as identified in our workshop discussions and supported by the literature. More modular designs based on open standards would empower users and communities to repurpose components or extend object lifespans (see Joshi &

Pargman, 2015). Making both physical hardware specifications and software code open source would empower users to make longer, more sustainable use of products.

Existing practices highlighted in our workshop show that re-imagining end-of-life IoT objects is possible where the knowledge, demand, or community exists. Manufacturers can frustrate this through proprietary software, hardware, and infrastructure. Re-use communities often exist despite unsupportive manufacturers or challenging designs, with dedicated users reverse-engineering objects to keep them alive and relevant (see Fox et al., 2018; Houston et al., 2016).

Creative reuse practices identified in the workshop, like *kintsukoroi* ("golden repair" of ceramics) or *steampunk* (a subculture of design and making re-envisioning current technology through a Victorian lens) may hold inspiration for IoT designers (DeSilvey et al., 2018; Tanner, 2016; Tanenbaum et al., 2012). *Solarpunk* (steampunk and cyberpunk's more optimistic descendant) is a potential aesthetic for renewable, sustainable, horizontally distributed IoT design (Zer-Aviv, 2019). Embracing unorthodox aesthetics in IoT design may create objects that enable creative re-imagining and longer, more sustainable lives.

Sustainable Caregiving for Objects

Our relationship with IoT objects impacts our choices for responsible end-of-life disposal. Our workshop participants identified how emotional attachment prevents or delays us from discarding them. The easiest destination for end-of-life objects is often the domestic bin. From there they are landfilled or incinerated, their resources and capabilities annihilated. Disposal is symptomatic of value loss – economic, material, functional, nostalgic, emotional.

Our workshop looked at rituals and ceremonies that engage people with end-of-life objects and their value. Rituals and nostalgia help reveal the material consequences of consumption. Manufacturers and retailers could implement end-of-life IoT rituals that mirror purchasing rituals – the research, marketing, messaging, tracking, packaging, and support – thereby reversing the "take, make, dispose" supply chain.

Caring can be encouraged by including user-accessible upgrade and repair options. In line with the literature in this area, our workshop showed users have greater attachment to objects they have repaired or upgraded. User serviceable components extend objects' useful lives and increase user investment in time, money, effort, and knowledge (see Mashhadi et al., 2016). Undertaking a basic repair may make users feel more attachment, care, and stewardship toward that object. Objects not designed for disassembly and repair make this connection impossible. Forthcoming right-to-repair legislation may mean future objects are better designed for upgrade and repair, but designers and manufacturers should act immediately.

Conclusion

We believe our workshop findings contribute to growing discourse in design research seeking to challenge prevailing modes of IoT design and manufacture and explore new sustainable models that respond to environmental and climate crises. There is much work to be done to move IoT away from throwaway black boxes to anything resembling a sustainable technology ecosystem. Although we focused on IoT since it is an expanding technology with high-profile examples of unsustainable objects, the opening discussions in our workshop were not limited to IoT, but rather incorporated ideas from a variety of object types; it follows that the strategies we have developed could have value for objects beyond IoT. We would welcome the application of the practices, ideas, and strategies presented in this paper to manufactured objects more broadly to address their climate and environmental impacts.

Following the workshop, organisers have gone on to undertake a study involving in-depth interviews with users of end-of-life IoT devices exploring the barriers to circular afterlives – *Re-Imagining IoT Objects for Sustainability*. Further work is ongoing relating to *Sustainable Caregiving for Objects*, exploring our future relationships with IoT objects and data through speculative design. We hope the strategies presented here provoke further research by others in this worthwhile field.

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TWO INSTITUTIONS, THREE TREES, TWELVE MAKERS: CURRICULUM CO-DESIGN FOR SUSTAINABILITY, CLIMATE JUSTICE AND AFRICAN AMERICAN MATERIAL CULTURE

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Abstract
This paper reflects on the process and outcomes of an experimental woodworking studio arising from a collaboration between a museum of African American history and an art and design college. Three dying Zelkova trees on the Charles H. Wright Museum of African American History's campus, destined for mulching, were reclaimed for a project exploring climate change, climate justice, and African American material culture through the creation of cultural artifacts.

The city of Detroit removes between 10,000 to 20,000 trees each year (Helm, 2016; Howrani Heeres, Detroit's Director of Sustainability, personal communication, 2022). When the trees at the museum were identified, the museum's Chief Sustainability Officer connected with the neighboring College for Creative Studies. Together, over the course of nearly two years, they developed a curriculum informed by extensive consultation and research amidst the city's designers, makers, artists, curators, activists, arborists, and planners.

The studio recruited half of its participants from the College's student body, and half from the community of Detroit, Hamtramck, and Highland Park, greatly enhancing the diversity of lived experiences within the group. Operating as an atelier, the students were asked at the outset to leave behind any preconceived ideas, where the thinking is completed before the making begins (Dunnigan, 2013, p. 98; Ingold, 2013, p. 21-22), and instead be led by both the material qualities of the wood and, with lectures from external experts, the contextual situatedness of the brief. This is akin to Ingold's (2013) morphogenetic mode "making in anticipation of what might emerge" (p. 21-22), but also respectful of design decolonization's advancement of different ways of knowing (Schultz et al., 2018, p. 4; Ansari, 2018) – or "[...] different kinds of knowledges [sic]" (Mbembe, 2015, in Campbell, 2016, p. 2) in the emergence of creative practice as a form of research. There were no boundaries to modes of thought and reflection.

In terms of the diversion of waste streams, the overall contribution to carbon sequestration is negligible. It is in the narrative that there is evidence of impact. The artist statements

exhibited alongside the artifacts provoked as much of a response as the artifacts themselves. Outcomes spoke powerfully to decolonization, land injustice, African American history, ancestry, place, and diaspora.

Humans have been designing things since before there was a word for design, (Cross, 1999, p. 25; Friedman, 2000, p. 5), and so too with storytelling. In the twenty-first century, designers routinely bring shape and form to narratives, which in turn shape and form the way humans experience the world. The story of this project, arising from two important cultural institutions in Detroit, has provoked and stimulated thinking amidst the city's community and is beginning to ripple into policy making.

Author Keywords
Climate justice; social justice; African American history; making; trees; sustainability.

Introduction

In 2018, the Charles H. Wright Museum of African American History (The Wright Museum) discovered three dying Zelkova trees on their campus. These trees were marked for removal and destined to be mulched for compost. However, in 2019, as part of its mission to be a zero waste institution, the museum formed a collaboration with the College for Creative Studies (CCS) to instead harvest the timber for use in a creative endeavor.

The initial question arose as to how can two neighbors, a museum and a college of art and design, set a precedent for creative practice towards climate justice in the community? Wider questions that emerged are outlined later, but in seeking answers, research methodologies unfolded as action research, practice-as-research, community consultation, focus groups, interviews, and a *Treeposium*. All of this activity was extensively documented as diagrams, notes, plans, photographs, and films collated in a labyrinthine intranet site.

From all of this, a project emerged as a pilot for more ambitious levels of community and artistic engagement. The City of Detroit removes some 10,000 to 20,000 trees each year for various largely necessary reasons (Helm, 2016; Howrani Heeres, City of Detroit's Director of Sustainability, personal communication, 2022). The timber is typically mulched, while wood from larger trees can be utilized for creative and practical endeavors. Against this impactful backdrop, the Wright Museum and CCS combined their respective institutional expertise to intentionally design a woodshop class – the ***d.****Tree Studio* – that framed an understanding of African material culture in the context of sustainability and tree experiences in Detroit.

The **d**.Tree Studio project examined the socio-cultural and political history of Detroit through time, place, and space, and sought to connect and elevate voices of the African American experience throughout the diaspora. The creative outcomes and their intended narratives are discussed later in the paper (see Figures 1 to 5).

The foundational themes of the **d**.Tree Studio are:

- Respecting people, place, and history
- Objects are not neutral: All objects mediate, they have meaning and spirit in time and place

- Learning from the trees: The trees have witnessed changes in relationships in communities over time
- Sustainability

This is by no means the first time felled trees have been diverted for an artistic endeavor: notable examples include the *Witness Tree Project* out of the Rhode Island School of Design (2009 to 2018)[1] and the *Wych Elm Project* at Edinburgh's Royal Botanical Gardens in Scotland (*Wych Elm*, 2009). However, the unique perspective of this project is in its speaking to specific themes around African American history and culture and sustainability in a city in the midst of an extraordinary revival.

Through meaningful dialog on numerous perspectives and experiences and in-depth critical inquiry, this project offers a playbook for other institutions to collaborate and undertake work towards similar objectives, along with providing a foundation for its own continuing endeavor into new phases of the project.

The impact of the Coronavirus pandemic needs to be acknowledged. The Zelkova wood was milled in January 2020 and moved to the basement of the College for storage. The studio was originally scheduled to start in September 2020. The pandemic pushed subsequent planning meetings online and delayed the start of the studio by twelve months. In hindsight, this proved advantageous for planning and allowed for greater depth in detailing the project's aims and themes.

Furthermore, the project was almost derailed by climate change: unseasonably heavy rain led to severe flooding in midtown Detroit. The basements of both institutions were flooded with raw sewage backing up from a failing city sewer system. The milled lumber and tree branches were stored in the College basement and, by chance, in the only section unaffected.

Background

Urban forests and trees have agency in cities. The practical benefits of a healthy urban tree canopy are varied – shade, carbon sequestration, mitigation of air pollution and storm water run-off, noise reduction, and reduced crime (Carmichael, 2017, p. 21).[2] Equally, trees can provide a "tone and feel," marking out socio-economic-cultural-ecological spaces of one kind or another (Jones, 2017, p. 111). Furthermore, in cities, trees can delineate areas of uneven distribution of social well-being "… in relation to ethnicity and income" (Jones, 2017, p. 115).

Urban trees require ongoing management and stewardship. As previously mentioned, the City of Detroit removes thousands of trees each year due to disease, storm damage, instability (posing a risk to people or property), or the expansion of civic infrastructure. From the city's point of view, the most cost effective way to deal with the felled trees, regardless of their size, is to mulch them for compost. Paul Hickman (personal communication, 2022) of Urban Ashes, part of the Urban Wood Network,[3] explains that the life cycle assessment (LCA) of trees in Detroit is one of planting, trimming, and removal. Costs are in the "tipping" of trees and to optimize the LCA, funding needs to be transferred to maintenance and careful planting. Furthermore, while the decision to remove a tree is not taken lightly, once a mature tree is removed, it takes many years for replanted trees to make up for the carbon sequestration.

Removing urban trees is altogether different to felling trees in commercial lumber operations, and while the costs are much higher, the timber is equally usable. Other U.S. cities, notably Pittsburgh[4] and Baltimore,[5] have successfully implemented urban lumber operations.[6] The United States-based Urban Wood Network advances the notion of urban lumber as a material resource rather than waste. They emphasize that city trees have their highest value when still alive, but cite the U.S. Forest Service in claiming that "[...] reclaimed wood from all dead and diseased community trees could equal nearly 4 billion board feet or about 30% of annual hardwood consumption in the United States" (Urban Wood Network, 2022). This could amount to a significant reduction in the consumption of hardwood from commercial operations.

From the perspective of political ecology, urban forests have interests that include and favor some, exclude and marginalize others, and typically benefit some groups more than others (Sandberg et al., 2015, p. 6). The replanting of trees in Detroit has its own social challenges. As the city recovers from economic and population decline over the last 50 or more years, the replanting of trees is associated with gentrification and those seeking only to make a profit. Decision makers are seen as political or corporate "elites" with vested interests in maximizing profit and capital accumulation (Carmichael, 2017, p. 31). Furthermore, having had hazardous trees removed, people do not want to be burdened with maintaining new ones where civic services have failed to do so (Funes, 2018). As such, the replanting of trees is often viewed as government imposition. More is needed to engage with and include the range of stakeholders on the importance of trees to cities and their inhabitants. It is not just for civic authorities to take control: "Political ecologists consider urban forests as human constructs that are not the preserve of urban forest professionals but a variety of interest groups including residents, environmentalists, social scientists, and artists" (Sandberg et al., 2015, p. 6).

Also, in foregrounding practical benefits, civic efforts may overlook socio-cultural factors like beauty and cultural heritage (Carmichael, 2017, p. 17; Jones, 2017, p. 114). Here, the narratives arising from arts and cultural perspectives held by an African American history museum and a college of art and design may be more successful in leveraging community control and participation.

Detroit has a history of racial division, social injustices, and social upheaval (Boyd, 2017; Surgue, 1996). Such experiences continue in the present day, as poignantly underlined by the 2021 Summer of Protest in response to the murder of George Floyd. This brought to the fore once again the unavoidable legacy of colonialism and slavery in the United States. African American history and African material culture provide powerful narratives towards decolonization, which has many parallels with sustainability objectives. Rather than making alterations to existing power structures of the global North, both call for a complete deconstruction of these and their failing economic systems (Hickel, 2021), and a rebuilding of entirely new ones that are fit for all humans and the planet.

Methodology

Navigating the complex factors of historical and current social injustices combined with climate justice and sustainability required in-depth discourse and critical inquiry, and documentation of the subsequent reflective practices and planning. It was essential for the project to be clearly defined with carefully considered aims and objectives based on qualitative research.

Action research – reflection in and on one's own practice (Swann, 2002) – arose in the on-going conversations and planning (practice) that is well-documented in notes, diagrams, and charts. This is also practice-as-research, a multi-modal form of research consisting of a praxis in an iterative process of "doing-reflecting-reading-articulating-doing" (Nelson, 2013, p. 32).

Semi-structured interviews and personal communication with key artists, creatives, activists, and policy makers from the city helped to frame the objectives of the project. A visit to the workspace of prominent Detroit creative Olayami Dabls (known as Dabls) and a tour of his extensive outdoor works provided examples of a deeply rich narrative on decolonization. Dabls is referred to here as a "creative" because he asserts that in many African cultures there is no word for art. He rejects the terms art and artist as a Western commodification of practice. This is also the reason that the **d**.Tree Studio participants are referred to as makers and not artists in this context.

Focus groups gave rise to rich dialog. Conversations with long-standing city residents and elders provided valuable perspectives and oral histories that helped to set in place the project themes.

The Treeposium

Perhaps the most impactful and insightful event was the *Treeposium*[7] (tree symposium) led by Leslie Tom of the Wright Museum, with a five-person panel consisting of an award-winning African American creative (see above), an African American architect and urban planner, an Asian American landscape architect and infrastructure planner, a Native American (Anishinaabe) artist, storyteller, and filmmaker, and an African American city elder. The Treeposium had over 900 views and started with a four-minute film, voiced by city elder Etta Adams, that succinctly framed the project. The conversations arising from this event provided deep anecdotal insight into the themes of the project.

The accompanying film was made in the months before the Treeposium. The writing, storyboarding, and production for this was, in itself, action research in that the practice gave rise to new knowledge and insights. The research data was documented in an extensive intranet site and was vital to informing the practices of the studio.

The d.Tree Studio

The two institutions formed the **d.**Tree Studio, an atelier comprising twelve makers. Five were students at the College, and seven – community members – were new and emerging artists with strong links to the city. All were enrolled into the class at the graduate level, and the seven community members were provided with a full scholarship. The class was taught by Ian Lambert with input and support from Leslie Tom, John Rizzo of CCS, and guest speakers.

Studio members learned about socio-cultural research methods (storytelling, listening, and inquiry) and practical woodworking techniques in the pursuit of artistic practice. Participants also explored cultural place-making and narrative development methods.

The **d.**Tree Studio explored connections between design, African American material culture and history, and sustainability. The Studio affirmed that there is a deep connection between story making and object making. It acknowledged that objects are not neutral, pushed back on disposable culture, and challenged the class to reveal the stories embedded within objects that convey belonging, respect, and wisdom.

The wood is from trees with deep roots in Detroit, growing in soil that contains memories of the land, even before Detroit became Detroit. The Zelkova trees were cut and milled from wood to lumber which extended their life cycle (see Figure 1). The trees' new form allows for the exploration of its transition to artifacts examining the past, present, and future of African American experiences in Detroit. An urban tree's place, location, and role as a cultural landmark can be embodied in the artifacts they become.

Figure 1. Zelkova wood planks in the wood shop (2021).

The studio members were briefed that all objects mediate (Dant, 1999, p. 13) and the outcomes could arise as subtle community installations, small pieces of furniture, carvings, craft objects, or artworks along with a narrative that is tested through an iterative community process. This iterative process provided feedback to students on how the object/narrative and message is received and which woodworking methods to hone.

Studio members were advised to avoid starting the class with a concept in mind, where the thinking is complete before the making begins (Dunnigan, 2013, p. 98; Ingold, 2013, p. 21-22). Instead, they were encouraged to be led by both the material qualities of the wood and, with lectures from external experts, the contextual situatedness of the brief. This is akin to Ingold's (2013) morphogenetic mode, "making in anticipation of what might emerge" (p. 21-22), but also respectful of design decolonization's advancement of different ways of knowing (Schultz et al., 2018, p. 4; Ansari, 2018) – or, "[…] different kinds of knowledges [sic]" (Mbembe, 2015, in Campbell, 2016, p. 2) in the emergence of creative practice as a form of research. There were no boundaries to modes of thought and reflection.

Sustainability

The life of a tree can span years, decades, or centuries where they take root. They catalog time, environmental change, social experiences, and the history of the places they are planted. They communicate their experiences through their health, their rings, their leaves, and their roots.

Wood is an important resource in many local industries as well as in artistic creation, and the project aimed to bring attention to urban lumber as a resource within the community. Without intervention, these trees would add to landfills and increase carbon emissions. By making wood objects, studio members were practicing carbon sequestration. The studio framed the use of urban lumber as a sustainable design medium to push back against a disposable culture.

Selection of Makers

Community members applied following an open call across the city through various channels. Student members applied following a call across the College; they could hail from any discipline, but needed to be at the sophomore level or above at the start of the class. Candidates did not need to be expert makers, but were required to have basic (foundation level) experience working in machine shops.

The **d.**Tree Studio sought candidates that:

- Had a diversity of backgrounds and ideas
- Had a connection to Detroit or neighboring Hamtramck or Highland Park
- Were curious and open to the process of learning from the trees
- Understood the possibilities and opportunities of the project
- Were able to be reflective throughout the experience
- Understand stories they were drawn to
- Could offer a critical lens of analysis to the process of storytelling and making

Applications were sought that:

- Demonstrated curiosity and openness to the introspective, iterative, inquiry-focused learning process
- Were insightful, critical, and persuasive

Schedule
Members undertook preliminary reading/viewing/listening during the summer months. The class was structured into three phases:

Phase 1: Research and Preparation
The first four weeks of the class allowed participants to explore the **d.**Tree Studio context in greater depth, become familiar with the materials and processes, and undertake some introductory tasks, including a quick self-portrait in wood.
Objectives: Explore the context in-depth, gain familiarity with the materials, and explore artistic concepts.

Phase 2: Create Proposal
In the second four weeks, participants collated exploratory contextual and creative findings, and devised a proposal in direct response to the brief. Continuing a process of material inquiry, models and maquettes were used to explore narratives and plan the execution of the final outcome. This phase concluded with a critique by external artists and designers.
Objectives: Develop ideas and make models and maquettes.

Phase 3: Make and Finesse Artwork
The final six weeks of the class was devoted to the making and completion of the final creative outcome. This phase ended with the exhibition in early 2022.
Objectives: Make an artifact and prepare for the exhibition.

Funding
The costs of the project were equally met by both institutions, with an additional $10,010 of funding at the latter stage awarded by the Michigan Council for Artistic and Cultural Affairs.

The Work and Exhibition
The work was shown in a public exhibition in March 2022, held at one of the College's galleries in a building that, by coincidence, once housed the Wright Museum. The opening night included guests from both institutions' leadership and key figures from Detroit's policy makers, activists, makers, and artists. The exhibition was covered in the media and there were over 100 public visitors. Each of the makers was asked to prepare an exhibition statement on their work (cited below).[8]

The studio outcomes were varied in approach and scale, ranging from free-standing sculptures to performance props and backdrops, wall hangings, and a record player playing Duke Ellington. Five pieces are foregrounded below, with a brief overview of the other seven.

Among the most talked about pieces was a decolonized chess set (see Figure 2) made by a sophomore illustration student, herself a one-time state age-group chess champion.

The piece explores the notion that colonization is so deeply rooted in society that it goes unrecognized. She deconstructed the traditional European influence of chess to address imbalanced power dynamics and created rules based on a collaborative process that revolves around community, liberation, and humility as opposed to dividing, conquering, and dominating. The chessboard here is circular to reflect the African drum and dance circles. The pawn, which traditionally is the weakest and smallest piece, is recast as the largest to show its potential and importance within the community (Faith Serio, maker statement, 2022).

Figure 2. Faith Serio (2021), *Decolonized Chess Set* [sculpture: Zelkova wood].

The artist was asked to speak at the exhibition opening and detailed how she grew up in a small farm town in up-state Michigan, oblivious to the ingrained colonization more visible in the city:

> This project propelled me to research and learn about African material culture and decolonization. My creative outlook has shifted and allowed me to realize the power in community and how the art that I create has the ability to inspire positive change. (Faith Serio, maker statement, 2022)

Figure 3 shows *Rooted*, a hair pick for African hair, scaled up in size, that speaks to intergenerational connectivity between mothers and daughters and honors the wisdom, creativity, and knowledge of Black women. This piece by Kristian Varano (2022), a photographer and Detroit community member, is dedicated to her daughter: “May your hair grow strong in the roots of Mother Africa.”

Rooted was inspired by the wooden combs of Africa which are used in the rich tradition of hair styling and adornment. This same sentiment is echoed in the rich hair culture of Detroit.

> The **d**.Tree Studio experience allowed me to be seen and heard as I communicated with other aspects of my life that are valuable and vulnerable at the same time. I was successful in utilizing my voice as a Black creator and woman in this work. (Kristian Varano, maker statement, 2022)

When presented at the final critique, Varano was six months pregnant and as she sat and spoke, she unknowingly cradled the work in her arms, as one might cradle a baby. When this was pointed out, it elevated the poignancy of narrative for the audience.

Figure 3. Kristian Varano (2021), *Rooted* [sculpture: Zelkova wood].

The aquatic-like forms of *The Shaping* (Figure 4) are intended create a resemblance to the transatlantic slave trade and Detroit's commerce. Jasmine Brown (2022), a second-year MFA Color and Materials Design student, experimented with the language of tension, weaving with the bark to explore the practice of "healing through the spiritual movement of spoken word and poetic performance of the material." The piece explores how humans emerge from a complex series of historical events shaping language.

> In a world filled with gifts, the Zelkova tree was given to me by The Charles H. Wright Museum of African American History to create a

> relationship between the material, the spiritual, and the living world. I came to listen to the Zelkova tree; we do not share a common tongue [...] With my newfound knowledge of the trees as our ancestors, I grew closer to the material, listening to the snap and crackle of the Zelkova, knowing the tree upheld its divinity because it was entrusted to me. (Jasmine Brown, maker statement, 2022)

Figure 4. Jasmine Brown (2021), *The Shaping* [sculpture: Zelkova wood and bark].

Community member and metalworker Lily Kline's untitled piece (Figure 5) explores the significance of entities that are specific to the region:

> ... fractured bits of a home, perfectly broken infrastructure pulled from the Detroit River, natural materials such as wool yarn, leaves foraged around Belle Isle, and jute, a plant-based fiber that allows the entirety of the plant to be used for food, a form of fuel, and building material. The fragments of what was once a working system demonstrate how capitalism is now failing and the vulnerability of homes, communities, and natural resources. The materials and fragments are intended to demonstrate their power and energy as almost sacred elements. By weaving them together as a form of textile art provides a device for storytelling and historical documenting, and aspects of the natural environment. (Lily Kline, maker statement, 2022)

Figure 5. Lily Kline (2021), *Untitled* [mixed media sculpture: Zelkova wood, reclaimed windows, jute, bronze, leaves].

Other works included Cosmogram/Tesseract by community member and artist Reuben Telushkin. It is a rumination on nonlinear narrative: the syncopation of repeated layers of the same shape until a critical mass of redundancy of layers is achieved, creating "…a viewing experience wherein there is no front or back, no beginning or end, no natural point for the eye to rest" (Telushkin, 2022). What is seen depends on the point of view:

> Because trees are nonlinear storytellers and timekeepers, they assert a circular cosmology of time: death followed by rebirth, endings as beginnings, and output as input. This work was rooted in history and guided by knowledge of what came before: the Sankofa principle-turning back to go forward, closing the loop, the completion of the cycle, handing down the story, and life feeding back into itself. A circular concept of life and time. (Reuben Telushkin, maker statement, 2022)

Time is Cyclical by senior illustration student Kelsey Bailey is a woodblock print using a seven-foot plank from one of the tree trunks with a carved narrative of Detroit's social history. "I was able to connect with the feeling and notion of the ancestors being within the trees, literally carving figures into the wood…" (Bailey, 2022).

Trees Grow on Money by community member and designer DaTrice Clark addresses land injustices in the city using turned wooden vases holding paper flowers made from *Monopoly* money presented on a serving tray:

> My work exhibits how the harvesting of trees disrupts communities, displaces people, and reroutes resources, all for the sake of capitalism. In short, what nature provides for free, man puts a price on and serves it back to us for a fee, hence the serving tray. (DaTrice Clark, maker statement, 2022)

Tree Crankie, created by community member and performance artist Zach Kolodziej, is a tree-shaped *crankie* theater created for a staged public performance at Detroit Cantastoria Fest – *Sing! Of a Tree in Detroit* – recorded for the exhibition. The piece seeks to uplift trees as the site of storytelling and storytellers in their own right. This project is informed by the African indigenous knowledge that the tree is the original historian: "They are the ancestors from which our lives originated, the keepers of sacred knowledge" (Zach Kolodziej, maker statement, 2022).

The Reveal, by community member Leslie Tom, an architect and sustainability leader, focuses on how interior traumas, when exposed, express the exterior identity. Traumas continue to be centered around creating a new Detroit or erasing respect for history. It connects to African material culture by observing and respecting the resonant sound of the African drum and improvisations of African dance, which inspired the piece. "I am forever changed by the trees, as I did not realize how nature holds so many ways to create new, beautiful, meaningful objects" (Leslie Tom, maker statement, 2022).

Reflections as Reminders by senior product design student Olivia Holt considers the lessons the trees tell us. The tree rings show us how the trees survived and adapted when necessary, showing us how to grow stronger in self as life passes on, just as our ancestors before us. "Trees are the first of the living. They have been here since the beginning of time, quietly holding on to the secrets of the world. They tower above us, while watching us walk through life..." (Olivia Holt, maker statement, 2022).

The Sonic Experience by sophomore product design student Francis Bazil was created with the power of music and culture in the diaspora in mind. It is a record player housed in Zelkova wood presented as a modern-day *djembe*, an African drum traditionally carved from a single piece of hardwood.

The Sacred Stick by community member and furniture maker Jason Kehdi was created based upon the African belief that trees are to be revered because our ancestors are in the trees. Such beliefs were labeled as superstitious by Europeans enthralled by a scientific epistemology, but:

> If a child is only taught scientific facts and finds themselves standing before a field of grass they may stomp through the field without a care because their thought is, "It's only grass." However, if a child is taught wondrous stories about spirits and fairies that live amongst the grass, the

> child may be apt to tread lightly through said fields with the thought of protecting the spirits and fairies. (Jason Kehdi, maker statement, 2022)

All of the makers' work and accompanying reflective statements give a rich and diverse set of original perspectives on the past, present, and future. They evidence the power of voice in thematic creative practices and outcomes. Such conversations are unlikely to arise in political or logistical discussions alone, but serve to resonate across disciplines in advancing understanding and change.

Conclusion

The **d**.Tree Studio mission was, and still is, to develop artistic outcomes embodying a narrative that serves to advance discourse on social justice in the City of Detroit. The Wright Museum drives a thematically deep and informed approach to the design and making of artifacts. The collaboration between the museum and CCS provides a hub for new artistic talent to design and craft outcomes that use deep and thoughtful narratives drawn from socio-cultural experiences, aligned to the socio-cultural African American experience in the city.

The **d**.Tree Studio asked: How do we create a space to elevate Detroit and African American experiences while creating a context for critical history, culture, and science as a lens for what the Detroit trees have experienced in the past, present, and future?

The project:

- Advanced a narrative of community arts using Detroit urban trees
- Had a strong focus on community narrative aligned to the mission of the Charles H. Wright Museum of African American History
- Worked at the intersection of community arts, education, culture, and history
- Advanced a narrative of sustainability, inclusivity, space, and change
- Respected listening and diverse storytelling
- Advanced artistic expression and practical woodworking techniques
- Foregrounded cultural place-making and adaptation

The trees have witnessed the changing relationships in the community over time and teach us:

- Respect for people, place, and history
- That objects are not neutral: They have meaning and spirit in time and place

The role of the studio in the climate change space is as one of many cultural and artistic enablers, providing tools for communities. As Sandberg et al. (2015, p. 6) say, the arts and humanities have an important role to play in the political ecology of trees, and so it is the case in the advocacy for climate change and social justice.

The **d**.Tree Studio has been impactful in advancing conversations on trees and sustainability through the arts, culture, and history. It has altered perspectives of practice of the participants (both studio members and its contributors), many of whom have been emboldened to advance their work into new areas.

This work continues today. The **d**.Tree Studio has started planning for a new phase that uses systems thinking and data mapping on trees across the city to inform site-specific narratives and adaptive works made from retrieved urban wood.

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1 See www.witnesstreeproject.org
2 See www.greeningofdetroit.com/
3 See https://urbanwoodnetwork.org/
4 See https://pittsburghurbantree.com/
5 See http://baltimorewoodproject.org/
6 In fact, Detroit had a municipal sawmill on Belle Isle in the late nineteenth and early twentieth century, where the city's felled trees were taken to be processed into usable lumber. The sawmill currently is under restoration for heritage purposes.
7 See www.dtree.me/treeposium
8 Artist statements are available for reference on the **d**.Tree Studio website, www.dtree.me

ΒOIHISȘA-ATA: A MATERIAL PROPOSAL FOR THE TECHNOLOGICAL DEMOCRATIZATION OF MICROBIAL FUEL CELLS IN THE COLOMBIAN CONTEXT

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Abstract
βoihisʂa-ata, meaning "Earth cloak – one" in the Muisca language, is an interactive, connected, and smart composite material that detects electrogenic bacteria living in the soil. It is a do-it-yourself (DIY) material (Rognoli et al., 2015; Rognoli & Ayala-Garcia, 2021) developed through a material tinkering approach (Parisi et al., 2017) by an interdisciplinary team of designers, engineers, and biologists. βoihisʂa-ata's design was guided by principles of The Blue Economy (Pauli, 2010) and linking the project's cultural value to the local Colombian context. These goals led the team to reimagine and democratize the technology of microbial fuel cells (Logan et al., 2006) from a material perspective to spark social innovation. βoihisʂa-ata is valuable because it transforms the relationship between humans and soil by revealing the microbiome, an invisible dimension of soil health (Dunaj et al., 2012).

Typically, to be able to "see" the microbiome, one needs to physically take soil samples to a laboratory, culture the bacteria living inside, genetically sequence the bacterial genomes, and compare them to a database (Nielsen et al., 2002). This gives a very precise, momentary vision of microbial life in the soil, but it needs laboratory equipment in a sterile environment and trained microbiologists to perform the assays, and is costly.

In contrast, βoihisʂa-ata gives a general picture of what is happening in the soil by estimating a subset (electrogenic bacteria) of the bacterial population based on the electrical power the soil is producing (Keego Technologies LLC, 2016). Basic tools such as a sewing needle and wire cutter are needed to make βoihisʂa-ata. It is created by burying one half of the fabric flat in the soil, folding the other half over it, and pressing it into the ground.

βoihisʂa-ata can have a societal impact by providing agency to those who want to measure the health of the soil without complex technologies. Stakeholders can build and use βoihisʂa-ata themselves to achieve greater insight without relying on third-party technology. The proposed form factor is constructed from easily accessible raw materials and manufacturing processes which facilitates βoihisʂa-ata's scalability and advances academic

design principles by merging the DIY materials and interactive, connected, and smart (ICS) materials approaches.

Author Keywords
Interactive, connected, smart materials; ICS materials; do-it-yourself; DIY materials; microbial fuel cells; technological democratization; soil microbiome; social innovation.

Introduction

Microbial Fuel Cells

Microbial fuel cells (MFC) produce electrical power by harvesting electrons from electrogenic bacteria (Logan et al., 2006).

It is possible to harvest electrons from electrogenic bacteria due to their unique biology. Electrogenic bacteria have evolved to live in the absence of oxygen (Koch & Harnisch, 2016). Instead of air, they "breathe" the rocks and metals in the environment around them, specifically iron, sulfates, and nitrates (Barbato et al., 2021). The electrogenic bacteria "breathe" by reducing these compounds, giving them the electrons released from their decomposition of organic matter around them (Logan et al., 2006).

A microbial fuel cell mimics this, giving the bacteria an environment to which they can donate their electrons. The bacteria grow on a conductive structure, called an anode. They give their electrons to the anode and the collected electrons flow to the cathode. At the cathode, the electrons react with an electron acceptor, finishing the reaction. Typically, this means that instead of rocks or metals in the soil, oxygen in the air reacts with the electrons and turns into water (Logan et al., 2006). See Figure 1 for a more detailed, graphical representation of this process.

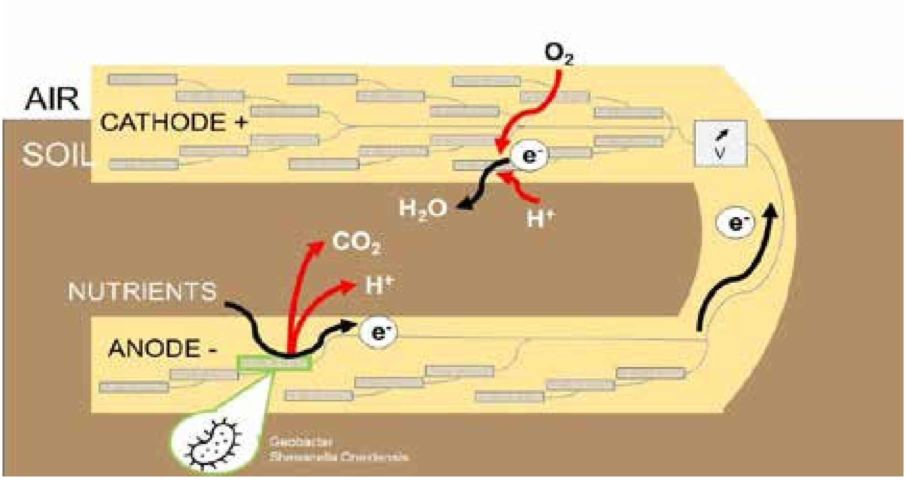

Figure 1. A cross-section view of Ꞵoihisꞩa-ata in the soil, displaying how it functions as a microbial fuel cell. Bacteria such as Geobacter and Shewanella Oneidensis, which naturally occur below the soil surface, grow onto the stainless steel mesh. They break down organic compounds in the soil, such as acetate, into energy, with carbon dioxide, protons,

and electrons as byproducts (Logan et al., 2006). They donate the electrons to the stainless steel mesh (or anode) they grow on top of. The electrons flow through a voltmeter to the cathode which is lying directly on top, parallel to the anode. At the cathode, the electrons combine with atmospheric oxygen and protons to produce water, finishing the reaction.

Electrogenic Bacteria: A Ubiquitous Biosensor

The electrogenic bacteria which grow inside microbial fuel cells are theorized to be present everywhere in the world. There are 94 known species of electrogenic bacteria and they are found in diverse anaerobic environments: buried in sediments at the bottom of oceans and lakes as well as the soils of forests and wetlands (Koch & Harnisch, 2016).

In addition to being widespread, electrogenic bacteria are sensitive to their surroundings. Their metabolic activity will change according to the kinds of compounds present in the soil around them; this change is reflected in the number of electrons gathered by the microbial fuel cell they are living inside (Tront et al., 2008). Therefore, the electrical power generated by the electrogenic bacteria can be used to detect the presence of heavy metals and pollutants (Adekunle et al., 2019; Barbato et al., 2021; Chouler et al., 2018; Deng et al., 2015). With microbial fuel cells, it is possible to read the soil and water through listening to what the electrogenic bacteria are saying, but first we must learn their language.

Interpreting the Language of Electrogenic Bacteria

One way of interpreting what the electrogenic bacteria are saying is by using computers to perform statistical analyses and machine learning to recognize patterns in the data and make predictions (Adekunle et al., 2019; Barbato et al., 2021). While scientific experiments can identify specific compounds in the laboratory, reading the electrogenic bacteria in the natural world quickly becomes difficult due to the number of confounding variables which are difficult to control for. In addition to compounds in the soil or water, the electrogenic bacteria's metabolic rate is affected by pH, temperature, presence of oxygen, moisture, and the amount and type of food around them (Ganjar et al., 2018; Jadhav & Ghangrekar, 2009; Oh et al., 2009).

However, our team theorizes that individuals who are highly attuned to their environment can intuitively account for the changing environmental variables which affect the electrogenic bacteria. The meaning of the signal of the electrogenic bacteria's metabolic activity for the environment can emerge with time as people can begin to incorporate it into the way they see the world. This theory arose through our experimentation with microbial fuel cells. In order to arrive at the right design within which electrogenic bacteria will live, we had to learn how to tie the electrical signal they produce to the different factors of the environment around them. We believe that everyday Colombian citizens can do the same and use their lived experience of the environment to understand what the electrogenic bacteria are saying.

The Colombian Context: Social Innovation Through the Blue Economy

The value of enabling individuals to read the environment through the electrogenic bacteria within it becomes more evident when tied to a local context. In our case, we chose to design specifically for the context we perceived around us in Colombia, focusing on the theme of land and water use, which are intertwined with societal issues as well.

A specific example comes from rice farming. Colombian share-cropping rice farmers are often reliant on fertilizers and pesticides to ensure a harvest which gives them enough profit to continue renting the rights to the land, sometimes focusing on short-term profits rather than the continued fertility of the soil (Hansen, 1983; Leurquin, 1967). The repeated use of fertilizers and pesticides to increase crop yields has led to the depletion of the soil as well as growing contamination from heavy metals found in the fertilizers and pesticides (Gimeno-García et al., 1996; Marrugo-Negrete et al., 2017). The heavy metal contamination compromises local human and environmental health (Tchounwou et al., 2012).

To identify the contamination of heavy metals and demonstrate its link to agricultural practices, scientists take soil samples from the agricultural rice-growing regions and analyze them in laboratories (Marrugo-Negrete et al., 2017). Governmental agricultural agencies and universities are beginning to step into action with programs to investigate reform in rice-growing practices (Bermeo, 2019). However, the share-cropping rice farmers are limited in informing their practices themselves, and likely their troubles with maintaining crop yields will only increase due to climate change: the land suitable for rice farming in Colombia is predicted to decrease by 60% by 2050 due to climate change moving from lower to higher altitudes (Castro-Llanos et al., 2019).

With homemade microbial fuel cells, rice farmers could begin to analyze their fields themselves and link the contamination of the soil and its fertility to the electrogenic bacterial population that the microbial fuel cell reveals. Identifying that the current land use practices will need to adapt for their continued survival, they can inform their approach by listening to what the land has to say. Alternative approaches for sustainable rice agriculture have been proposed, such as incorporating other plant and animal species into the rice field ecosystem, and the importance of cultivating the correct microbial community living around the rice plant root system has also been identified (Ali et al., 2019; Chirinda et al., 2018; Vanegas et al., 2013; Watanabe & Liu, 1992). These kinds of approaches which leverage the resources of the local ecosystem, working together with nature, could be termed the Blue Economy (Pauli, 2010). A similar approach was implemented in Las Gaviotas, Colombia where a water-scarce, inhospitable savannah was transformed into a biodiverse forest with bountiful water by adapting human practices and intentionally cultivating specific native species of plants (Pauli, 2010). Careful, thoughtful human activities informed by the ecosystem can lead to a healthier natural environment and human society (Pauli, 2010).

The model of the Blue Economy in integrating human activities into the local natural ecosystems has already demonstrated success in Colombia through Las Gaviotas, but to replicate it for cases such as rice farmers requires an approach for how individuals can forge an environmental awareness through reading electrogenic bacteria.

Do It Yourself (DIY) and Interactive Connected Smart (ICS) Material Approaches

The design vision of enabling people to begin to read the soil by themselves inspired us to simplify a microbial fuel cell to its extreme by seeing if it can be made into a material. Specifically, we sought to create a do-it-yourself (DIY) material that does not necessarily need to be industrially produced but can be crafted and adapted in its location using local materials and production methods (Rognoli et al., 2015; Rognoli & Ayala-Garcia, 2021). The DIY approach to the creation of the microbial fuel cell carried into our vision of its use. Like its structure, the use of the material should be clear through its dynamic nature: translating aspects of itself to make the electrogenic bacteria's activity visible for interpretation. We therefore classify this material as part of the interactive, connected, smart (ICS) family of materials as well as DIY in order to define its unique properties using a design framework (Parisi et al., 2018).

We used a DIY materials approach in combination with material tinkering to advance the development of the DIY-ICS microbial fuel cell material (Parisi et al., 2017; Rognoli et al., 2021; Rognoli & Ayala-Garcia, 2021). Material tinkering enabled us to use our own personal experiences in making, using, and interpreting the iterative versions of the material to understand how others will be able to do the same and read the environment through the electrogenic bacteria (Parisi et al., 2017).

Transdisciplinary Collaboration
We recognize that a complex project of designing a proposition for everyday Colombian citizens to read the environment through interpreting the material properties of a hand-made material goes far beyond the kind of thinking found in a single discipline. Based on this, we took a systems level, transdisciplinary approach to understand the project and develop it further (Max-Neef, 2005). The success of the project depended on the team members cross-pollinating each other with their disciplines of plant biology, microbiology, material design, interaction design, electrical engineering, economics, and agriculture to form a unique perspective on the project. Each team members' evolving perspective went beyond any domain's traditional expertise; this was necessary to understand the value of the project for the Colombian context.

Method
Finding New Value Through Adapting Project Direction
The project began as an exploration of what value microbial fuel cell technology could hold for the Colombian context through a DIY-ICS material approach. Our belief going into the project was that the value of microbial fuel cells would be the electrical energy they can provide. The initial direction of exploration of this natural energy source was to build a biological computer as a proposal of computation that is inspired by principles of the Blue Economy. However, as the team began to prototype and understand the electrogenic bacteria more, we realized how sensitive they were to their environment. The direction of the project organically transitioned towards deciphering the language of the bacteria, which also aligns more with the intention of the project to create value for the everyday citizens and ecosystem of the Colombian context.

The two-step process we used to develop the design of the microbial fuel cell material prototype is adapted from the DIY-materials approach: (1) tinkering *with* materials and (2) tinkering *for* materials (Rognoli & Ayala-Garcia, 2021).

Phase 1: Tinkering with Materials
In the first phase, tinkering with materials (Rognoli et al., 2021), we explored materials for creating "material drafts" of microbial fuel cells which fit our design vision (Rognoli & Ayala-Garcia, 2021). Through tinkering, we could gain firsthand experience of how the materials and techniques used affected the electrogenic bacteria and how to interpret their signals using the aesthetic language of the dynamic material.

Relating Human and Bacterial Perspectives

We observed and evaluated the material drafts by relating our first-person experience to what the bacteria could be experiencing, trying to empathize with them. In order to explain the absence or presence of electron flow within the microbial fuel cell, we first needed to use our senses to diagnose the material. Through this diagnosis we could begin to understand how the microbial fuel cell's electrical power output responded to its environmental conditions, and then infer the root cause for the phenomenon.

To confirm our theories, we would then experiment with the material drafts, changing different variables to observe how the bacteria responded. The material draft through which we arrived at the conclusion that microbial fuel cells' value is that they can be used to read the soil as opposed to acting as a power source is the material draft of ꞵoihisȿa-ata.

Material Drafts as Experimentational Platforms

ꞵoihisȿa-ata's material draft is a textile of fique onto which an anode and cathode are sewn. The anode and cathode are fine stainless steel mesh coated with a mixture of carbon black and activated carbon using epoxy glue. The anode and cathode have electrical connections of stainless steel thread sewn through the body of the textile; the electrogenic bacteria's voltage can be measured from either side. See Figure 2 for images of the material draft in use.

Figure 2. Step-by-step photographs showing how to place ꞵoihisȿa-ata's material draft into a box of compost soil for testing. Steps from left to right: (1) a hole is dug and the anode is placed inside, (2) the anode is covered with soil, (3) the cathode is placed over it.

Three anecdotal examples of experimentation leading to insights about the electrogenic bacteria using the material draft of ꞵoihisȿa-ata are explained below.

Soil Moisture

We noticed that the microbial fuel cell produced the most power when the soil was soaked with water. The effect was almost immediate. If the soil was dry and water was poured on it, the voltage began to increase. A possible explanation could be that in dry soil, oxygen reaches the electrogenic bacteria at the anode and kills them, while when covered by water, they are insulated from the air (Oh et al., 2009). The electrogenic bacteria could need to be constantly covered by water to continue metabolizing. However, if the cathode was also submerged in water, then the microbial fuel cell voltage would immediately drop to zero. This is not due to the electrogenic bacteria, but because the cathode reacts much more slowly with oxygen to produce water if it is submerged since the concentration of oxygen in water is much lower than that of air (Dissolved Oxygen, 2017).

Soil Compression
We also discovered that the contact between the electrodes and the soil is an important factor by experimenting with pressing the textile loosely or firmly into the soil. The more compressed the textile is into the soil, the more electrical power is produced by the electrogenic bacteria. This is likely because with high compression, the improved contact decreases the internal resistance, allowing the electrogenic bacteria growing on the surface of the stainless steel metal mesh to release their protons more easily and the cathode to react with the protons in the soil faster as well (Abbas et al., 2017).

Soil Type
We also ran an experiment comparing the power outputs of the microbial fuel cells with different kinds of soils. Three kinds of composting soils were compared, with the difference being the composting start date: two years, one year, and six months. The compost soils were produced from a mixture of organic waste from a neighborhood in Bogotá and composted using the “paca digestora silva” method, which relies on anaerobic bacteria to break down organic residue and turn it into soil (Pérez, 2018). However, we did not find any conclusive results from the experiment. To test this, we put three microbial fuel cells in each kind of soil using an “open cell configuration,” meaning there was no resistance between the anode and cathode of each one. See Figure 3 for a photograph of one of the experimental setups.

However, because of the uncontrolled levels of moisture content and compression for each one, the confounding variables’ effect was simply too great to draw conclusions about the soil based on the microbial fuel cell’s voltage. This experiment convinced us that comparing microbial fuel cells in different soils may be too difficult of an intuitive leap to make even with time, and that it is more appropriate to compare a microbial fuel cell’s power output to itself over time. When accounting for environmental variables like temperature change, moisture content, and compression, the electrical power’s change over time could be more accurately correlated to microbial activity changing due to other factors, which could be soil contamination from heavy metals or pollutants (Adekunle et al., 2019; Barbato et al., 2021; Chouler et al., 2018; Deng et al., 2015).

Figure 3. Measuring the electrical power released by the bacteria living on ẞoihisȿa-ata's material draft. The multimeter measures 153.5 mV of a microbial fuel cell in an open cell configuration. An open cell configuration means there is no resistive load connecting the anode and cathode.

Citizen Science

These particular examples outline the method through which a kind of citizen science (Silvertown, 2009) can be practiced. Through rough experimentation and their senses, citizens can learn what electrical power of the microbial fuel cell should correspond to the environmental conditions they can perceive with their senses and intuition. When they come across discrepancies where the microbial fuel cell's voltage does not align with their experience and their mental model of the phenomenon, they can begin to investigate and search for an explanation. If the explanation cannot be immediately answered with their senses and if there are no experts, the explanation may emerge with time.

For example, a rice farmer may notice that a microbial fuel cell that has always produced a high amount of electrical power has begun to drop, and the rice yield for that part of the field has also begun to decrease. A theory can begin to form that the electrogenic bacteria on the microbial fuel cell are giving less of their electrons to the microbial fuel cell, instead donating them to the heavy metals which are in higher concentration around them due to repeated use of fertilizer and pesticides (Adekunle et al., 2019; Gimeno-García et al., 1996; Marrugo-Negrete et al., 2017). Scientists can be invited to perform studies or the rice farmer can also alter their practices, experimenting with alternative forms of fertilizing their fields (Ali et al., 2019; Chirinda et al., 2018; Vanegas et al., 2013; Watanabe & Liu, 1992) and reading its effects on the electrogenic bacterial population by using intuition and careful observation.

Phase 2: Tinkering for Materials

After understanding what the material can say about the environment through the bacteria, if we think it is complete enough to be presented as a proposal and be communicated to others, we synthesize our findings in a material demonstrator (Rognoli & Ayala-Garcia, 2021). Like the material drafts, we constructed the material demonstrator using self-production methods and accessible materials to understand how the process could be replicated and adapted by others.

In our design process, we tinkered with ten material drafts of a microbial fuel cell and tinkered for one material demonstrator, βoihisʂa-ata (see Figure 4).

Results

Figure 4. A photograph of βoihisʂa-ata folded in its exhibition box of soil.

Name
βoihisʂa-ata is the phonetic spelling of "Earth cloak – one" in the Muisca Chibcha language, the language of the indigenous people who originally inhabited the valley that is now Bogotá (Cartwright, 2015; Gómez, 2010). We used the Muisca Chibcha language to name our project because our project seeks to understand the local soil and the people who have the longest history of living with and interpreting it are the Muisca (Cartwright, 2015).

Construction
βoihisʂa-ata is a composite of stainless steel mesh and woven fique textile with dimensions of one meter by two meters. Four-centimeter by eighty-centimeter stainless steel mesh strips are woven through the fique textile using horizontal cuts in the woven textile, forming a herringbone pattern of ten columns twice, one on each half of the textile, creating the anode and the cathode. The stainless steel mesh strips are secured to the fique by sewing the mesh securely using fique fiber. The stainless steel mesh strips are connected electrically

by sewing a stainless steel thread through the fabric. The electrical connections are marked using bright paint so they are easy to find and repair if necessary: orange color indicates the cathode's sewn electrical connections, while bright green highlights the anode's sewn electrical connections. The cathode's electrical connections and anode's electrical connections meet at the modified voltmeter below the cathode (see Figure 5), which indicates its position at the visual nadir of the cathode's herringbone pattern. The voltmeter is a secondhand, modified analog instrument which originally had a range of zero to one hundred V; we changed it to zero to one V by taking it apart and changing the resistor inside. The name of the textile, βoihisʂa-ata, is painted in the left corner.

Use
βoihisʂa-ata is used in the same way as its material draft precursor, as shown in Figures 2 and 3. A shallow hole of less than four centimeters is dug into the soil, into which the anode half of the textile is lowered. The soil is then packed back onto the anode, covering that half of the textile completely. It is important to pack the soil well and even to moisten it to ensure that the anode is covered completely; if it is exposed to oxygen, the electrogenic bacteria will not be able to grow on its metal mesh (Oh et al., 2009). The cathode is then laid over the anode in parallel and also pressed firmly. Either side of the textile may be used as the anode or the cathode; they are identical in function. It is only important to keep the voltmeter on the surface of the ground and not bury it in the soil so that the electrical power of the microbial fuel cell can be interpreted. However, the voltmeter can be detached from the electrical connections and placed on the other side if needed.

The voltmeter has been modified to give an estimate of the bacterial population through the electrical power generated, based on formulas relating electrical power to the number of bacteria, drawn from knowledge of the average number of electrons each bacteria produces (Keego Technologies LLC, 2016). Through the voltmeter, the user can see bacterial activity and read the soil (see Figure 5).

Figure 5. A photograph of ϐoihisʂa-ata's voltmeter which has been adapted to translate the electrical power of the bacteria to display an estimate of their population.

Material Aesthetic Language

To clearly use and interpret ϐoihisʂa-ata to understand the language of the bacteria, we felt it was necessary to create a clear aesthetic language which valorized the materials accessible in the Colombian context of the project.

Our philosophy in constructing the materiality of ϐoihisʂa-ata was to emphasize a harmony between the different material languages we interpreted in the fique, the stainless steel mesh, and the bacteria. The sewing patterns follow the natural grain of the fique textile, while the screen-printed patterns follow the rigid organization of the stainless steel mesh.

With the analog voltmeter that we modified to provide the correct range of zero to one V and display a translation of the voltage found to numbers of bacteria (see figure 5), we wanted to showcase the modifiable, open-source nature of the project. We made it obvious that the voltmeter was modified through crude penmanship with permanent marker. With this, we want to convey the message that ϐoihisʂa-ata is only one interpretation of how a microbial fuel cell can turn into a material and that we encourage adapting this material demonstrator for other contexts and needs. Materials are open for manipulation of their form to explore future possibilities with them (Rognoli & Ayala-Garcia, 2021).

Finally, ϐoihisʂa-ata disassembles itself while in use. Besides the voltmeter, the body of ϐoihisʂa-ata is solely composed of stainless steel and fique so if it is forgotten, the environment around it will not be affected. The fique used will be consumed by mold, mushrooms, and microorganisms within months to years of being installed, leaving behind the metal skeleton which will continue to function better and better with time as more bacterial colonies adhere to the surface of the metal. The metal skeleton will continue to function until the stainless steel threads connecting the meshes eventually corrode, and then the mesh can be used again to be woven into a new supporting structure. In this way, we see the material satisfying the necessities of cradle-to-cradle (Braungart & McDonough, 2009) by reutilizing its parts of natural origin, and thus separating these from the single material of stainless steel attached to a sturdy analog voltmeter.

Material Technical Properties

Physical

βoihisȿa-ata's technical properties are a mix of those of fique and stainless steel. In its length, the material has the property of fique: it can fold itself into four-centimeter widths. In its width, the material has the property of the stainless steel mesh: it is resistant to folding due to the opposition of the stainless steel. Fique burns and as a complex cellulose, it is resistant to staining from natural dyes and soil. Stainless steel melts at high temperatures (1400 to 1530 Celsius), and does not stain (Spira, 2021). βoihisȿa-ata is tough: it is difficult to cut with a knife and, due to the fique textile's sturdy fibers, is resistant to all manner of pulling, throwing, and dropping.

Electrical

The average resistance of each stainless steel mesh panel from origin to voltmeter is in the range of three to five ohms. Because the average power output of the material depends heavily on the soil and the environmental conditions the bacteria is in, these benchmarks still need to be done. But when tested with voltages applied to the anode and cathode, the voltmeter does show the correct voltage; therefore βoihisȿa-ata serves to conduct the electrons emitted by the electrogenic bacteria.

Discussion

DIY-ICS Materials Approach

As a DIY-ICS material, βoihisȿa-ata holds value for informing the DIY materials approach for designing with species (Parisi et al., 2018; Rognoli & Ayala-Garcia, 2021). Our version of material tinkering differs from the original version, which is a continuous conversation between the designer and the material (Parisi et al., 2017; Rognoli et al., 2021). To develop the project, we not only needed to dialogue with the material but also with the bacteria living inside the material. Relating our perspective to the bacteria could present a methodological contribution to adapt the DIY materials approach for projects that involve co-making with more than humans.

Material Aesthetics

The co-making influenced the material aesthetics of the project as well because we needed to consider the needs of both the electrogenic bacteria and the users who will interpret the material. The material aesthetic of the project was also influenced by our search for pairing the project to its Colombian context using principles of the Blue Economy (Pauli, 2010), which led us to experiment with new materials and techniques.

For example, initial prototypes of the textile were explored by thermoforming PVC fabric due to its waterproof and airproof nature, allowing it to retain water for the electrogenic bacteria while keeping air out. However, we quickly decided against using PVC after considering the project's proposed context of use in the countryside to spur social innovation through better understanding the soil, because if forgotten in the environment, the PVC will pose a hazard for the local ecosystem. This spurred us to consider alternative fibers for the textile structure, and fique – known as the national fiber of Colombia (El fique, 2006) – emerged as the ideal candidate due to its biodegradable nature and already widespread use in transporting coffee beans as well as often being woven into textiles and rugs.

The search for pairing the project to the context through sustainability extended to each design choice. A method was designed to coat stainless steel with activated carbon using pine resin dissolved in alcohol as opposed to using epoxy glue, whose production is environmentally damaging (Kumar et al., 2018). A sturdy secondhand analog voltmeter was used instead of a digital one because it is a passive sensor and will not consume energy while also being easily modifiable. Through all of these design choices informed by the context, the project can become integrated into the local culture and more readily integrated into the ecosystem and the human community.

Colombian Context
The following pressing questions are still speculative and remain unanswered by the βoihisʂa-ata proposal:

- Can people really interpret the soil using only the electrical power produced by the electrogenic bacteria inside the microbial fuel cell and the environmental data they can perceive?
- Can rice growers use this information to reform their agricultural practices and move toward a healthier environment and healthier society?

For both questions, we would answer that we are not sure but through further investigation of this proposal in the future, we aim to find out.

However, in our design process we demonstrated that we could relate environmental factors such as soil moisture and soil compression to the electrical power of the microbial fuel cell. Although we could not relate soil quality to the electrical power of the microbial fuel cell, we speculate that in the future this could be possible. By identifying all of the key factors that affect the electrical power of a microbial fuel cell and creating a comprehensive equation to model the relation of these factors to the output power, it would be possible to get a partial picture of what may be going on in the soil just from knowing some of the factors and the electrical power of the microbial fuel cell. An understanding of the soil through listening to the electrogenic bacteria may not come from citizen science alone and will likely require advanced machine learning techniques and scientific expertise to make it a sound practice, but we believe citizens should be allowed to make a start and experiment because their approach and findings can inform the future scientific benchmarking investigations and give them the independence to make sense of their environment.

Wide-scale reform of rice growing practices in Colombia entails more than enabling farmers to become aware of the link between fertilizer use and heavy metal contamination of the ecosystem. But it is one piece in the grander puzzle, as shared with us by Laura Rugeles, one of the leaders in a project between Colombian universities and the government seeking to reform the rice growing practices in the region of Tolima, Colombia (Bermeo, 2019). According to Rugeles, it is difficult to know the condition of the soil without doing slow, costly laboratory tests, and there is a high need for the growers to know the state of the soil, especially its fertility, because this will influence their use of fertilizers (Rugeles, personal communication, November 2021). Therefore, we believe that microbial fuel cells can hold a path towards social innovation and βoihisȿa-ata shows how that may be possible in the Colombian context. Finding the microbial fuel cell use context with the most potential for social innovation will require field studies of βoihisȿa-ata to test how its speculated value compares with the value derived by users across varying situations.

Conclusion

βoihisȿa-ata is presented as a material proposal for reading soil by interpreting how the electrogenic bacteria's production of electrical power relates to environmental factors such as the presence of heavy metals and pollutants. As a DIY-ICS material, βoihisȿa-ata is able to be made by hand with resources and techniques accessible in the agricultural areas of Colombia, its intended context of use. This allows potentially anyone to create βoihisȿa-ata and begin to observe electrogenic bacteria through their production of electricity, making continuous environmental monitoring possible by individuals, independent of universities or institutions with the resources and laboratories typically necessary to understand the soil.

Acknowledgements

We thank Dr. Giovanna Danies and Diego Hernandez for their mentorship and laboratory experiments to cultivate electrogenic bacteria. We also thank the Universidad de los Andes design lab coordinators and technicians' help in using workshop facilities. Finally, we would like to thank the composting community of La Macarena for their donation of soil samples for the investigation as well as Laura Rugeles and Dr. Gabriel Roveda for sharing their expertise in the Colombian rice agriculture economy and the link between plant biology and the soil microbiome.

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A NEIGHBORHOOD-CENTERED DESIGN METHODOLOGY

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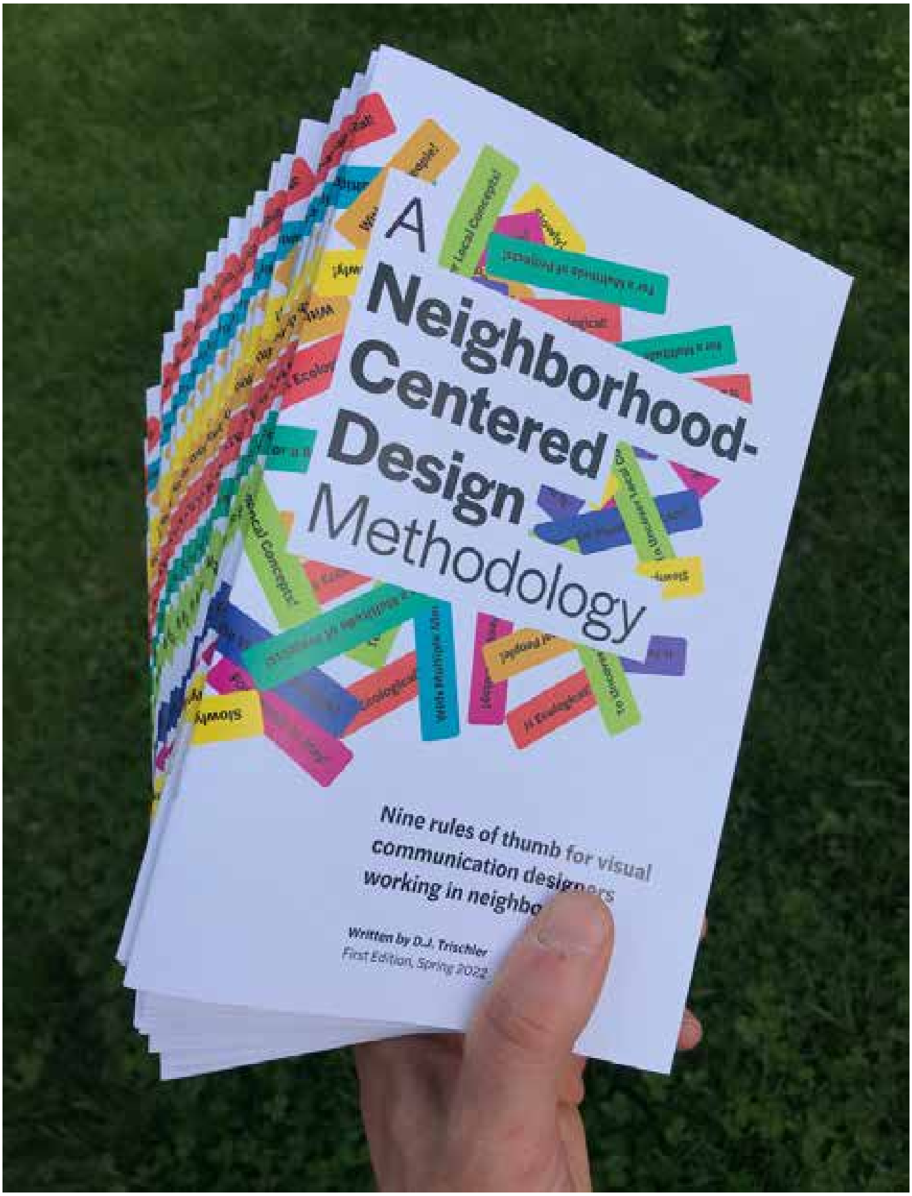

Abstract
Visual communication designers use place branding to enhance the perception of and attachment to neighborhoods. While this can help communities obtain external funding and attention, it can lead to the displacement and separation of residents, which weakens communities in the face of crises, climate or otherwise. These effects are partly due to designers needing more resources. This exploratory study used six ethnographic methods within three neighborhoods of Cincinnati, Ohio, to call attention to the complexity inherent in branding a neighborhood and provide the beginnings of a neighborhood-centered design methodology for designers as they enter these spaces.

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ALLEY ACTIVATION, URBAN ACUPUNCTURE, AND CLIMATE RESILIENCE IN DETROIT

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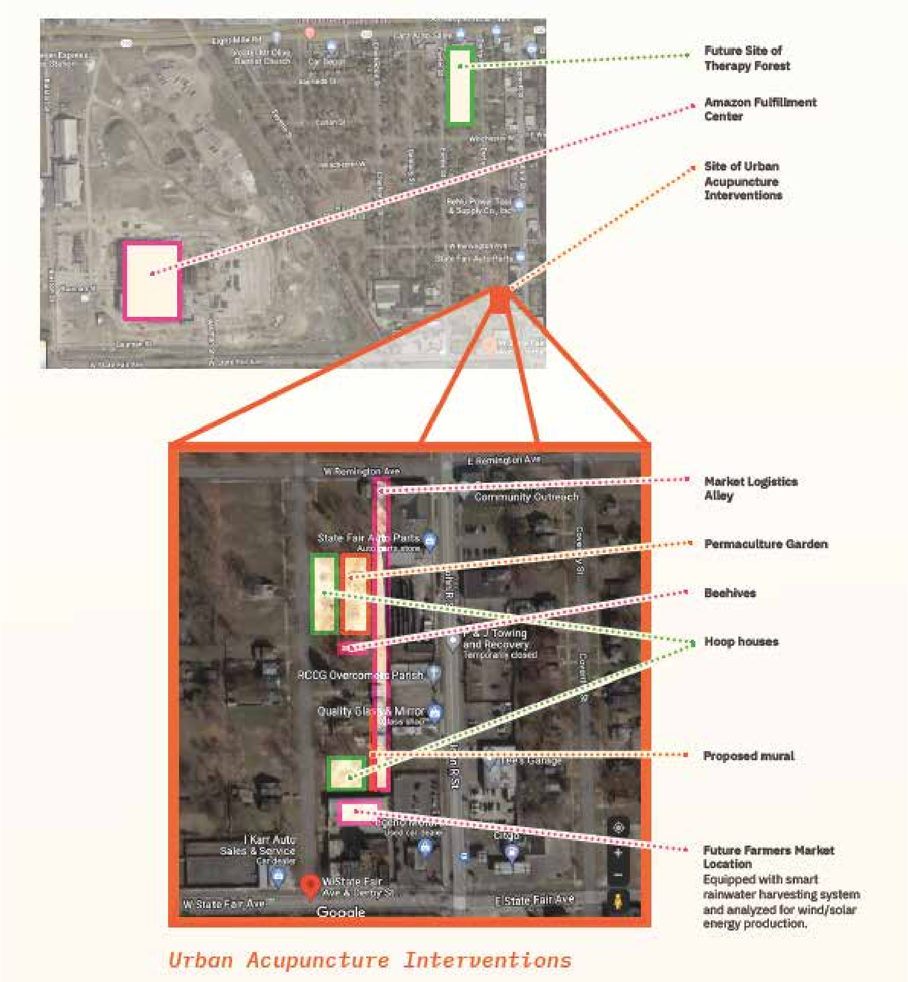

Abstract
Urban acupuncture is an approach to urban design that focuses on hyper-local, community-driven interventions meant to stimulate communities' social, ecological, and economic life to improve overall urban resilience. Given the fiscal constraints in post-industrial cities such as Detroit and Flint, Michigan, this approach emphasizes the use and re-use of existing structures and materials and social and human capital within neighborhoods rather than capital-intensive developments or high-concept designs requiring significant external inputs and expensive ongoing maintenance.

The Derby Street community, located within the Nolan neighborhood in Northeast Detroit, provides an ideal proof-of-concept for this approach due to the presence of a local nonprofit organization (Rescue MI Nature Now) that has already been intensively engaged in revitalizing neglected land and structures. The application of relatively modest investments in soil remediation and landscaping, highly visible public art, and rainwater harvesting technologies to alleys and adjoining lots and structures that were once neglected promise to transform this community's function and identity. The planning process will situate these interventions within the long-term vision for the community, highlighting the potential for future targeted investments and productive partnerships with neighboring businesses, government agencies, and nonprofit foundations seeking to support equity and resilience goals.

This project seeks to demonstrate the capacity of Detroit alleyways to enhance the quality of life and foster climate resilience in neighborhoods disproportionately impacted by histories of racist segregation, ongoing industrial pollution, and accelerating climate change. Detroit's alley network is extensive, encompassing approximately seven thousand individual segments and more than nine million square meters of space. The city recently committed to clearing alleys of debris. Still, without a long-term maintenance strategy, they may be reclaimed by opportunistic vegetation and become magnets for dumping and sites of blight. By enhancing the capacity of alleys and other marginal spaces to sequester carbon and reduce emissions through green cooling, strategically compounding environmental benefits by layering nature-based solutions, formerly forbidding spaces become more attractive to residents as sites of education, recreation, relaxation, or entrepreneurialism, reducing car use.

Our objectives include: 1) nature-based conversion of two alleys to maximize the capacity of the space to absorb and capture carbon and stormwater through plantings, composting, and rainwater harvesting technology; 2) engagement of community residents in each stage of the design and implementation process through both face-to-face and virtual outreach and co-creation activities while building local capacity to carry out alley redesign; 3) evaluation of the results of environmental interventions in ecological and social terms, utilizing a direct measurement of runoff and capture of stormwater and analysis of soil carbon; GIS-based mapping and modeling to project impacts across urban space; and qualitative evaluation of local social impact. The digital poster will lay out the concept of urban acupuncture, present evidence from ongoing interventions in Detroit, and a phased design vision for the short and long-term future.

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DESIGN’S COLONIAL MYTHS: RE-ENVISIONING THE DESIGNER’S ROLE IN ADAPTATION

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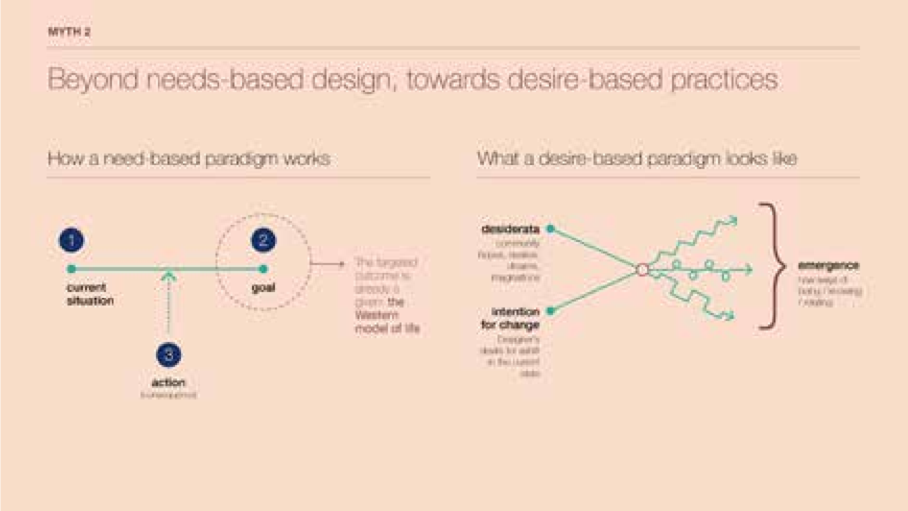

Abstract
“A solution is often a problem’s way of masking its desire for continuity”
- Akomolafe (2018)

Why has design often failed to solve “wicked problems” such as income inequality and climate change? To drive effective change, design practices need to move beyond a focus on better outcomes toward how designers relate to each other and the worlds around them. Designing for adaptation begins with deconstructing the myths (grounded in Western and colonial mindsets) at the core of the designer’s paradigm, moving away from the what and towards the hows and whys.

Drawing on the work of Akomolafe (2017) (post-activism), Barad (2007) (agential realism), and Wilson (2008) (relational accountability), and inspired by our experiences teaching decolonial design research to graduate students, we explore three design myths that reproduce the very problems design is attempting to solve. We propose that design and design education need a new starting point - one that is grounded in relationality, positionality, and non-human agency.

Myth: Designers are central agents in facilitating the development of community solutions. Provocation: The idea of designers as facilitators reproduces violent power dynamics.

What if designers played the role of de-mystifiers? What if designing with communities included non-human agential beings?

Myth: Designers are equipped to unearth our most pressing needs and design the right solutions to move us forward.
Provocation: A need-based design paradigm fails to challenge existing assumptions within our current system. *What if design practices prioritized asking unarticulated questions (over outcomes), exploring hopes and desires (over problems) (Nelson & Harold, 2014) (Tuck, 2009), and embodying different relationships with time (over rapid action)?*

Myth: Designers need to develop unbiased insights to get to the right solutions. Provocation: Design research paradigms continue to exist within a positivist and Western research framework, where subject and object are separate, and data is waiting to be discovered (Escobar, 2018). *What if the designer was an intrinsic part of what constitutes "data"? What if design and research were relational practices where understanding one's positionality was the starting point?*

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RISING

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Abstract
The sea level of New York has risen 9 inches since 1950 due to global carbon emissions, and New York adds to global warming as the third-largest carbon emission city. In 2019, Mayor Bill de Blasio announced the Lower Manhattan Coastal Resiliency Project. At the beginning of 2022, Rutgers professor Jason Barr proposed an expansion of NYC, "New Manhattan," as a single solution to cheaper NYC real estate and increasing issues of global warming-related climate threats. Our team envisions a recent future in New York where protecting the environment becomes a more crucial need for human beings to live. Rising is a collaborative, interactive experience based on real-world environmental crises. Our project includes scientific modeling, interactive installation, and card games. We will

build an installation with an animated projection where New York's dynamic climate data alter visuals. The audience will engage with the projection by using a card game, in which the card will be the input for the installations' sensors. Then, the visual of the installation will change according to the sensor parameters. Through this interaction, we will display to people directly how their daily actions accelerate the melting of icebergs.

The audience has different goals, and they play cards that can either benefit them personally or serve the common good. Individuals' choices build up to a huge factor that will decide the ending of the experience. The main factor for determining the end of the experience is to make visitors realize that collaborations are necessary for saving our environment.

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CLIMATE ECOSYSTEM

A COMPARATIVE STUDY OF SUSTAINABLE DESIGN EDUCATION MODES IN THE CHINESE CONTEXT

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Abstract
Climate risk has been a long-term and deep-standing problem that seriously threatens human survival. Facing the global challenge, the Chinese government has been promoting the socioeconomic transition towards the goal of sustainable development. Given the circumstances, how can design education make changes in sustainability in China? Considering dual challenges from global and local, some Chinese design colleges have been proactive in leading sustainable design education reform. Over a decade, they have shown remarkable achievements in sustainable design education in China.

Aiming to examine the exemplified modes of sustainable design education in China, this paper uses the case study approach. It makes a comparative analysis of four universities in the DESIS-China Network. This study proposes a three-level theoretical framework of "micro-meso-macro," dividing multiple educational practices into three aspects: curriculum arrangement, organization construction, and community building. Furthermore, this paper summarizes some common problems in developing sustainable design education in China. From two perspectives of knowledge – innovation and people cultivation – this study makes suggestions for the future development of sustainable design education in China. It also offers insights into building a multidimensional ecosystem for sustainable design education with diverse collaborative forms of dots, chains, and networks.

Author Keywords
Design education; sustainable design; comparative study; higher education; collaborative network.

Introduction
Climate change is one of the most urgent global challenges and threatens the survival of humankind. The excessive emissions of greenhouse gasses due to human activities caused the ecological crisis, which seriously influenced all aspects of society, such as food security, public health, and economic development. In the face of the common challenges worldwide, the Paris Agreement established a new mechanism for global climate governance, requiring all countries to work together to create climate justice (United Nations, 2015). IPCC (2018) released a report calling for limiting the increase in the global average temperature to 1.5ºC above pre-industrial levels; otherwise, the climate crisis can cause irreversible damage to our planet

Over the years, the Chinese government has been implementing a national strategy of actively responding to climate change and promoting a socioeconomic transition towards the goal of sustainable development (The State Council Information Office of the People's Republic of China [SCIOC], 2021). In pursuit of a transformation from the traditional economic model towards the circular economy, there is a desperate need for us to rebuild our lifestyles through the reform of design education in sustainability.

In the early twenty-first century, the idea of sustainability has not been popularized among the public in China. Ezio Manzini began to visit China and organized workshops on sustainable living in several design colleges, which became the earliest discussion of sustainable design education in domestic design academics (Gong, 2010). In 2009, DESIS-China was formally established as a local organization of the DESIS network. The co-founders are six Chinese universities: Tsinghua University, Hunan University, Jiangnan University, Tongji University, Guangzhou Academy of Fine Arts, and the Hong Kong Polytechnic University. DESIS-China aims to "actively support design initiatives and projects in the field of design for social innovation and sustainability in China" in all areas of society (Manzini et al., 2010). Over the past decade, these design colleges have positively explored multiple ways of sustainable design education and taken a proactive role in leading educational reforms in China. With their efforts, the construction of a design education system in sustainability has preliminarily taken shape, which promotes the growth of sustainable design education in other Chinese universities as well as has an impact on an international scale.

This study aims to examine the exemplified modes of sustainable design education in China. Based on understanding multiple educational practices, this study compares different patterns and interprets innovative ideas. It also attempts to make suggestions for the future development of sustainable design education in China.

Literature Review

Evolution of the Sustainable Design Field

With the growing concern for environmental degradation, many scholars have started to attach great importance to the field of sustainability. In the 1970s, in *Design for the Real World*, Papanek (1971) advocated that design should be socially and ecologically responsible rather than an accomplice in consumerism.

The evolution of the sustainable design field has "expanded from a technical and product-centric focus towards large scale system level changes" (Ceschin & Gaziulusoy, 2016). To be more specific, some early studies focused on recycled material usage (Burall, 1991) and sustainable behavior (Lilley, 2007, 2009). Then the discussion extended to the scope of social systems. From the perspective of design for social innovation, Manzini (2015) noted the importance of informing living systems with sustainable qualities. John Thackara (2017) considered reconnecting urban and rural ecosystems through design.

Among the academic leaders in China, some scholars have made theoretical and practical innovations in the field of sustainable design. Leong and Tong (2009) asserted that sustainable design could allow the remodeling of Chinese food and transportation systems. Liu (2010) outlined the evolution of sustainable design concepts and enriched the methodology of sustainable design from the perspective of systemic design

(Liu & Vrenna, 2021). Gong (2011) explored sustainable lifestyles through product-service system design in the context of social innovation. Lou (2018a) proposed the Four Systems theory to encourage the agenda of sustainable social interaction design within hybrid communities.

Global Challenges of Sustainable Design Education

Facing complex socio-technical systems, design education in the twenty-first century must change (Norman & Klemmer, 2014). In particular, problems of sustainability are inherently uncertain as a kind of wicked problem (Rittel & Webber, 1973), which requires designers to develop comprehensive capabilities and interdisciplinary perspectives. Ken Friedman (2002) pointed out four types of challenges for design education: performance, systemic, contextual, and global. In response to the global challenge, Friedman (2002) emphasized that designers should have a global vision and make an effort to achieve the Sustainable Development Goals (SDGs) (United Nations, 2015).

Local Difficulties of Sustainable Design Education in China

In addition to global challenges, Chinese design education is confronted with local difficulties. In the process of modernization, handicraft cultures failed to transform smoothly into urban cultures within the industrial civilization. Born in arts and crafts, Chinese modern design education has had a tradition of overemphasizing the high standards of craftsmanship and ignoring the increasing needs of industrialization, which makes it difficult to provide solutions for the new problems with mass production (Hang, 2009). In this way, there has been a disconnect between theoretical research and practical demands in design education. Also, since the reform and opening-up in the late 1970s, the accelerated transformation of the Chinese economy has generated an urgent need for innovation in design education modes.

However, current studies mainly illustrate predominantly Western modes of sustainable design education, and there is little attention on Eastern countries. Notably, there is a limitation in conducting a systemic analysis of Chinese sustainable education modes in both global and local contexts.

Given the status quo, this paper proposes a research question: how could sustainable design education make changes in response to the demand for social and economic transition in China? First, this study provides a theoretical framework for analyzing sustainable design education. This study then reviews educational practices and compares different modes by selecting four representative design colleges in DESIS-China. Finally, this paper explains common problems and makes suggestions for the future development of sustainable design education in China in aspects of disciplinary structure, organizational collaboration, and industrial transformation.

Methodology

This study uses the case study approach, including multiple qualitative research methods, to collect information from four universities from DESIS-China members: Jiangnan University, Tsinghua University, Hunan University, and Tongji University. This study conducted in-depth interviews with teachers from these four schools and combined insights from relevant documents. The respondents are all experienced in educating,

researching, and practicing in the field of sustainable design.
The study presents a theoretical framework to conduct a comparative analysis of these cases. As Friedman (2002) stated, universities have four main goals: knowledge preserving, knowledge creation, specialist training, and citizen education. From the perspective of ecological systems theory (Bronfenbrenner, 1979; Zastrow et al., 2010), multi-level interactions exist between the individual and the environment, especially at micro, meso, and macro levels. Within the realm of sustainable design education, these three levels correspond respectively to practical activities of curriculum arrangement, organization structure, and community building. This study integrates these two theories into a framework (Figure 1) to illustrate the educational practices of four design colleges at three levels and identify characteristics of different modes.

Results

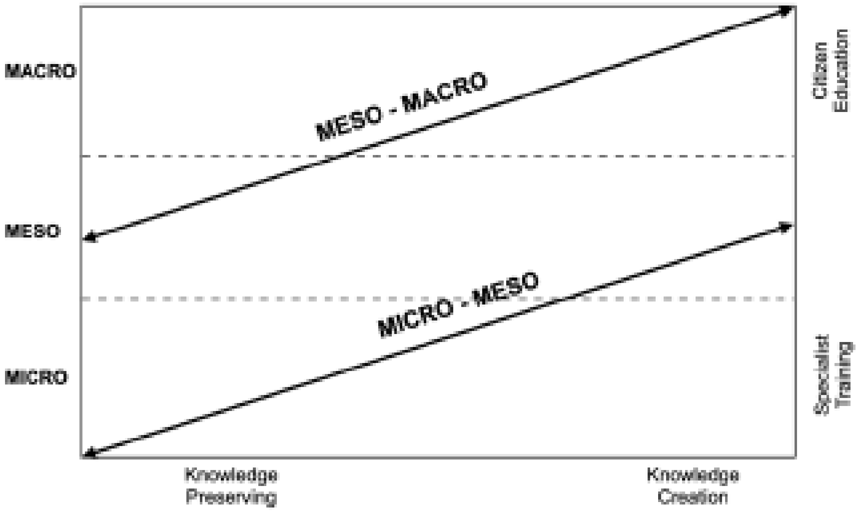

Figure 1. A theoretical framework for sustainable design education.

This part gives a detailed description of the findings. Based on the theoretical framework, this paper analyzes different practices of each case and makes a comparison of the ideas behind at three levels as follows:

- Curriculum arrangement at the micro level
- Organization structure at the meso level
- Community building at the macro level

At the Micro Level: Curriculum Arrangement
Curriculum arrangement is acknowledged to be part of the primary content in constructing an educational system. To understand curriculum arrangement at the micro level, this study investigates many aspects in detail. One part is about the topics and methods of the courses; the other is about the directions and challenges of educational reform.

There has not yet been any sustainability-specific course in Jiangnan University. In contrast, the relevant courses in both undergraduate and graduate programs have been infused with the ideas of sustainability in recent years. For example, in the industrial design program, the content of sustainability design is mainly taught in the product-service system design courses. In the environmental design program, a course called *Ethnic Art Investigation and Design Innovation* intends to build awareness of protecting intangible cultural heritages and explore sustainable ways to promote their development. As for the topics, Jiangnan University puts sustainable design education within the context of the whole society and explores complex social issues such as traffic, energy, and urban, rural, and traditional heritages.

The Academy of Arts and Design at Tsinghua University provides a general course of introduction to sustainable design for the whole university. Meanwhile, relevant specialized courses are offered in industrial design and environmental design programs. The topic selections of the methods are usually grounded in the real problems of the industrial environment and community living. In addition to this, the planning of a course can be divided into two parts: the first half is mainly about teaching basic theories and historical evolution in the field of sustainability in the method of lecture; the second half cultivates the practical abilities of students in the method of field study. Additionally, the problem-based learning method is used throughout the design process to encourage students to find the problem for an actual situation and explore possible solutions. With the emphasis on fostering the awareness of sustainability and systems thinking, teachers usually spend little time in class training specific tool usage. Instead, self-learning is highly encouraged after class, especially for the skill of life cycle assessment (LCA). The university offers an excellent experimental environment, and students can get access to databases to accomplish assessments. Moreover, suppose any student has a personal interest in further exploration. In that case, teachers will offer support through one-to-one or small group tutorials to supplement necessary knowledge within the specific problematic situation.

For the past few years, Hunan University carried out structural reform in the curriculum in response to the national strategic need to build new engineering and technical disciplines. In the industrial design program, the module system of studio courses was reframed and divided into six studios, including smart equipment, smart mobility, smart health, data intelligence and service design, sustainable and ecological design, and digital cultural innovation. After entering the third year of their undergraduate program, students can choose one studio course according to individual interests and career planning; this choice could produce a lasting effect on the graduation design projects in the fourth year (Hunan University, 2021). On the one hand, the module system incorporates the previously scattered sustainable design courses into a coherent system, allowing students to receive more intensive training while focusing on sustainable issues. On the other hand, the new system requires a higher standard of team allocation and personal abilities in teaching. A specific teaching team prepares each module's teaching content and course forms, where the teachers need to actively collaborate with others from different academic backgrounds to equip students with cross-disciplinary knowledge and skills. Yet the practice of taking sustainable design as a specific module also brings a new challenge of ensuring adequate linkages between modules to prevent each module from becoming a separate silo.

Compared to other colleges, the College of Design and Innovation (D&I) at Tongji University more thoroughly breaks through the disciplinary barriers. Sustainable concepts are closely bonded with the subject features of each educational program, allowing the curriculum arrangement to be more flexible. In particular, the sustainable design course offered by the environmental design program considers the interactive relationship between humans and environments; some studio courses in the industrial design program explore diverse applications of recycled materials; even the master program of design history and theory has courses focusing on relevant content such as a study of sustainable business models in service design cases. These courses usually begin by encouraging students to have a firsthand experience of life, and then stimulate deeper thinking of the phenomenon and raise the awareness of sustainable lifestyles in the design process. Additionally, reform of the curriculum brought opportunities for students to select courses from other disciplines, which means that the structure of students in a class could cover a range of various majors so that they can also learn from each other in close teamwork. With sustainable design concepts merged into the whole process, the course methods could include but are not limited to lectures, workshops, field research, and case studies. The core of the curriculum is to develop a cross-field vision and global thinking for students. Specifically, for different stages of design education, D&I builds a 3D T-shaped educational framework to arrange courses within the undergraduate-master-PhD higher education system (Lou & Ma, 2014), which helps to progressively cultivate all kinds of talents.

Overall, all four colleges take sustainable awareness as one of the basic qualities of designers and highlight the training of systems thinking and comprehensive abilities. To develop cross-disciplinary knowledge literacy and critical thinking about social problems, the courses usually introduce various social topics, including food, fashion, housing, traffic, and aging. In the process, multiple educational methods are used to arouse learning interest and induce creativity.

But there are still many challenges in the process of curriculum reforms. One of the challenges is how to deal with the relationship between sustainability-specific courses and general design courses. There are two trends: one is to take sustainable design as a primary value merged into general design courses; the other is to offer specialized courses to intensively teach professional knowledge and skills in sustainable design. Furthermore, it is difficult to build adequate connections between academic research and industrial demands though some teachers are equipped with this kind of consciousness when determining curriculum topics. There are still worries that some conceptual outcomes of sustainable design education fail to be translated into practices.

At the Meso Level: Organization Construction

Barnard (1968) defined a formal organization as "that kind of cooperation among men that is conscious, deliberate and purposeful." The organization construction of a design college concerns the construction of cooperation. At the organizational level, the teaching teams responsible for sustainable design education show various structural characteristics expressed in diverse collaborative forms, from informal to formal, including cross-disciplinary, cross-college, and cross-school collaborations. As Schein (2010) argued, organizational cultures reflect "a pattern of basic assumptions" and influence both the organizations' tangible components and underlying values. The organizational cultures of design colleges infiltrate different degrees of collaborative relations subtly.

D&I at Tongji University recognizes sustainability as part of the organizational culture and has embedded it in most program objectives. Under the guidance of the college mission, D&I contributes to cultivating innovative talents for sustainable development and organizes an array of activities for teaching and researching. At the same time, the programs' goals correspond to the design college's overall mission. For instance, the environmental design program aims to facilitate an ecosystem of life and space with human-centered design thinking and cross-disciplinary methods.

The cultural atmosphere of sustainability could also impact the development of sustainable design education. These four design colleges all have horizontal collaborations with other colleges at their university. In particular, there are several university-level research institutes at Tsinghua University for cross-disciplinary research about sustainable development. Tongji University and the United Nations co-founded the UNEP-Tongji Institute of Environment for Sustainable Development (IESD) to promote sustainable development in the higher education context and establish a new type of international education (IESD, n.d.). Also, the School of Design of Jiangnan University works together with another preponderant discipline via the School of Food and Technology to study future issues. In addition, there are an increasing number of organizational units inside design colleges to support the educational activities of sustainable design, such as the Eco-Design Research Institute at Tsinghua University, the SustainX Lab at Tongji University, and the DESIS lab at Jiangnan University. These units serve as platforms for interactions between teaching and researching.

Under the influence of some key academic leaders, a greater diversity of collaboration forms to a deeper degree have sped up the academic influence's diffusion from regional to international. Liu from Tsinghua devoted himself to building the network of LeNS-China, which is part of LeNS, an international learning network on sustainability. Since 2010, Jiangnan University has hosted the DESIS International Symposium annually to provide an academic exchange platform for domestic and foreign experts. The themes over the years have witnessed the advancement in Chinese sustainable design education (Table 1). Lou from Tongji facilitated the alliance of the two organizations of Cumulus and DESIS, which promoted the sharing of academic resources in the field of sustainable design in the worldwide community of design education (Lou, 2011).

Different design colleges have formed different organizational cultures, given their historical origins. To improve the organization structure, one challenge is to break with the conventional organizational culture by understanding the distinctiveness of the design college. The design college ought to incorporate the concept of sustainability into the organization's overall values to lead innovative practices of teaching and researching.

Another challenge lies in constructing an interdisciplinary team for sustainable design education. There is a lack of in-depth involvement across the stages of educational practices. There have been some emerging forms of organizational cooperation at the college-level and university-level, but a stable and mature mechanism has not yet been formed. Design colleges are likely to temporarily invite researchers from other disciplines to give lectures or lead workshops. However, there is an extreme absence of participants from different disciplines in crucial educational stages, such as course development and teaching evaluation.

	Year	Theme
1	2010	Social Innovation and Local Development
2	2011	Transformation Design for Public
3	2012	Service Design and Social Innovation
4	2013	The Chinese View of Sustainable Qualities
5	2014	Digital Social Innovation
6	2015	Shaping Research Questions in Design Thinking: Identifying, Validating, and Distilling
7	2016	In Action
8	2017	Design Framework: Sustainable Creativity of Design
9	2018	Social Innovation and Design Opportunities
10	2019	Design 2030: Next Innovations for the Planet
11	2020	Interdisciplinary Dialogue on the Systemic Design of "Rural Revitalization"
12	2021	Pluriversal Cultures and Common Crisis

Table 1. Themes of the DESIS International Symposium.

The development of sustainable design education is subject to multidisciplinary cooperation. It requires teachers to absorb new knowledge spontaneously and constantly in the collaborative process. More than that, it depends on design colleges and universities to assist teachers in improving abilities from the management perspective. To open up more possibilities of cooperation, ranging from formal to informal, colleges must build a platform for sharing knowledge and exchanging experience.

At the Macro Level: Community Building

At the macro level, community building in the social context is the key content of exploring innovation in sustainable design education. The role of universities has changed over the past few decades. Bok (1982) noted that universities should step out of the ivory tower and take social responsibilities in addition to performing basic functions of academic research. Mavin and Bryans (2000) stated that universities must be prepared for the rapidly changing conditions of contemporary society and function as community resources.

Some design researchers have realized the risk of over-reliance on the typical global manufacturing model. With economic and technological development in society today, Ezio Manzini (2015) reconsidered the culture of "small and beautiful" and proposed an alternative lifestyle called "The SLOC scenario" – standing for small, local, open, and connected – to produce a new vision on how to form a sustainable networked society. He believed that the SLOC scenario could function as a powerful social attractor to catalyze social actors and guide innovative activities.

Many Chinese design colleges have started to explore the possibilities of engaging in social issues with local communities and seeking to make changes on a larger scale. The project of NICE2035 initiated by D&I is a typical design-driven and community-supported experiment for social innovation. This project allowed Tongji University to have a knowledge spillover effect on the local communities and co-create sustainable life-styles in the future with the residents. Instead of discussing concepts inside an enclosed environment, both teachers and students walked off campus to have encounters with social reality. In this way, the university worked as an open center of co-creation and recognized the community as a future living lab to stimulate the potential of productivity in urban life (Lou, 2018b).

In addition, the Eco-Design Research Institute of Tsinghua University worked together with local residents to complete the Fangxingyuan community garden design project, which successfully transformed a wasteland into a multi-functional space. The project integrated participatory design principles into the whole design process. In the process, the designers developed a toolkit of participatory design to prompt the willingness of residents to participate and help enhance their design abilities (Eco-Design Research Institute, n.d.).

These design colleges have contributed to social innovation by incubating creative communities. First, by reconsidering their roles in social development, some design colleges actively participate in the process of social innovation. The space where design education activities take place has expanded beyond the university instead of being limited to the classrooms. Functioning as open co-creation centers to stimulate the creativity and vitality of the entire society, some colleges incubate innovative ideas for enabling sustainable life-styles. Second, these universities actively implement design practices to improve the living environment and shape good relationships in the neighborhood. Taking sustainability as the basic value, designers use the methods of participatory design and co-design to encourage residents to participate in the design process, which is significant for fostering public awareness of sustainability and stimulating the creativity and productivity of the city. In turn, these practical experiences could enrich sustainable design methodology and advance a paradigm shift in design disciplines.

Nevertheless, the exploration of sustainable design education at the macro level is still in its infancy. First of all, to meet the complexity and dynamics of problematic situations, designers must consider multiple factors such as culture, economy, and policy and constantly adjust methods and strategies in the design process. As Donald Schon (1984) put forward in the theory of reflective practice, people must keep thinking about what they are doing while they are doing it. While moving from theory to practice, designers must address specific problems, which means that they must know how to adapt design strategies while applying design theories to concrete practices. There are usually goal conflicts among multiple participants in the process of co-design. Therefore, to establish a networked community of creativity, universities face the challenge of coordinating the co-creation work among multi-stakeholders, including industry, government, and the public.

Discussion

The review of the educational practices of the four colleges indicates multiple modes of sustainable design education in China which have achieved innovative results at different micro, meso, and macro levels. First, in terms of curriculum arrangement at the micro level, the design colleges have reformed relevant courses to meet the demand for economic sustainability and national higher education policies. The selection of course topics is dependent on social issues ranging from personal life to industrial needs. By using flexible forms of the courses, the students are offered basic sustainability concepts and encouraged to learn by doing. Besides, some design colleges take seriously the need to provide students with a collaborative learning environment to accumulate interdisciplinary knowledge and experience. Although different design colleges perform differently on whether it is necessary to have specialized courses in sustainable design, they all attach importance to sustainable awareness cultivation as a fundamental design value. Also, it is imperative to develop critical thinking and global visions for students through discovering problems in a specific situation.

Second, in terms of organization construction at the meso level, different colleges have formed different organizational cultures and behavioral characteristics due to their histories. Under the guidance of the college mission, the concept of sustainability permeates the organizational behaviors to various degrees, which influences specific teaching and research activities. Among them, the establishment of diverse forms of cooperation is the key. Relying on the whole atmosphere of the universities, design schools have formed a variety of organizational units, from informal to formal, which carry out cross-disciplinary, cross-college, and cross-university cooperation. In particular, there is a trend for the scale of organizational alliance between institutions to grow from regional to global, providing a broader platform for academic exchanges and experience sharing among domestic and foreign scholars. By exploiting the potential of diversified organizational cooperation, Chinese design colleges have contributed to sustainable design education worldwide.

Third, in terms of community building at the macro level, some design colleges have begun to commit to social responsibilities and seek to play an active role in social innovation. From inside the campus to the public, teachers and students enter and have encounters with local communities. By empowering residents with the methods and principles of participatory design and co-design, more residents are motivated to participate in the design process. In co-creating future lifestyles with industry, government, and the public, universities incubate creative communities to activate the city, so that the changes can continue and bring lasting benefits.

Sustainable design as a discipline branch has not yet formed a mature system. To promote its theoretical innovation, it is necessary to reexamine its discipline orientation, research objects, and research paradigms. Although sustainability is acknowledged as a fundamental design value, there is still a significant gap in the methods and principles of sustainable design. Further trials about the methodology integration of general design, including system design, co-design, participatory design, and sustainable concepts, could be required in the next step.

Significantly, the ambiguity in the field of sustainable design sets higher requirements on the knowledge and abilities of educators. Thus, some new questions have been raised about how educators could benefit from organizational cooperation on a broader scale. Yet it is important to note that since Chinese sustainable design education has unique historical origins and cultural traditions, educators cannot copy Western patterns indiscriminately. The ancient Chinese ecological philosophy is deeply rooted in the modern Chinese concept of sustainability, but it has not gained enough attention from the educators of sustainable design.

Entering the post-industrial society, theoretical knowledge has become the source of innovation and the basis for formulating social policies (Bell, 1976). However, design colleges' involvement in social innovation is still in the early stages in China. Therefore, another challenge is how to move from specialist cultivation to public education to improve the sustainable awareness of the whole society. Currently, there exist many problems in the context of Chinese industry, such as the unreasonable industrial structure and weak ecological awareness. To achieve structural upgradation, people must recognize the contradiction between the dominant mass production model and the collaborative distributed economic system. Given that joint efforts of multiple stakeholders are essential for sustainable socio-economic transformation, educators need to reflect carefully on how universities can serve as a hub for knowledge innovation and a bridge for the co-creation of stakeholders, including the government, enterprises, and the public in future.

Conclusion

This paper compares practices in sustainable design education from four design colleges in China and reveals multiple modes in this area. Furthermore, it summarizes the existing problems from both global and local in the process of developing sustainable design education. Given the current situation, this study makes several suggestions for the future development of sustainable design education in China. First of all, in terms of disciplinary structure, more attention should be paid to discipline orientation to cope with the relationship between general design and sustainable design. A reasonable approach to tackle this issue is to integrate sustainability concepts into introductory courses, where educators need to teach basic concepts in sustainability and foster students' systems thinking and global visions to deal with sustainability problems in the complex social reality.

Secondly, in terms of organizational cooperation, design colleges should deeply embed sustainability into the organizational culture, which could help establish flexible forms of cooperation and facilitate interdisciplinary communication. The universities ought to create a sustainable cultural atmosphere to encourage more possibilities for collaboration. Also, relevant institutions need to build academic alliances and offer platforms for knowledge sharing on a larger scale.

Thirdly, in terms of industrial transformation, design colleges should take the initiative to engage in social change and shift the role of design from catering to market demands to leading industrial innovation. Despite prolonged efforts required in the transition process, design colleges must show future alternatives of new lifestyles to the public and activate creative communities to co-create a better future.

Finally, aiming at the two perspectives of people cultivation and knowledge innovation, this paper argues that a multi-dimensional ecosystem of sustainable design education should be constructed to generate diverse collaborative forms from dots and chains to networks (Figure 2). For the evolution of the educational ecosystem, it is essential to establish a collaborative mechanism from expert decision-making towards public participation and a knowledge network from local communities to global associations.

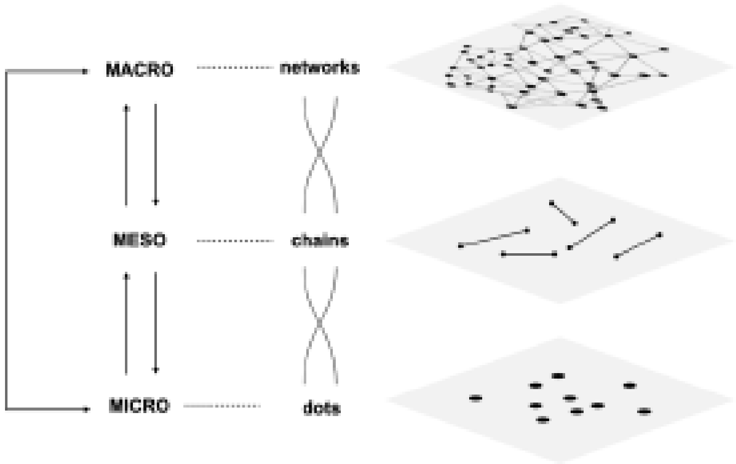

Figure 2. A multi-dimensional collaborative network for sustainable design education.

A limitation of the study is in the scope of case selections which only covers four design colleges in China. Also, it may omit some critical information in specific educational practices. In the next step, the author will continue to focus on the problems of sustainable design education in a wider range.

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RELATIONAL DESIGN FOR SUSTAINABILITY IN U.S. SUBURBS

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Abstract
United States suburbs are often stereotyped for their ecologically invasive and socially inequitable design due to many factors, including redlining, urban renewal, auto-oriented development, and exclusionary single-family zoning (Hayden, 2003; Jackson, 1985; Rothstein, 2017). Entire suburban neighborhoods and strip malls are built on greenfield sites that were once thriving indigenous ecosystems (Nassaur, 1997). Sprawling neighborhoods can be built and decline within a single generation. This pattern of disposable suburban design has proliferated the landscape where, today, the majority of people in the U.S. reside (U.S. Census, 2020).

Policymakers and urban planners are advancing "new urbanist" interventions to combat the impacts of sprawl (Duany et al., 2000). Suburbia is being retrofitted through densification efforts, multi-modal transit options, and mixed-use developments (Williamson & Dunham-Jones, 2009). But the speed of traditional sprawl is outpacing sustainability agendas, and the question of sustainability in suburbia lacks an acknowledgment of the many systemic inequities beyond the built environment that also impact suburbia's sustainability. At the same time, suburban population growth continues to significantly outpace urban growth in the U.S. Not only are suburbs where most U.S. residents live, but they are also increasingly the most socioeconomically, culturally, ethnically, and racially diverse places in the U.S. (Frey, 2018; Lacy, 2016). Suburbs are emerging as complex middlegrounds and misunderstood places where the debate on sustainability may be won or lost (Bosch & Polzin, 2022; Lung-Amam, 2017). As people flock to suburban areas for more affordable housing options, designing sustainable suburbs becomes imperative.

In this article we explore the national conversation around suburban sustainability concerns, illuminating specific local actions in U.S. suburbs that leverage their decentralized design and increase sustainability. We believe that designers from diverse areas of the field can play a significant role in stewarding sustainability agendas in suburbs. We offer ideas for how designers can better facilitate relational, community-led change, while bringing their essential skills to bear on these often forgotten and misunderstood places.

Author Keywords
Suburbs; relational design; transition design; new urbanism; community organizing; sustainability.

Introduction

The design profession at large has typically held an elitist view towards suburbs and more often concerned itself with urban and cosmopolitan environments (Adamson, 2018; Jackon, 1985). However, suburban landscapes are where the majority of life takes place in the U.S. and where a debate on sustainability is growing (Daniels, 2021; June & Williamson, 2021). Without more invested interest and growing affection for this ubiquitous American landscape, suburbs lack the design interventions and transdisciplinary networks that can design, pollinate, and organize for more sustainable futures. This paper addresses the question of ecological sustainability in suburbs and urges designers of systems-level change to develop an interest in and understanding of the complex challenges and opportunities that suburbs present.

Figure 1. A stereotypical sprawling suburb in Levittown, Pennsylvania, ca. 1959. (https://commons.wikimedia.org/wiki/File:LevittownPA.jpg)

Often, suburbia in the United States is represented through a birdseye image of a sprawling single-family tract home landscape (Figure 1). However, this abstraction minimizes the idiosyncratic reality of those who inhabit the place. In pursuing living futures, it is imperative to wrestle with the complexity of any seemingly single issue – and sustainability is not an isolated issue (Aronoff et al., 2019; Rittle & Weber, 1973). The major issues of our time which include social justice and climate change meet head-on in America's middle grounds – the suburbs.

In the first section, we provide a brief history of the causes and conditions of the proliferation of suburbs in the U.S. With this context, we outline the key current day challenges to advancing sustainability in U.S. suburbs. We then offer examples of various approaches and interventions from suburbs across the U.S. that are addressing these challenges. Finally, we implore designers of systems level change who have lived experience and connections to suburbs to bring their designerly skills to bear in these contexts. We then offer ideas for how to develop their capacity to build networks for local change to proliferate and be stewarded over time.

A (Very) Brief History of U.S. Suburbs

"[s]uburbia was not designed with climate change, sustainability, or resilience in mind" (Williamson & Dunham-Jones, 2020, p. 70).

Suburbs are an immediate outcome of cities and date back historically just as far (Jackson, 1985). It is important to recognize this history because, though synonymous with the American Dream, suburbs are not a uniquely American phenomenon (Jackson, 1985; Vaughn, 2015). Though today they are the predominant place context in the U.S., it has taken several waves of suburbanization to achieve this status. Suburbs are misunderstood places that are ripe for sustainable design intervention and stewardship. Understanding the history of U.S. suburbanization provides more context for designers wishing to engage with complex change.

In the early 1900s, cities like Pittsburgh had such terrible air quality that daytime was often indiscernible from night (American Institute of Planners, 1939). Congestion, pollution, and public health issues in cities were some of the many driving factors that led to the proliferation of suburbs in America (Hayden, 2003; Jackson, 1985). As early as 1945, suburbanization was subsidized and marketed to white nuclear family households, and a pattern of privileged relocation continued over the decades (Hayden, 2003; Rothstein, 2017). Dolores Hayden (2003), a prolific suburban scholar, details the suburban history that has been predominantly shaped by profit-driven developers. Hayden's historical account details that 'building in the borderlands began around 1820. Picturesque enclaves started around 1850 and streetcar build-outs around 1870. Mail-order and self-built suburbs arrived in 1900. Mass-produced, urban-scale "sitcom" suburbs appeared around 1940. Edge nodes coalesced around 1960. Rural fringes intensified around 1980' (Hayden, 2013 p.4).

The nineteen sixties, seventies, and eighties brought waves of suburbanization often attributed to "white-flight" (Boustan, 2010; Rothstein, 2017). Urban planners and policymakers developed racist policies in the form of redlining and urban renewal that gutted urban tax bases while preventing non-white movement to suburbs (Boustan, 2010; Rothstein, 2017). Congested interstates and highway expansions were built through mostly poor neighborhoods (Rothstein, 2017). A powerful example of suburbanization's intent is modeled in the Levittown development on Long Island, where hundreds of identical single-family homes with green water-intensive lawns sprawled out without a single community space. Black families were barred from buying homes in Levittown and in most suburban developments across the U.S. (Rothstein, 2017).

Many protested the proliferation of suburbia. Jane Jacobs (1962) was an open critic: "Suburbs are perfectly valid places to want to live, … but they are inherently parasitic, economically and socially, too, because they live off the answers found in cities." Urban historian Lewis Mumford (1921) surmised, "Suburbia – the vast and aimless drift of human beings, spreading in every direction … demonstrates the incapacity of our civilization to foster concrete ways and means for living well" (p. 44). But it was perhaps Rachel Carson's *Silent Spring*, published in 1962, that brought awareness to the environmental consequences of America's growth at any cost. Carson (1962) articulated, "The question is whether any civilization can wage relentless war on life without destroying itself, and without losing the right to be called civilized" (p. 99). *Silent Spring* investigated this "war on life" by detailing the impacts of using DDT pesticides on local flora and fauna as well as on human health. The prolific use of DDT resulted in killing off large swaths of native species, with the most noticeable being birds. Suburban "homemakers" reporting on the devastating changes to their environments motivated Carson to write *Silent Spring.* In turn, *Silent Spring* helped to spur the environmental movement in the U.S. (Daniels, 2021). As much as suburbs and the auto-dependance they represent are arguably a major contributor to climate change, suburban inhabitants can be credited with energizing the environmental movement in the U.S. (Seller, 2015). However, the white affluent suburban enclave typically drives policy decisions that favor environmental issues over social equity. Today, the NIMBY (Not In My Backyard) movement, composed of mostly affluent home-owners, restricts more affordable development – often in the name of environmental protection (Dougherty, 2022).

Suburbs, perhaps somewhat unintentionally, have changed over the decades. The racist history of the past is being confronted by demographic and political changes. The urgency of climate change and a severe housing crisis necessitates more rapid changes to predominant patterns of the past. Today, U.S. suburbs are some of the most diverse places in the U.S. The question of sustainability and suburbia rests on how to balance the middle-class dream of homeownership that suburbia affords with disrupting the unsustainable culture of consumerism and convenience that is built into that affordability. In the section that follows, we pick up on the main sustainability challenges in U.S. suburbs today while highlighting opportunities and examples of how to design for sustainability in suburbs.

Sustainable Suburbia: Challenges and Opportunities

Cities Versus Suburbs

As the impacts of climate change become more urgent, the role of both suburban landscapes and behaviors in shifting course becomes more critical. Scholars and activists have documented the negative environmental impacts of suburban sprawl (Figure 2), including increased emissions and air pollution due to the dependency on cars, a loss of natural habitat and biodiversity, increases in impervious surfaces such as concrete leading to water pollution, and more (Daniels, 2021; Williamson & Dunham-Jones, 2020). This list of environmental consequences has given suburbs a reputation for being unsustainable and environmentally harmful. In reaction to this vilification of suburbs, the density of cities has been heralded as the antidote to sprawl, resulting in a robust body of academic and professional literature focused on cities and sustainability (Daniels, 2021; Kotkin, 2022).

Figure 2. Preserved prairie land butted up against suburban development in Aurora, Colorado (Dorn, 2022).

As a result, the recent call to make suburbia more sustainable centered on making suburbs more like cities, especially in terms of density (Glock, 2022; Daniels, 2021). These so-called new urbanist agendas have posed a threat to many suburban homeowners who prefer lower-density living at the exclusion of often lower-income households (Dougherty, 2022). Regarding environmental impact, lower density developments like suburbs have been deemed to have greater consequences in terms of greenhouse gas emissions (Daniels, 2020; Norman et al., 2006). However, a comprehensive review of densification effects by Pont et al. (2021) finds conflicting evidence of the merits of density in terms of sustainability. A greater body of research is needed to assess opportunities for leveraging the polycentrality of suburbs for sustainability.

In discussing sustainability in the context of U.S. suburbs, we adopt a definition of sustainability by the U.S. Environmental Protection Agency (EPA), since many planning policies are impacted by environmental standards set by this office. The EPA (2021) acknowledges sustainability as a pursuit in which "everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment" coupled with action to "create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations."

Furthermore, this work recognizes the need for sustainable practices to be designed into a wide cross-section of disciplines in order to effect change. Transportation and mobility, economic justice, housing affordability, ecological conservation, green technology, and more are intersecting issues that need to be addressed simultaneously through extensive discussion, participation, and innovation. It is imperative that designers of systems-level change take part in this conversation, understand the main sustainability concerns regarding suburbs, and ultimately help bring sustainable design interventions to bear. What lies ahead is an outline of the key areas of concern and opportunity regarding suburbs and ecological sustainability.

Major Sustainability Themes

Social Equity

Sustainability advocates have traditionally focused on environmental outcomes and have underestimated the impact of social inequity on sustainability (Daniels, 2020, p. 227). However, these agendas are highly interdependent (Glover et al., 2008). Achieving social equity is essential to resilient and sustainable communities, and equity is a cross-cutting issue that must be considered within each area of concern. Historically, environmental efforts have prioritized white communities over historically Black and brown communities. For example, the inequitable pattern of developing affordable housing near environmental hazards such as waste transfer plants and highway expansions through lower-income communities (Currie & Sorensen, 2018). The result of designing suburbs for an increasingly smaller middle class in America is showing. Issues that had been previously seen as solely pertaining to cities, such as poverty and houselessness, have now become more visible in suburbs. Poverty is in fact growing in the suburbs with a 55% increase between 2000 and 2018 (Frey, 2018). It is critical that designers bring a primacy to social equity while advancing sustainability agendas. This paper promotes liberatory sustainability design practices that are led by communities who have experienced environmental impacts within their own suburban communities.

Zoning and Growth Boundary Policies

The suburban landscape has been built upon single-family zoning policies, which are enacted to reduce density by restricting mixed-used and multi-family developments (Rothstein, 2017; Williamson & Dunham-Jones, 2021). However, the U.S. is in a severe housing crisis with a shortage estimated at up to five million units (Schuetz, 2022). A wicked problem persists wherein municipal services are unable to continue servicing low-slung developments without growing their tax bases with further sprawl (Mahron, 2021). Without addressing exclusionary zoning policies, a trend of suburban ecologically invasive sprawl and low density, auto-oriented development proliferates the suburban landscape, which is environmentally and financially unsustainable (Dougherty, 2022). A movement known as YIMBY (Yes In My Backyard) argues that addressing inequitable zoning policies will lead to more environmentally sustainable outcomes (Yimbytown, 2022).

Rezoning suburbs for what is known as "inclusionary zoning" can address sustainability and equity issues in suburbs. In their book *Case Studies on Retrofitting Suburbia*, Joan Williamson and Ellen Dunham-Jones (2021) lay out many of the challenges and opportunities for making suburbia more sustainable. While existing unsustainable suburbs can be retrofitted, new suburban development can and must disrupt the status quo to be more sustainable. However, many will argue that rezoning for more density will destroy the perceived benefits of suburbs, including more open space compared to cities. On the other hand, researchers have found that as the millennial generation is beginning to re-embrace suburbia, they desire more walkability and mixed-use surroundings

(Schwieterman, 2018). Several U.S. suburbs such as Carmel, Indiana and Frisco, Texas are already adapting to address these concerns and meet these preferences (Making Cities Liveable, 2022). Political movements are addressing these contentious issues by bypassing local control and passing statewide inclusionary zoning mandates in states like California and Oregon (Schuetz, 2022; Nolan, 2022).

Transportation and Mobility
For many Americans, imagining the end of the world might be easier than imagining the end of the car. Disrupting car dependency in suburbs is critical to confronting climate change. Completely eliminating car dependence is extremely unlikely; however, giving people more transportation options can help to reduce carbon emissions and improve physical and social health (Litman, 2017). Electric vehicles are one solution to reducing carbon emissions, but they do not address other externalities associated with car dependence, such as decreased physical activity. More critically, vehicle collisions are one of the leading causes of death in America (Centers for Disease Control and Prevention).

At a minimum, sustainability-focused urban planners will advocate for transit-oriented development that equitably serves suburban residents while releasing fewer emissions (Ibraeva et al., 2020). For example, organizations like Move Redmond (2022) advocate for better walking, biking, and transit in Redmond, a suburb of Seattle. Breaking a misguided culture of individual convenience at all costs while incentivizing alternatives that create a new infrastructure for more sustainable convenience is critical to addressing climate change. Increasing the number of organizations and coalitions who are designing interventions to reduce car dependence in suburbs is a significant leverage point for change.

Ecological Conservation
Sustainability also hinges on ecological conservation and preserving biodiversity in suburban environments. Suburban sprawl offers open space to its human inhabitants at the cost of consuming native ecosystems and reducing biodiversity (Hinners, 2019). For example, native prairie grasses once cultivated by prairie dogs – a keystone species – in Colorado are replaced with water-intensive Kentucky bluegrass (Plains Conservation Center, 2022). The loss of habitat for prairie dogs results in a ripple effect through the native ecosystem, leading to lower biodiversity and a reduction in ecosystem services. Incentivizing less sprawl through changes in zoning policies and encouraging landscaping that preserves and promotes native habitats are two of the biggest areas for sustainable impact on suburbs (Figure 3).

Fortunately, there are proofs of concept that suburbs can design for and replenish native biodiversity. Landscape Architect Joan Nassauer's (2009) work offers strategies to leverage the social behaviors of neighbors to increase the use of ecologically innovative landscaping in suburbs. Nassuaur's (2009) research shows that suburban residents are not as committed to their grass as previously thought. In fact, most residents simply need to see another neighbor convert their lawn from grass to native plants for them to be able to imagine it, and do so for themselves. In that sense, designing for sustainable use of open space that creates a domino effect through social norms can create more sustainable suburbs.

Figure 3. City of Aurora, Native-Scaping Project (https://www.auroragov.org/residents/water/landscaping).

Built Environment and Green Infrastructure
Available housing quality and affordability are critical issues facing all American cities. Suburbs have been a key to social mobility for many people in the U.S. and are needed to sustain a middle class (Klotkin, 2020). However, suburbs are also falling prone to deteriorating housing stock because of low-quality building materials and lack of homeowner maintenance (Mahron, 2022). Due to the history of rapid and repetitive suburban development, the negative impacts of aging infrastructure are not dispersed over time, making suburbs less resilient. Similar to the effects of monoculture patterns in agriculture, this results in large swaths of suburban landscapes deteriorating simultaneously, impacting the environmental and financial sustainability of a place. Additionally, the lack of innovation within the construction industry in the twenty-first century has led to oversized and under-occupied homes proliferating in the suburban landscape (RMI, 2022).

Improving the sustainability of suburbs through the built environment can be achieved through advances in both policy and technology. Through policy, suburbs can continue to infill and zone for multi-family and additional dwelling units, leading to the growth of multi-generational and cohousing living arrangements. This shift is already occurring, as intergenerational cohousing in suburbs has increased in recent years due to housing costs and the increase in immigrant communities in suburbs (Lung-Amam, 2017). Local activist Ean Tafoya (2022) from Green Latinos in Colorado observes how homes originally designed for single-family households have grown to include sometimes two and three generations that often share cars as well. Additionally, technological innovations in construction of net zero homes are helping to chip away at the unsustainable status quo in suburbs, though there is still work to be done to move beyond conventional heating and cooling (Urban Land Institute, 2022). Because of inclusionary zoning policies, green building companies like Green Canopy are creating prefabricated, middle-income, multi-family homes on sites formerly zoned single family (Green Canopy Node, 2022). Land trusts are popping up to preserve mobile home housing stock (Lab et al., 2022). These innovative uses of policy and technology should inspire future policy making and technological advances.

In this section we described some of the main concerns related to sustainability in suburbs. We discussed several sustainability interventions that have been prescribed by suburban researchers, companies, policymakers, and designers. They have been synthesized for a design audience, who – with increased understanding about the significant role of suburbs – can factor suburban opportunities and challenges into their design work. We argue that there is a need for sustainable design interventions for suburbs by a diverse array of designers.

Relational Design for Sustainability in Suburbs

Design, as a diverse profession, has moved from being primarily aesthetic and object-oriented to aspiring to design for systems-level change and transition design (Irwin et al., 2016). Increasingly, designers seek to design in ways that more deeply involve those who are impacted by the very systems that design aims to repair, improve, or transform (Carey et al., 2022; Costanza-Chock, 2020). However, sustainable design has skewed towards an elitism that is often uninterested in suburban contexts (Adamson, 2013; Jackson, 1985). This is true across many fields of research: suburbs are under-studied (Lacy, 2016). As sustainability challenges mount, wicked problems (Rittel & Weber, 1974) in suburbs require the attention of diverse designers of systems level change. In this section, we offer ideas, some gathered from the field of community organizing, for how designers aiming for more sustainable and equitable futures can embody a relational approach. We urge designers interested in sustainable and systemic design to approach suburbs with an understanding of their dynamism and potential. Finally, this paper asserts that design prioritizing long-term relationships and network-building can increase local participation and stewardship, broaden and diversify interventions, and ensure more co-accountability and adaptation.

What has been designed, in turn, creates a design ecosystem within which we go forth designing (Simon, 1988). Designers involved in sustainability transitions now often practice from an understanding that everything is connected and interdependent (Irwin et al., 2016). Given that the majority of people in the U.S. live in suburbs, and that most of these suburbs were designed before climate change became the urgent issue it is today (Williamson & Dunham-Jones, 2021), it is imperative to design for a diverse ecosystem of sustainable interventions (Irwin, 2015). By designing relationally, designers can ensure that power in design decisions is shared amongst those whose lives will benefit from the changes sought. Relationality can be understood as ancient knowledge of an innate human characteristic causing us to be fundamentally interdependent, even when we do not recognize this understanding (Escobar, 2018). In contrast, Cartesian-style thinking has resulted in an operating paradigm in which we become individual units, rarely considering our actions at the level of a community (Scary, 2011). As designers begin to embody a deeper understanding of relationality and interdependence for mutual benefit, then they will develop greater skill by which to co-design liberatory systems (Friere, 1970). In this pursuit of co-liberation, designers can play a significant role in designing networks for transdisciplinary action in suburbs where a culture of individualism has been dominant.

Sustainable interventions must often be stewarded from those who live in impacted contexts. Therefore, designers must grow a capacity for relationality as a precursor to design actions (Dorn, 2019; Escobar, 2018). Outdated design practices would have encouraged designers to be the primary facilitators of change as opposed to designing for others to lead change (Costanza-Chock, 2020; Manzini, 2015). However, design thinking has proliferated nearly every industry and sector as a tool for human-centered and innovative changemaking (brown, 2009). Even beyond the pursuit of empathy building – a core step in design thinking – relational and liberatory practices are being uplifted by scholars such as adrienne maree brown (2017), Arturo Escobar (2018), and Sascha Constanza-Chock (2020), among many others.

A key principle in community organizing involves a relationships-first orientation (Alinsky, 1968), one that we urge designers aimed at sustainable systems-level change to adopt. The simple diagram (Figure 4) is a revised version of an iconic poster, "Don't Panic, Organize" (Lionni, n.d.) that promotes the notion of community organizing. The image prompts designers to shift from an empathy co-design stance towards an organizing relational approach. According to community organizing principles, no matter how big the problem, it is always something that can be overcome as the result of collective action and a large number of small actions (Alinsky, 1989; Ganz, 2009; Schumacher, 1989). Community organizing holds knowledge about power that has often been left out of design education, but is essential for a good design ethic today (Aye, 2017; Costanza-Chock, 2020). Power in community organizing is understood to be the ability to act and to make others act (Alinsky, 1989; Feire, 1970). For designers to adopt relational approaches, longer-term commitments to places and projects become important (Dorn, 2019). Relationship-first ethics promote designers to be facilitators of networks of embedded actors who can steward change. In this way, designers can be capacity builders for local networks, and they can also become embedded in a place such as a U.S. suburb.

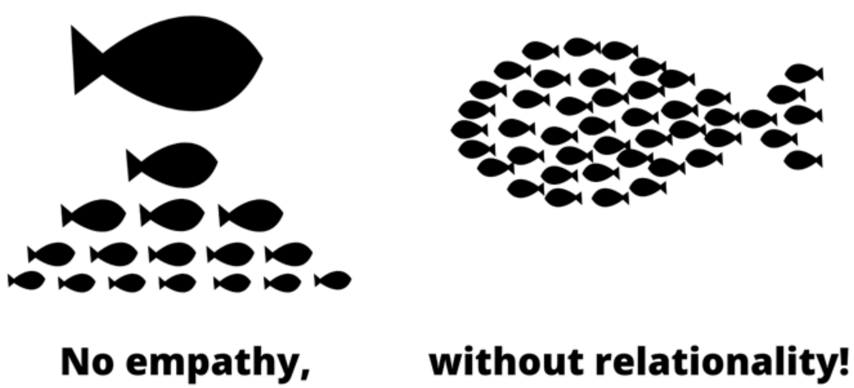

Figure 4. What design can learn from community organizing (Dorn, 2022).

Networked change then also becomes emergent and unpredictable (brown, 2018). Shifting power involves building relationships through a number of configurations, including one-on-one and small and large groups (Ganz, 2019). Organizations such as Suburb Futures exist to facilitate these types of networks in the context of U.S. suburbs. Suburb Futures

(2022) is a transition design project that "works relationally to bring about more equitable and living futures in U.S. suburbs." It does so through facilitating events and programs that bring together participants from differentiated fields that otherwise rarely intersect. These events and programs aim to 1) build a diverse community of transdisciplinary leaders, 2) build more nuanced understanding and narratives about U.S. suburbs, and 3) co-design policy solutions. Rather than offer a limited scope design process, Suburb Futures (2022) highlights how design projects can be fully embedded within a context in ways that commit to stewarding change along with a network of actors over longer time horizons (Carey et al., 2022; Dorn, 2022). Through this example, we offer designers aimed at sustainable futures encouragement to act as weavers and pollinators of knowledge between localities.

Our current condition of a warming planet is by design, but what we have designed can be redesigned (Klein, 2014; Bridle, 2018). However, no single designer can produce the change needed to create more sustainable futures. Change will be a result of a large number of small, often place-based interventions that are stewarded by local actors over time (Schumacher, 1978). In the context of the suburb, it is essential to bring together networks of transdisciplinary leaders who can work together to motivate action and sustain lasting change. Sustainable futures require that we bring intentionality to the design of a more adaptable, equitable, and lovable version of the suburban landscape. Answering the Cumulus 2022 call, here we offer inroads for designers of systems-level sustainable change to become allies and stewards for sustainability in suburbs. We encourage designers to become relational network-builders who help to motivate and sustain adaptive sustainable design interventions in U.S. suburbs.

Conclusion: U.S. Suburbs, Where the Future Goes to Audition

Suburbs are the most commonplace context in the U.S. More than 52% of people residing in the U.S. are located in suburbs (U.S. Census, 2020). Despite their significance, they remain locked in stereotypes as "ticky tacky boxes," and their dynamism is misunderstood (Kolson, 2019; Reynolds, 1962). Increasingly they are becoming home to some of the highest levels of racial and ethnic diversity in the U.S. (Frey, 2020). At the same time, unsustainable design and development runs rampant in suburbs. In this paper, we argue that designers of systems-level change are needed in the suburban context. We prompt designers to turn their affectionate gazes towards the U.S. suburb and to connect or reconnect to a sense of possibility in stewarding more living futures within this context. Very few residents of the U.S. are untethered in some way to the suburbs. We believe that systemic designers are needed to play a role in stewarding more sustainable futures in ways that are inclusive of all lived contexts in the U.S., especially the ubiquitous suburban one.

In the sections above, we outlined some of the key issues relating to suburbs and sustainability. These include: social equity, zoning and growth boundary policies, transportation and mobility, ecological conservation, and built environments and green infrastructure. We then offer a relational approach for systemic design that we believe can steward more lasting change from within the suburban context. We argue that design-led systemic change is too often approached from outside the lived experience or context and that to ensure equitable and lasting change, sustainability must be brought about from within the suburban context.

We also offered examples of interventions being stewarded by local leaders in suburbs. In doing so, we are encouraging designers to be relationship builders with local leaders in suburbs who are close to stewarding the change by which they are impacted. We encourage designers to bring designerly skills offered through design justice, transition design, and others to then facilitate transdisciplinary actors who can work together to create change (Costanza-Chock, 2020; Irwin, 2015).

As places, suburbs are defined by their relationships to cities. Their name explicitly denotes them as “sub” urban, which today has connotations of being less than – fewer desirable places to live, less loved, and less studied (Bourne, 1996). Up close, they are habitats, just as are rural and urban environments, for a complex human and more-than-human world. Suburbs, like any place, require affection if they are to survive. Our intention in offering this paper is to encourage a design audience to envision and invest in the potential of U.S. suburbs to be places of social and ecological justice. We urge designers with suburban connections to bring their skills to bear through a relational practice that promotes community-led change. Sustainable suburbs promote a sustainable planet.

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BARRIERS AND CAPABILITIES FOR EMBEDDING A STRATEGIC DESIGN FOR SUSTAINABILITY APPROACH IN ORGANISATION

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Abstract
Manufacturing companies play a key role in climate change. Through their use of resources and their activities, they release tonnes of greenhouse gases daily (McKibben, 2012). However, they also have the opportunity to be part of the solution to this problem by incentivising virtuous behaviour and changing themselves (Seelos & Mair, 2005). This can only happen through the introduction of a sustainable culture within the daily practices of all corporate figures, especially in decision-making and design processes (Faludi et al., 2020; Mosca et al., 2015). Strategic design for sustainability (SDfS) is closely linked to both and is capable of supporting practices and principles to enable the desired change (Manzini & Vezzoli, 2003; Gallego et al., 2020).

To successfully implement a SDfS approach within an organisation, it is important to understand what the barriers are that prevent its integration and what the typical capabilities of strategic design and sustainability are that need to be implemented to overcome them. Through collaboration with an Italian company in the corrugated packaging sector, it was possible to conduct observations and six semi-structured interviews with company figures involved in the design and managerial decision-making process. By triangulating the data (Denzin & Lincoln, 2005) with the literature, it was possible to identify eight barriers and ten soft skills and capabilities necessary to overcome them.

The analysis of the results shows that within the SDfS approach, capabilities such as multidisciplinary collaboration, communication, and negotiation are fundamental for company improvement and play a primary role in overcoming five out of eight barriers. Only through dialogue and collaborative learning it is possible to work together to tackle climate change and act for sustainability (Galimberti, 1994; Johnson et al., 2000). Systemic thinking and future thinking are common to both strategic design and sustainability because of the need to look holistically at different aspects and stakeholders' interests but also to envision and achieve desirable futures (Hess et al., 2015; Zurlo, 2022). Finally, skills such as data interpretation and visualisation can be seen as serving others by helping in the clarification and transmission of concepts and knowledge (Buhl et al., 2019; Papile et al., 2020).

Author Keywords
Strategic design; sustainability; design in organisation; barriers; capabilities.

Introduction

The role of the manufacturing industry in climate change is already well known. The first signs of this relationship can be traced back to the first industrial revolution and the beginning of the massive use of fossil fuels to support production (Perrow & Pulver, 2015). Through the direct release of substances into the environment or through the indirect encouragement of inappropriate behaviour, organisations are one of the main contributors to carbon pollution and greenhouse gases (McKibben, 2012). Firms are also social actors endowed with will, agency, and the capacity to influence the political, legal, social, cultural, and informal environment using the three powers defined by Levy and Egan (1998): the structural, the instrumental, and the discursive. The first – structural power – refers to the ability of firms to sustain economic growth; instrumental power refers to the ability to influence policy; and finally, discursive power is related to the ability to influence and direct public opinion (Perrow & Pulver, 2015). Signs of these powers can be seen in the development of the E.U. Emission Trading Scheme and in the food industry where companies respectively use their instrumental and discursive power (Betz & Sato, 2006; Boasson & Wettestad, 2013; Environmental Protection Agency, 2008).

However, it must be recognised that companies can be part of the solution to the problem by improving themselves and cooperating with states and society (IPCC, 2007) by making good use of the powers previously listed. Perrow and Pulver (2015) mention five possible actions that companies can take to improve emissions, namely: awareness-raising actions, disclosure of information on emissions, sustainable investments, development of new eco-friendly products, and finally, the implementation of an appropriate organisational structure. Although these actions may seem straightforward, not all companies manage to implement them. They proceed at different speeds, and even though the leading organisations have caught up in recent years, some are still lagging in the ecological transition. Furthermore, over the last 50 years, there has been a progressive understanding of how climate change can be addressed, leading companies from end-of-pipe solutions to systemic and integrated initiatives (Adams et al., 2016; Brezet, 1997). However, if we hope to succeed in the global challenge we are facing, not only do all companies need to be able to adapt and improve in the shortest time, but it is important that sustainability concepts also penetrate the daily actions of all the individuals inside an organisation. Sustainability must therefore be seen as part of the corporate culture and as a competence, implementing what is already present (Pulver, 2007) and being integrated into both managerial decision-making and design processes (Berkhout et al., 2006; Faludi et al., 2020; Lowe & Harris, 1998; Waage, 2007).

Design has a double link with both strategic corporate decisions and sustainability. About the latter, while at the dawn of the ecological movements this link was only present in product design, expressing itself in design philosophies such as eco-design, in recent years this relationship has strengthened (Ceschin & Gaziulusoy, 2016; Kim et al., 2020). Indeed, the focus of design has broadened by moving toward product-service systems, business models, and even corporate strategies (Baldassarre et al., 2020; Ceschin & Gaziulusoy, 2016). Strategic design encompasses a bit of all this, designing and promoting integrated systems and influencing a company's strategic decision-making process with its principles, tools, and methods (Calabretta et al., 2016; Manzini & Vezzoli, 2003). Strategic design(er) has the ability to design and influence the company's relationships with stakeholders, producing a long-term impact and managing complex situations with diverse interests at play (Calabretta et al., 2016; Gallego et al., 2020; Zurlo, 2010).

As Manzini and Vezzoli already recognised in 2003, the skills and knowledge typical of strategic design can be put to work for sustainability and implemented within the corporate culture, leading to an improvement for companies towards emissions and sustainability in general. The integration of this approach and this mindset within a company is not an easy task, as firms try to resist change, leaning towards a state of enduring comfort with what is familiar and fearing the unknown (Gharajedaghi, 2006). To simplify and foster integration, it is necessary to know what the entry barriers are, but also to understand what the skills and knowledge of strategic design(er) for sustainability are that can be transferred through targeted actions. Therefore, this research aims to answer the following questions: Which barriers hamper the integration of a strategic design for sustainability approach into an organisation? Which unique capabilities of strategic design and sustainability need to be implemented to overcome these barriers?

Through collaboration with an Italian company in the corrugated packaging sector, it was possible to conduct observations of bad and best practices and six semi-structured interviews with company figures involved in the design and managerial decision-making process. By triangulating the data (Denzin & Lincoln, 2005) with the literature, it was possible to identify eight barriers and ten soft skills and capabilities necessary to overcome them.

The article is therefore divided into five main parts. First, a background section clarifies what strategic design means and its link to sustainability. This is followed by the methodology, indicating how the research was conducted. Then the results where the barriers and capabilities emerged are described. Finally, we present a discussion of where further elements necessary for the inclusion of SDfS and the importance of certain capabilities are indicated. The conclusions at the end briefly show the remarks, limitations, and future perspectives of this research.

Background

As mentioned earlier, design has undergone a strong evolution in recent decades, moving away from the most familiar applications such as the design of physical or graphic artefacts. This shift has led design culture to evolve and mature, pushing it towards cross-fertilisation with other disciplines. Strategic design moves its first steps from such a hybridisation, from the meeting of design culture and business culture (Zurlo, 2007). In its early days, this was seen as a cohesive approach, capable of linking the product to the brand image, creating a unique system of corporate identity. Following this school of thought, Mauri defined strategic design in 1996 as a design activity "whose object is the integrated set of products, services and communication (product system) with which a company presents itself on the market, positions itself in society and shapes its strategy." Over time, this conception has evolved, leading strategic design(er) to increasingly interface with and influence the future decisions and directions of companies to achieve specific strategic results (Meroni, 2008). Indeed, Zurlo (1999) defines it as

> that project activity that is involved in the formulation and development of corporate strategy. [...] It is an activity that generally interfaces with management (i.e. with those who decide on strategy) and is carried out in a group through the synergy of interdisciplinary skills. And it is an activity that makes sense if contextualised within a business context. Strategic design can therefore fall within the more general framework of the relationship between design and business strategy.

Through the inclusion of the design elements within management and strategy, Manzini and Vezzoli (2003) highlight the possibility of strategic design to reconfigure the role of the company, customers, and stakeholders by adding a time perspective and thus linking long-term strategic objectives with trends and new market opportunities. The same authors claim for the first time the relationship between strategic design and sustainability, defining strategic design for sustainability (SDfS) as "the capability to create new stakeholder configurations and develop an integrated system of products, services and communication that is coherent with the medium-long term perspective of sustainability, being, at the same time, economically feasible and socially appreciable today" (Manzini & Vezzoli, 2003). Sustainability was the last important piece in defining the objectives and values of strategic design. Although there may be several definitions available in the literature, in all of them the elements already mentioned above emerge and constitute the cornerstones of strategic design: a strong link with corporate objectives, the ability to hybridise with other disciplines and figures, the need to look to the future, the possibility of reviewing relations with the various stakeholders, and the need to do all this by generating value that is not only economic but also socially responsible and environmentally sustainable (Calabretta et al., 2016; Freire et al., 2017; Gallego et al., 2020).

In recent years, strategic design has been recognised as a mindset capable of stimulating the industrial mentality and culture to respond to environmental and social challenges using specific design tools and methods. To succeed in this, however, it is necessary to integrate strategic design into internal dynamics and processes (Franzato, 2010). Hence, it becomes of crucial importance to understand what the barriers to the implementation of such a design mindset and approach are and what the resistances against sustainability aspects related to it are. There is currently a shortage of evidence and specific research on this in the literature. This article aims to fill this gap, creating an organic vision of the problem, and taking a holistic view between strategic design and sustainability through the results of a qualitative analysis in the field, thus adding a more practical perspective.

Methodology

Through collaboration with an Italian company producing secondary corrugated packaging, it was possible for the authors to explore and define potential barriers for SDfS. The manufacturing company focuses mainly on business-to-business and does not have a specialised figure dedicated to sustainability (e.g., sustainability manager) which is seen as a shared responsibility among everyone. Instead, strategic decisions are taken by top management and the CEO (see limitations in the "Conclusion" section).

To gain a clear perspective, a qualitative approach was applied to the research by conducting participatory action research (PAR) (Gray, 2004). PAR is based on the action research methodology, which in turn consists of three main points:

- The research subjects are involved in a democratic partnership with the researcher;
- The researcher is seen as an agent of change; and
- Data are generated from the direct experience of the researcher and participants.

The last of these represents the characteristic element of PAR, enhancing it and placing it at the heart of the methodology. In fact, participants are not simply involved, but immersed in the research and involved in the data collection and analysis (Gray, 2004). Furthermore, the focus of the research is on carrying it out with and for the people who will greatly benefit from the output (Jones, 2018). Given the close contact of the research with practice and the different business figures involved, three methodologies were the most appropriate: first, conducting participatory observations; then, semi-structured interviews; and finally, a triangulation of the data with the literature to validate the information obtained.

Participatory Observation

To verify the state of the art regarding a sustainable strategic perspective and capabilities related to it, it was necessary to undertake an in-depth analysis of the partner company. Therefore, a qualitative analysis was carried out in the form of participatory observation. The possibility of being physically inside the company and conducting on-site observations allowed the researchers to immerse themselves in the culture of the organisation under investigation, thus enabling them to highlight the internal mechanisms, practices, and attitudes of the subjects under analysis (Muratovski, 2016). The introduction of the researcher within the workplace also allowed for unstructured interviews during the observations, enabling the description of the design and managerial decision-making processes, highlighting, if necessary, the relationships with sustainability aspects. For this reason, the observations were mainly conducted within the design and marketing department.

Semi-Structured Interviews

To consolidate what emerged during the observation phase, face-to-face semi-structured interviews were conducted with specific company figures. The questions were aimed at assessing the state of the art regarding the methods for creating and sharing strategies and the level of integration with sustainability, as well as the challenges encountered in these elements. In addition, to observe the level of reluctance to the introduction of innovation related to SDfS, the possibility of the inclusion of new methods and tools was exposed (Berná-Martínez & Maciá-Pérez, 2012). For this reason, interviews were conducted with key figures with managerial decision-making power and the company's designers, all of whom are directly involved in an SDfS approach (CEO, three managers, and two designers). A total of six people were interviewed with an average time per interview of 65 minutes. All interviews were recorded, transcribed, and analysed. To promote an ethical approach, all interviewees were informed about the recordings and the confidentiality of the information.

Data Triangulation

To correlate and validate the findings from the previous research steps, it was decided to proceed with a data triangulation with online scientific literature, thus ensuring academic integrity, rigour, and reliability (Bradbury-Huang, 2010; Given, 2008). A conceptual literature review was conducted concerning barriers to the introduction of SDfS in companies and the skills required for both strategic design and sustainability (Thomas & Hodges, 2010). This made it possible to highlight traces of the results obtained in the work of different authors. The review was approached by querying Scopus and Web of Science (WoS) search databases for specific keywords within the title, abstract, or keywords in different combinations, firstly for barriers ("strategic design," barriers or challenges, sustainability or sustainable development) and then for capabilities ("strategic design," sustainability or sustainable development, capabilities or competencies or skills). The publications that were concerned with measurement methods and tools were excluded. From these results, further documents were obtained through a snowballing sampling analysis (Wohlin, 2014). From this analysis, seven texts related to barriers and twelve texts related to capabilities emerged.

Results

Through transcription, analysis, and coding of the research results, it was possible to identify eight challenges and barriers that hinder the introduction of the SDfS approach within the company. Four of the eight identified barriers emerged during the observation phase and were then highlighted again during the semi-structured interviews. Three out of eight, on the other hand, were mentioned directly by the company figures during the interviews, and one was not mentioned directly but emerged from the subsequent analysis. All the barriers found a counterpart within the literature, although in different industries from that of the company under analysis or related only to strategic design or sustainability. The barriers identified can be clustered into three groups: information sharing and collaboration, knowledge and awareness, and forward-looking (Table 1). The individual barriers will be explored below following these categories.

Information Sharing and Collaboration

B1. Awareness and Sharing of the Company's Objectives

It was clear from the interviews that not all employees were aware of the company's objectives. This gap is evident when the different figures – CEO, managers and employers – describe the goals. While the CEO can go into detail about the future direction (vision) and the necessary actions (strategies), the managers show partial knowledge more focused on their department. Employees, on the other hand, are completely unaware of the company's intentions. This makes it complicated to create a shared objective or a shared vision (Senge, 2006) and to allow different figures to share ideas and thoughts. Furthermore, some initiatives and projects risk being misunderstood and unwelcome. Since the SDfS has a natural tension to the future, it is important that everyone feels and understands the objectives.

CLUSTER	BARRIERS OF THIS STUDY	BARRIERS IN PREVIOUS STUDIES	REFERENCES
Information sharing and collabora-tion	B1. Awareness and sharing of the company's objectives	• The corporate group has a large influence • Leitbild (there is no clear and comprehensive vision on circular economy (CE) that is shared by all participants, either internally in the company or externally between actors)	Hallstedt et al., 2013; van Keulen & Kircherr, 2021
	B2. Departments are experienced as silos	• Internal conflicts between business functions • Fear of sharing sensitive information • Conflict of interest	Ceschin, 2014
Knowledge and awareness	B3. Awareness of the systemic consequences of actions	• Simulation of sustainability consequences across the product's life cycle • Win-win-win situations for people, planet, and profit	Hallstedt et al., 2013
	B4. Knowledge of design possibilities and knowledge of sustainability aspects	• CEOs do not understand strategic design • Lack of skills to understand users and markets • Companies require new competences, skills, and experiences • Absence of an internal common language and alignment of mindsets • Lack of CE knowledge • Lack of knowledge can be a barrier	Liu & de Bont, 2017; Ceschin, 2014; Adams et al., 2017; Schult & Hallstedt, 2017
	B5. Awareness of key stakeholders	• Social span (company only thinks within own company realms and own industry)	van Keulen & Kircherr, 2021
Forward-looking	B6. Management's commitment and belief in the objectives	• Lack of management commitment • Sustainability is not included at a high level in advanced engineering • The mindset and commitment of the staff is an important aspect to ease the transition to a CE model	Hallstedt et al., 2013; Schulte & Hallstedt, 2017; Rizos et al., 2016
	B7. Learning and knowledge fertilisation	• Designers lack multidisciplinary backgrounds • Know how/knowledge (the know-how to develop CE solutions is not available and/or not applicable)	Liu & de Bont, 2017; van Keulen & Kircherr, 2021
	B8. Short-term thinking	• Incorporating backcasting together with forecasting • Costs and short-term economic thinking are perceived as the dominant barrier	Hallstedt et al., 2013; Schulte & Hallstedt, 2017

Table 1. Barriers derived from the analysis.

B2. Departments Are Experienced as Silos

The different departments and divisions of the company are seen by both management and employees as independent silos that do not contaminate each other. Although necessary collaborations exist for the proper functioning of the company, information sharing and project collaboration is not encouraged. Following the framework proposed by Gharajedaghi (2006), this fits into a view of the divisional corporate structure where each department, like a part of the body, follows its function dictated by a unicum, the brain. Such a perspective limits the fertilisation of ideas and knowledge, two cornerstones of SDfS.

Knowledge and Awareness

B3. Awareness of the Systemic Consequences of Actions

Within departments, choices are often made mechanically, "because it has always been done that way." Blindly following the same pattern of actions without understanding their motivations and consequences limits the possibility of innovation and the emergence of new opportunities. Furthermore, this limits the prediction of unconscious and uncontrolled consequences not only to the external environment but also to different departments within the company itself.

B4. Knowledge of Design Possibilities and Knowledge of Sustainability Aspects

Regarding sustainability, the knowledge observed in the company under analysis mainly concerns environmental sustainability, leaving the social and economic behind. Regarding strategic design, it is still unknown what its possibilities are. Many still see design as related to products, graphics, or design thinking and its tools. The lack of understanding and knowledge makes it difficult for companies to explore and integrate this approach and its possibilities. This also complicates communication as there is a lack of a common vocabulary.

B5. Awareness of Key Stakeholders

Suppliers and customers are the key stakeholders. Designing and making decisions by looking only at these two main groups is reductive. Considering laws, communities, shareholders, and all the actors that are part of the value chain would increase awareness but also clarify why certain actions are taken. Furthermore, clarifying, mapping, and sharing the stakeholders that gravitate around a company would enable life cycle thinking, resulting in sustainability benefits (Vezzoli & Manzini, 2008).

Forward-Looking

B6. Management's Commitment and Belief in the Objectives

Some corporate actions are perceived as just market goals or are not shared and felt by employees. The commitment of all people in the company, with more emphasis on managers and CEOs, is recognised as valuable by several authors (Hallstedt et al., 2013; Schulte & Hallstedt, 2017; van Keulen & Kirchherr, 2021). It becomes important to best communicate the commitment and ideals that the company stands for. Furthermore, it is important that managers and CEOs show openness towards the opinions of others, fostering dialogue and the emergence of new ideas and future possibilities from collaborating and negotiating with those with different expertise.

B7. Learning and Knowledge Fertilisation

Sustainability is a constantly evolving field, as are the tools and methodologies used in strategic design. The related knowledge must be constantly updated for the company to be competitive, trying to make people understand their importance as learning moments are often experienced as a waste of time. Furthermore, investing in the education of the company's human capital fosters a sense of commitment and allows those involved to share their knowledge by hybridising it with others.

B8. Short-Term Thinking
An interviewee said, "The risk is that the person, when in a regime of everyday life, tends to spend more time doing than thinking. And so that strategic part becomes more and more narrow, and there is a risk of going very much on doing and very little on strategic thinking." Costs and short-term economic goals drive the activities of companies, moreover, and daily tasks immerse individuals in the present. This precludes a vision with medium- to long-term horizons from a strategic and sustainable perspective, which is necessary for an SDfS approach.

Since SDfS in this article is treated as an approach and a mindset, the more technical and commercial aspects, although they emerged, were not considered in the subsequent stages. Among these, it is worth emphasising how the economic aspects were mentioned by several company figures as a barrier to new possibilities. As emerged from Barrier 8, the price represents a strongly attractive element that overrides other values and characteristics. Furthermore, as the company under analysis is a manufacturer of secondary packaging, the material and new technologies also emerged as limits to future possibilities.

Based on the results of the analysis, these barriers can easily be converted into recommendations and enablers, beginning to glimpse indications and possibilities for overcoming them (Table 2).

CLUSTER	BARRIER	ENABLER
Information sharing and collaboration	B1. Awareness and sharing of the company's objectives	E1. Communicate the company vision and plan of action, their benefits, and expected results
	B2. Departments are experienced as silos	E2. Facilitate and improve collaborations between different company departments
Knowledge and awareness	B3. Awareness of the systemic consequences of actions	E3. Create awareness of the (systemic) consequences of everyday actions
	B4. Knowledge of design possibilities and knowledge of sustainability aspects	E4. Create a shared understanding and visualisation of topic and words
	B5. Awareness of key stakeholders	E5. Create a shared understanding of firm stakeholder connection and value chain
Forward-looking	B6. Management's commitment and belief in the objectives	E6. Show management commitment and openness to discussion
	B7. Learning and knowledge fertilisation	E7. Promote and facilitate a systematic competence and knowledge-building in a collaborative way
	B8. Short-term thinking	E8. Facilitating participation in medium- to long-term corporate objectives and understanding how daily actions contribute to these

Table 2. Translation of barriers into enablers.

Through the triangulation of data and the literature review, a strong link between barriers and capabilities also emerged. This made it possible to associate each challenge with capabilities and skills to be implemented within the company to overcome the barriers and introduce SDfS (Table 3). The skills and capabilities that arose from the analysis emerged both in texts focused strictly on strategic design or on sustainability, creating a panel of skills perfect for SDfS. These will be explored below.

C1. Multidisciplinary Collaboration
As already mentioned, the designer is a figure who gets his strength from knowledge connection, having the ability to translate and move ideas and concepts from one field to another (Zurlo, 1999). This ability is also taken up in sustainability as the complexity of the challenges related to it requires figures capable of crossing boundaries and collaborating with those with different backgrounds and knowledge (Cörvers et al., 2016).

C2. Future Thinking
Also referred to as anticipatory competence, temporal thinking, or future orientation, future thinking is the ability to analyse, evaluate, and create images of the future (Wiek et al., 2011a). This relates to both strategic design and sustainability since, in both cases, it is necessary to think about the consequences that decisions made today will have and to foresee problems or further steps needed to achieve goals (Meroni, 2008; Zurlo, 2022).

C3. Systems Thinking

Systemic, system, or rather holistic thinking indicates an individual's ability to analyse a system, relating it to another and looking at it from different perspectives. This allows – from both a design and sustainable perspective – consideration of different actors and possible negative effects that a project or an action might cause (Engle et al., 2017; Wiek et al., 2011a; Zurlo, 1999).

Complexity and uncertainty management			x		x			x
Visualisation	x			x	x			
Organisation and coordination		x					x	
Negotiation		x				x		
Knowledge connection and translation		x	x		x		x	
Communication	x			x		x	x	
Data interpretation			x					x
Systems thinking			x		x			x
Future thinking	x							x
Multidisciplinary collaboration		x				x	x	
	B1. Awareness and sharing of the company's objectives	B2. Departments are experienced as silos	B3. Awareness of the systemic consequences of actions	B4. Knowledge of design possibilities and knowledge of sustainability aspects	B5. Awareness of key stakeholders	B6. Management's commitment and belief in the objectives	B7. Learning and knowledge fertilisation	B8. Short-term thinking
	Information sharing and collaboration		Knowledge and awareness			Forward-looking		

Table 3. Association of barriers with the capabilities needed to overcome them (Calabretta et al., 2016; Cörvers et al., 2016; Dzhengiz & Niesten, 2020; Engle et al., 2017; Hess et al., 2015; Meroni, 2008; Remington-Doucette & Musgrove, 2015; Venn et al., 2022; Wiek et al., 2011b; Zurlo, 1999, 2022).

C4. Data Interpretation
Data interpretation is often referred to as critical thinking and data management, or is taken for granted as basic competence. However, in the professional world, the ability to analyse and understand data plays a fundamental role, especially in interfacing with other stakeholders and the development of new projects (Venn et al., 2022). Furthermore, from a strategic design point of view, correctly interpreting data can help provide new insights and signals of the progress of a started project (Calabretta et al., 2016).

C5. Communication
Communication is often part of a larger competence set: interpersonal skills. Indeed, it plays a fundamental role in the relationship with the other, being closely connected with other skills such as multidisciplinary collaboration or negotiation. The ability to communicate is of fundamental importance both because the strategic designer is inherently a figure who acts as an interface, as a communicative medium between different elements, and because it is necessary to be able to communicate correctly with all the stakeholders of a project (Wiek et al., 2011b; Zurlo, 1999).

C6. Knowledge Connection and Translation
Dealing with very different fields and figures, it is necessary to be able to create connections between these fields to carry out the technology transfer mentioned above. To facilitate the understanding of often-technical knowledge, but also complex problems, it is necessary to be able to translate this information into simpler messages (Venn et al., 2022; Zurlo, 1999).

C7. Negotiation
Also known as mediation, this capacity is present not only in any collaborative work but also in any creative effort (Zurlo, 1999). In multidisciplinary teams with different stakeholders, it becomes important to be able to facilitate the understanding of different points of view and build consensus towards a common direction (Venn et al., 2022).

C8. Organisation and Coordination
Often referred to as project management or strategic planning, this capability has a broader sense, namely that of creating the logistical conditions for activating resources (understood as both material and human resources) within and outside the organisation (Calabretta et al., 2016). Indeed, through coordination and organisation, it is possible to facilitate the implementation of new solutions (Venn et al., 2022).

C9. Visualisation
The ability to visualise enables the individual to accelerate communication and the development of new projects. Indeed, through visual artefacts such as images, diagrams, and infographics, but also prototypes and sketches, it is possible to enable a narrative and to make others understand and see. An interviewee from Venn et al. (2022) says, "You can try to gain attention for a river ecosystem with science and numbers, but a playful campaign with an artistic drawing of a fish or a kingfisher may prompt people to action more quickly."

C10. Complexity and Uncertainty Management
Sustainability is often identified as a wicked problem, a complex issue with no perfect

solution. It becomes necessary to be able to manage the complexity arising from these problems but also articulated systems with different stakeholders. This ability is usually linked to systems thinking and future thinking (Hess et al., 2015).

Lastly, it must be specified how the technical skills and capabilities required to carry out the actions of each specific sector are indispensable. What has been indicated above is to be considered complementary, overlapping with what is technically necessary, and which is usually already present within organisations.

Discussion

The research results confirm the link that has already emerged in the past between strategic design and sustainability. Like any new element, the introduction of researchers and the SDfS approach was viewed with scepticism and fear by corporate figures, highlighting some barriers. Although the body of literature on the latter is very rich in the field of sustainability and design, very little can be found concerning SDfS. The same can be said about the capabilities needed by a figure who wants to adopt such an approach. Concerning the latter, the analysis showed how the vast majority of the skills reported in the literature for one field can be detected also in the other. It should be emphasised that the strategic element is even considered a skill of its own among the capabilities required for sustainability, and that among these, typical elements of design are often referred to as basic – e.g., problem-solving, critical thinking, and even creativity (Dzhengiz & Niesten, 2020; Engle et al., 2017; Venn et al., 2022). Among other skills in the literature, we can also name normative or ethical thinking (Remington-Doucette & Musgrove, 2015; Venn et al., 2022; Wiek et al., 2011b). As this is linked to the identification of sustainability values and goals, it can be considered (as we have said in the background section) as a *conditio sine qua non* within the SDfS.

Although the results confirm and consolidate this relationship, it should be noted that the barriers in particular take different shades as they relate to the discipline and mindset of SDfS, especially in their resolution and overcoming. Many of them are only addressed through the relationship with the other, in cooperation, and through dialogue between different actors and figures. It thus becomes clear why Wiek et al. (2011a) highlight interpersonal skills as particularly important and necessary for the functioning of other competencies. Hence, management commitment becomes not only dedication, but also openness to dialogue and dissemination; learning is no longer vertical or specific, but collaborative and interdisciplinary. If SDfS is therefore an open, collaborative, and interdisciplinary approach, individuals will only be able to grow, learn, improve, and find solutions to complex problems together by talking to each other and addressing challenges collectively. Such a perspective is grounded in the words of Johnson et al. (2000) and Galimberti (1994). The former advocates cooperative learning as a new model of collective growth where the individual only learns if the group learns (Johnson et al., 2000). The second sees conversation, the exchange of information and messages between individuals as a privileged medium for human evolution (Galimberti, 1994). And, it is through a learning process of this kind – shared and communicative – that, according to Gharajedaghi (2006), it is possible for an industrial system or a society to evolve and change. In fact, he emphasises that for such changes, the sum of the learning of individuals is not sufficient, but rather a new culture is required, the achievement of a new shared positive vision. In this dimension of collective improvement and evolution, by dialoguing and learning together, individuals somehow take care of each other and their surroundings. Therefore, through the introduction of skills and knowledge related to SDfS and through actions that enhance these aspects, it seems possible to initiate a new widespread corporate culture aimed at growth and improvement of itself and the environment. It is precisely through an approach and a mindset of this kind that we can review the three aforementioned corporate powers initially harnessed in a positive way, to promote new ideas and solutions to complex and systemic problems such as climate change, which sees different actors, each with their objectives involved.

Conclusion

The article proposes the adoption of SDfS as a new mindset to be implemented within companies to improve their contribution to climate change. To be able to incorporate it properly, it is necessary to know the barriers and the capabilities to be introduced to overcome these challenges. Therefore, the article proposes eight barriers and ten capabilities enriching the literature in the field of SDfS through a more pragmatic perspective. The research was carried out within an Italian company in the secondary corrugated packaging sector. Although this was interpreted as a positive element providing a new, more practical perspective on the subject, it could also be seen as a limitation. In fact, this limits the sampling to a single company with a specific corporate structure without a sustainability specialist figure and a well-defined market that is affected by a perception of sustainability that is strongly material-based. Future research could test and validate the results obtained with different sampling and compare them with different geographical areas. Furthermore, although the research was carried out with a practical approach, the barriers and capacities highlighted could be used and tested in the future as a framework not only within a professional context but also in an academic and teaching environment by defining training activities and objectives. By expanding the sample, it might also be possible to define and highlight potential hierarchies for barriers and capabilities.

The research is set within a broader framework of doctoral research. Future research already planned will propose activities and practices in collaboration with the company under analysis to incorporate the identified skills and capabilities. This will provide further practical input for both the community of science and practice.

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DESIGN FOR CIRCULAR BUSINESS MODELS: A CONCEPTUAL FRAMEWORK

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Abstract
This paper provides a conceptual framework on design and its role in developing circular business models (CBM). Current industries are still underpinned by throw-away culture, resulting in the short lifespan for most consumer goods that largely contributes to growing environmental pressures. Most businesses operate in a linear economic system dependent on growth, where success is measured only by increasing sales volumes. Therefore, long-lasting products are recognized as a threat to business growth. Circular economy (CE) is introduced as a model to support sustainable economic growth, promoting high resource efficiency, longer product lifespans, and zero waste emissions. Implementing CE principles is increasingly recommended as a solution to meet sustainable development goals. Businesses built around long-life products and recovered resources cannot operate without a product-service system design that supports the circular business strategy.

In the recent literature, circular design is introduced as the form of design that enables the CE model. Various circular design strategies can be found in the literature to counter obsolescence and maximize product integrity. These strategies are tightly bound with circular business models driving profits from the circular model. Design thinking as a practice for business innovation might also favor the transition from linear to circular business models. However, it should be revised within the CE context, as the circular model imposes complex restrictions on the design process and requires new ways of thinking for designing within the systems. To date, design for CE and its relation to the development and implementation of circular business models are not sufficiently studied; it is still necessary to frame the phenomena better. By reviewing the scant literature on the intersection of design for CE and circular business models, this paper proposes a conceptual framework showing the most critical touchpoints between the concepts. It provides a synthesis and clarification of the emerging research theme of circular design. Further, it helps to capture the importance of a more holistic and systemic approach for many whose sustainability efforts are related to the technical approach, i.e. solving issues within the material and product level while leaving out the systemic change, which is essential for CE. It also explains the role of design within circular innovation and the successful delivery of circular business models. Seven essential aspects are provided to consider while designing for circular business models. Limitations, areas for improvement, and implications of the proposed framework are addressed to guide future research on the combined role of design and circular business models in the transition towards CE.

Author Keywords
Design for the circular economy; circular design; circular business models; design thinking for CE.

Introduction

A circular economy (CE) is seen as "an industrial system that is restorative and regenerative by intention and design" (Ellen MacArthur Foundation, 2015). As proposed by the Ellen MacArthur Foundation (2015), it is based on the philosophy of designing the industrial system that moves away from irresponsible resource depletion while gaining significant benefits by using smarter design of materials, products, systems, and business models. Still, most companies are deeply rooted in the make-use-dispose linear model, where long-lasting products are recognized as a threat to business growth. Design is named one of the key enabling factors for circular transformation (Bason, 2021), where transition calls for creative innovation in systems design and rigorous collaboration across and within value chains and among multiple stakeholders (Haigh et al., 2021; Medkova & Fifield, 2016). In CE, design is tightly bound with circular business models (CBM), driving profits from the circular model (Bocken et al., 2016; Moreno et al., 2016; Moreno et al., 2017).

Nevertheless, to date, design for CE and its relation to the development and implementation of CBM are not sufficiently studied; design for CE is studied more at the product level while at the system level is less explored (Webster, 2021). This paper reviews the present body of literature regarding design for CE. It proposes a conceptual view of the circular design framework by identifying the most relevant aspects for developing circular design and its relation to circular business models, showing the intersection and critical touchpoints between the two concepts.

Methods

This paper is built by reviewing the scant literature on the intersection of design for CE and circular business models. The author used the following (primary) keywords – circular design, circular design framework, design for circular economy, circular business models, product service system design, system oriented design – to search for relevant sources in Google Scholar, Scopus, JSTOR, EBSCO, and field-specific databases. To develop the proposed design for the CBM framework, the following three steps were undertaken:

- Step 1: Define the main aspects related to design for circular innovation.
- Step 2: Develop a circular design framework overview, define the state-of-the-art classification of circular design strategies (CDS) and circular business models (CBM), and develop the CDS-CBM taxonomy outlining the value for business and circularity outputs generated by different strategies and business models.
- Step 3: Synthesize and generalize the findings from Step 1 and Step 2, and develop a conceptual framework for design for CMB.

Design for Circular and Mission-Oriented Innovation

Design has always been integral to innovation (OECD, 2015), not limited to shaping products. The semantic dimension of design is recognized as an essential concept for product innovation; design-driven innovation is based on creating value propositions by radically changing the products, i.e. shaping their emotional, symbolic content (meanings and languages) through a broader change in society and technology. In this case, the innovation is pushed by a vision of the company about new meanings of their products within society, rather than pulled by user requirements (Battistella et al., 2012; Verganti, 2008). Similar to the idea that a product is represented not only by form and function but also by meaning, a company's complete business model transmits economic and technological value and also says a lot about the organization from a semantic standpoint (Battistella et al., 2012). In this case, design is used as a strategic asset of the company, i.e. the highest level of the Design Ladder (Danish Design Centre, 2016) that identifies four steps of design use, from none to design as a process and strategic asset, representing the company's ability to innovate – the more strategic design is used, the higher the ability to innovate. The same is true for circular innovation (see Figure 1). Placing a greater emphasis on design in the early stages of product/service development and giving design a more strategic position in the company's overall business strategy helps to reach radical innovation, shifting perspective to long-term, indirect value and intangible benefits not limited to the short-term outcomes and direct benefits for the company (Doherty et al., 2014). In CE, where waste is not an option, products should reach longer lifespans, broader social and technological value, radical shifts, and long-term systemic change. Integrating the CE approach early in the design process and at a strategic level of the entire business model is essential. Therefore, it is deduced that circular design applies to companies operating at the third and fourth levels of the Design Ladder – as a process and strategy (Stawicky, 2022), i.e. it is a fundamental condition for circular-oriented innovation.

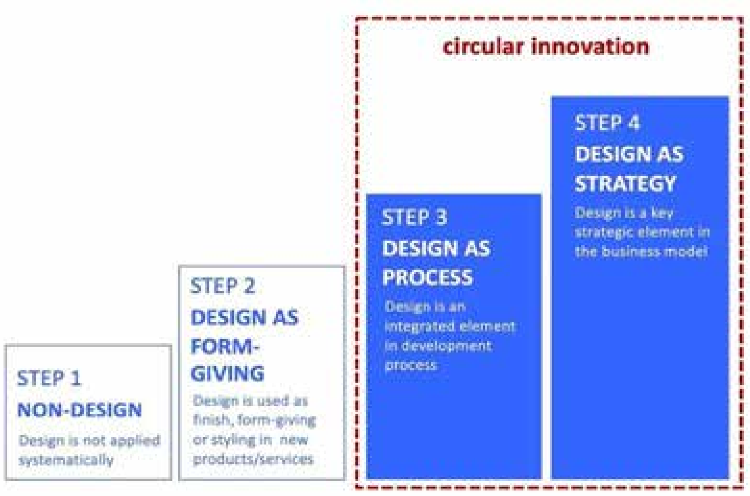

Figure 1. Design maturity levels for circular innovation (source: author, based on Danish Design Centre 2016; Stawicky, 2022).

Also, the circular-oriented innovation commonly requires collaboration between a wide range of stakeholders across a variety of fields and implementation within different levels: micro – within organizations, e.g., the individuals or teams; meso – within organizations and value networks; and macro – within societal, political, and institutional spheres and the whole system (Brown et al., 2021; RSA, 2016).

In CE, design thinking (DT) is argued to be rethought as well, as it demonstrates significant limits since it reproduces a user-centric, socially conformist corporate framework that emphasizes technical innovation and upholds a dubious solutionist character while missing critical and embodied cognitive and creative abilities. However, DT extended with arts-based and design culture-related elements may have a more significant potential to explore alternate futures and become relevant for sustainable change, e.g., rethinking processes by introducing practices related to group improvisation and dialogue which originate from jazz, where jam sessions are said to be particularly effective in fostering both individual and group creativity due to the characteristics of their embodied and contextually embedded group improvisational communication processes (Kagan et al., 2020).

Moreover, as proposed by the Danish Design Center (DDC) and other authors (Bason, 2021; Bocken et al., 2016), the design process must focus on achieving a complex and long-term transition toward circularity and systemic change, shifting from user-centric to *planet/life-centric*. Furthermore, the design-driven approach should be built on working with missions (Bason, 2021; Hanson et al., 2022), i.e. emphasizing the mission-oriented innovation that addresses societal challenges by transforming socioeconomic systems (Hekkert et al., 2020). The concept of design for circular and mission-oriented innovation is shown in Figure 2.

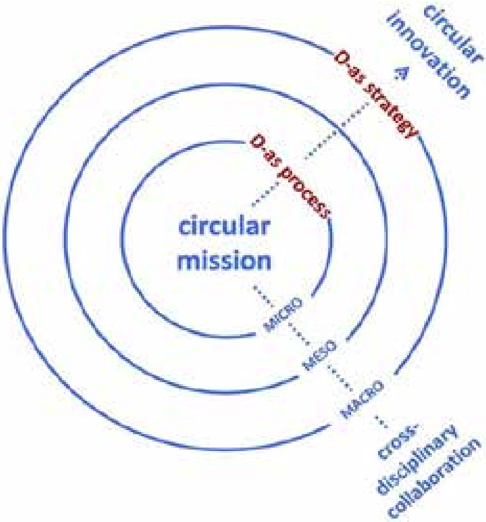

Figure 2. Design for circular and mission-oriented innovation (source: author, based on Danish Design Centre, 2016; Bason, 2021; Brown et al., 2021; Hanson et al., 2022).

The figure shows essential conditions for circular innovation, where the design process is driven by the circular mission and the interdisciplinary collaboration happens within micro, meso, and macro levels, while design is applied as a process or strategy within the company.

Circular Design Framework Overview

In the recent literature, circular design is introduced as one of the essential actors enabling the CE model. As defined by Medkova and Fifield (2016), circular design first considers people, the planet, and profit (following the triple bottom approach, or TBL). It is embedded as a core strategy for businesses and consumers, i.e. transformation of processes and change in consumer culture, which means moving from finite to regenerative, from transactional to relational, from linear to circular (Bocken et al., 2016; Bason, 2021). The vehicle for changes is a continuous redesign process which occurs by focusing on the four lines of discussions: (1) systems thinking; (2) awareness; (3) mental shift; and (4) communication around the main four elements. The elements are: (1) circular design strategies; (2) new business models; (3) cross-disciplinary intelligence; and (4) system conditions. Design in the circular economy is complex and requires a transformation in thinking "from the current product-centric focus towards a more system-based design approach" (RSA, 2016). CE emphasizes the importance of cooperation and collaboration across various fields; stakeholder value networks, which reflect different system conditions, are of particular importance in CE. Especially in the design phase, active communication between designers, material experts and engineers, environmentalists and economists, and end-users is essential for circular design solutions (RSA, 2016).

Design for Closing the Loops: Whole Systems Design

The goal of circular design is to minimize and eliminate environmental costs by preserving or restoring the product's value over time (Medkova & Fifield, 2016). A mix of green, eco-, and sustainable design features can be found in the circular design framework (Moreno et al., 2016). Various authors (Braungart et al., 2007; Den Hollander et al., 2017) criticize green design and eco-design as being bound to the same linear method by providing solutions that result in waste – renewable and recycled materials are frequently impossible to regenerate and recover. Therefore, a fundamental distinction is made between eco-design and circular design. Eco-design is mainly guided by the waste hierarchy (EC, 2009), prioritizing the *technical approach* and moving from waste prevention to reuse, recycling, recovery, and disposal. Instead, circular design prioritizes a *holistic approach*, going beyond the traditional design process bound to a linear model, considering the system as a whole and using systems thinking underpinned by preventive philosophy that helps to create a meaningful design for a long-term regenerative strategy. (Moreno et al., 2016; Bason, 2021). Circular design is guided by the inertia principle and product integrity (PI), which is defined as the extent to which a product remains identical to its original (e.g., as manufactured) state (Stahel, 2010; Den Hollander et al., 2017). The primary aim of design in CE is to prevent a product or service from becoming obsolete by creating products and services with high physical and emotional durability. Such products resist obsolescence, whether aesthetic, social, technological, or economic. Three typologies of design approaches for product integrity can be identified (Den Hollander et al., 2017):

1. Resisting obsolescence (prolonged use): where design is used to create physical and emotional durability;
2. Postponing obsolescence (extended use): where design is used for maintenance and upgrading;
3. Reversing obsolescence (recovery): where design is used for recontextualizing, repairing, refurbishing, and remanufacturing.

Three main design for sustainability (DfX) approaches – narrowing, slowing, and closing resource loops – represent the transformation from the *technical* to the *holistic* approach. They might be linked to design approaches for PI (Bocken et al., 2016; Den Hollander et al,. 2017; Moreno et al., 2016).

The radical circular transformation happens by moving from profit obtained from material products (resources) to the added value obtained from services and product-service systems. The free approaches employ different design strategies and circular business models that differ in terms of the circular output and level of product integrity (Table 1).

DfX approach		**Design approaches for product integrity**	**Driver for transformation**	**Outcome**
D-for closing loops	**Holistic approach** *Whole systems design*	**Resisting obsolescence (prolonged use):** *D-for physical and emotional durability*	**Services, product-service systems**	**RESOURCE SUFFICIENCY** Higher product integrity (PI)
D-for slowing loops	**Technical approach** *D-for resource conservation and products' environmental performance*	**Postponing obsolescence (extended use):** *D-for maintenance and upgrading*		
D-for narrowing loops		**Reversing obsolescence (recovery):** *D-for recontextualizing, repairing, refurbishing, and remanufacturing*	**Material resources**	**MATERIAL EFFICIENCY** Lower product integrity (PI)

Table 1. DfX approaches and their outcomes (source: author, based on Valušytė, 2021; Moreno et al., 2016; Bocken et al., 2016; Den Hollander et al., 2017).

Design for narrowing the loops improves products' environmental performance by using fewer materials, less energy, and preserving resources. It relates mainly to the technical approach, where design is used for material resource conservation and efficiency, deriving from green and eco-design practices. In contrast, design for narrowing and closing the loops relates to the holistic approach and whole systems design (Moreno et al., 2016), where additional value is driven by product-service systems, associated systems (such as enabling technologies), supply chains (Tura et al., 2019), and circular business models (Valušytė & Dagilienė, 2020; Valušytė, 2021). Therefore, the underpinning concept of the circular design framework is represented by the whole system design (Bocken & Short, 2020; Valušytė, 2021), or system-oriented design (SOD) (Sevaldson, 2013; Blaasvær & Sevaldson, 2019) – an approach to address the complexity and enable democratic design and business processes that represent the main driver towards a broader society-wide approach.

Circular Design Strategies

Various circular design strategies (CDS) can counter obsolescence and keep a product close to its original purpose (Bakker & Hollander, 2013; Bakker et al., 2014; Bocken et al., 2016; Moreno et al., 2016). CDS can be applied at different innovation levels – material product-service system (micro, meso, macro) levels, pointing towards multiple starting points for circular projects.

- *Material level:* Create new materials and their components or redesign existing materials.
- *Product level:* Improve existing products or develop entirely new product solutions.
- *Service level:* Go beyond individual products and towards combinations of products and services.
- *System level*: Consider the interconnected set of elements that are coherently organized to achieve a function or purpose.

All four levels are intertwined, yet each has its focus areas. There is no hierarchy between the levels, and design intervention on one level can impact outcomes on other levels (Gardien et al., n.d.). Moreno et al. (2016) group a variety of CDS into a taxonomy representing few circular strategy groups, while Valušytė (2021) extends the taxonomy by taking into consideration other authors showing the links between the main CDS groups with a broader number of more specific strategies, circular methods, and tools. Based on these authors, the CDS may be reduced to five groups (and related other specific strategies):

1. *Design for systems change:* Covers the entire spectrum of value creation for technical and biological cycles, referring to design thinking in systems (D-for regenerative systems, i.e. D-for biomimicry; D-to reduce environmental backpacks, i.e. D-for local and entire value chains).
2. *Design for long-life use of products:* Focusing on technical cycles, extending the product utility through life extension and services for reuse, repair, maintenance, and upgrade, or building a long-lasting bond between products and their users, changing the product ownership with services, and sharing systems. This group encompasses D-for attachment and trust, D-for reliability and durability, and D-for product life extension, i.e. D-for maintenance and repair, adaptability and upgradability, and ease of disassembly and reassembly.
3. *Design for multiple cycles:* Focusing on biological and technical cycles, referring to design enabling the more prolonged circulation of materials and resources in multiple cycles. The group encompasses D-for resource recovery, i.e. D-for easy end-of-life, cascaded use, and remanufacturing or disassembly.
4. *Design for resource conservation:* Focusing on biological and technical cycles, referring to a preventative approach through design with the minimum resources in mind. D-for closing resource loops, i.e. D-with smart processes and materials.
5. *Design for circular supplies:* Mainly focusing on the biological cycle and referring to the “waste equals food” or “cradle-to-cradle” mindset in which resources are captured and returned to their natural cycle without harming the environment.

The first strategy is the most effective in achieving resource sufficiency and closing the loops, while the last relates mainly to managing material resources and achieving material efficiency. This group encompasses D-to reduce consumption, i.e. D-for reducing material/resource use, production quality control, eliminating yield losses, material, resources, parts, and packaging.

Circular Business Models

Similar to CDS, various circular business models (CBM) can be identified in the present body of literature. Based on various authors (Bocken et al., 2016; Braungart et al., 2007; Moreno et al., 2016; Guldmann, 2016; Bocken et al., 2014), five major circular business model archetypes can be identified:

1. *Product as service:* Business models based on offering product a ccess while keeping the ownership to internalize the benefits of circular resource productivity.
2. *Sharing platforms:* Business models extending product value and increasing utilization rates of products by making possible shared use/ownership/access.
3. *Product life extension:* Business models extending the working life of a product.
4. *Resource value:* Business models aimed at recovering the resource value of materials and (other) resources used to create new value.
5. *Circular supplies:* An industrial symbiosis-based business model where the residual outputs from one process can be used to feed another one.

Again, the first one is most effective in achieving the resource sufficiency and closing the loops, while the last one achieves material efficiency.

Circular Design Strategies and Business Models Taxonomy

Moreno et al. (2016) provide design practitioners with a holistic view of how to approach circular design by considering the surrounding business models and integrating them with the design process. The framework integrates different schools of thought from CDS and CBM such as cradle-to-cradle, industrial ecology, biomimicry, blue economy, natural capitalism, industrial symbiosis, and the performance economy (Stahel, 1981, 1994, 2010, 2013). This framework encompasses the three fundamental principles for the transition to a circular economy proposed by the Ellen MacArthur Foundation (2012) related to the aforementioned schools of thought: principle 1: preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows; principle 2: optimize resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles; principle 3: foster system effectiveness by revealing and designing out negative externalities. Four forms of value generation are based on the aforementioned three principles: (1) cycling smaller/faster with less energy and resources; (2) cycling for longer; (3) cascaded uses; and (4) pure regenerative cycles.

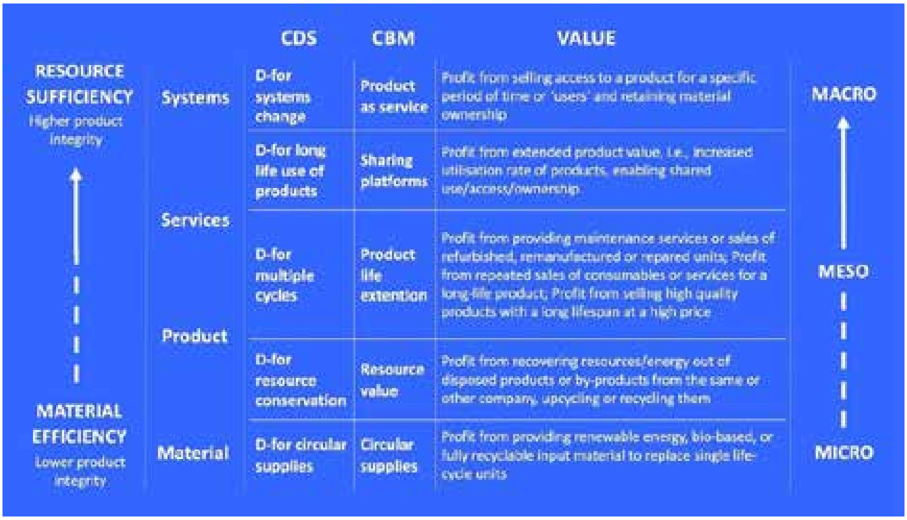

Figure 3. Taxonomy of circular design strategies and business models (source: author).

Figure 3 represents the taxonomy and previously mentioned other authors' work on circular innovation by reassuming the findings on CDS and CBM, their links to value creation, levels of innovation, and sustainability outputs. The most effective design strategy group for resource sufficiency and closing the loops is "design for systems change," referred to as design thinking in systems and design for regenerative systems, i.e. design based on biomimicry, as well as design to reduce environmental backpacks, i.e. applying design for local and entire value chains. The "product underpins this design strategy as a service" circular business model, which brings value by generating profit from access to product sales for a limited time or one-time users while preserving material ownership. The activity requires action at meso/macro scales and a systemic level of innovation. CDS and CBM are an essential part of design for the circular economy. Still, their successful application for circular transition depends on various factors within the overall circular design framework.

Conceptual Framework

Based on the literature review conducted and the generalization of the results presented above, this paper proposes a conceptual framework (Figure 4) representing the complex aspects and conditions needed to design for CE enabling business models. The framework shows the most critical touchpoints between the concepts of design and circular business models. The framework is composed of four main elements: circular design strategies (CDS), circular business models (CBM), circular design network (CDN), and system-oriented design (SOD), which is planet and life centered. All four elements are bound together and guided by the circular mission, which is the focal point of the entire framework and is underpinned by a continuous redesign process. The framework outlines free levels regarding the level of innovation (from material/product to services and systems) and micro, meso, and macro levels of intervention. The inner circle represents the innovation within the material/product level and implementation at the micro level. The second circle represents the innovation within the service level and implementation within the meso level, and the third outer circle represents innovation at a system level and implementation within the macro scale. The framework also indicates the use of design within the company required for circular innovation – from design as a process to design as a strategy. Moreover, the DfX approach, from technical to holistic, results in different outcomes – from material efficiency, i.e. lower product integrity, to resource sufficiency, i.e. higher product integrity, which is the desired outcome in CE and the primary condition for closing the loops.

All framework elements are accompanied by four "actions," essential in building the circular capability: mental shift, systems thinking, design thinking, and collaboration. The four actions for circular capability are placed on the fourth outer circle, which can be turned in both directions as a compass, giving different combinations across the framework elements and thus providing different insights.

The circular transition happens by climbing up from the inner circle to the outer one or combining approaches from all three circles. The more product and business innovation are oriented to system design, the higher the possibility of achieving resource sufficiency and closing the loops. To do this, design should be applied strategically within the company. The innovation should be implemented on a macro scale, i.e. taking into consideration societal, political, and institutional impacts; assessing the whole system within the design and business model; and collaborating across a variety of fields and stakeholders within the circular design network (CDN). Design thinking is bound with systems thinking that underpins the system-oriented design (SOD) process. The design process shifts from user-centered to planet and life centered. It is one of the main changes the DT framework experiences within the CE paradigm. The primary goal of DT for CE is bringing the use of design to a strategic level of the company, i.e. helping organizations innovate towards the circular transition through strategic design.

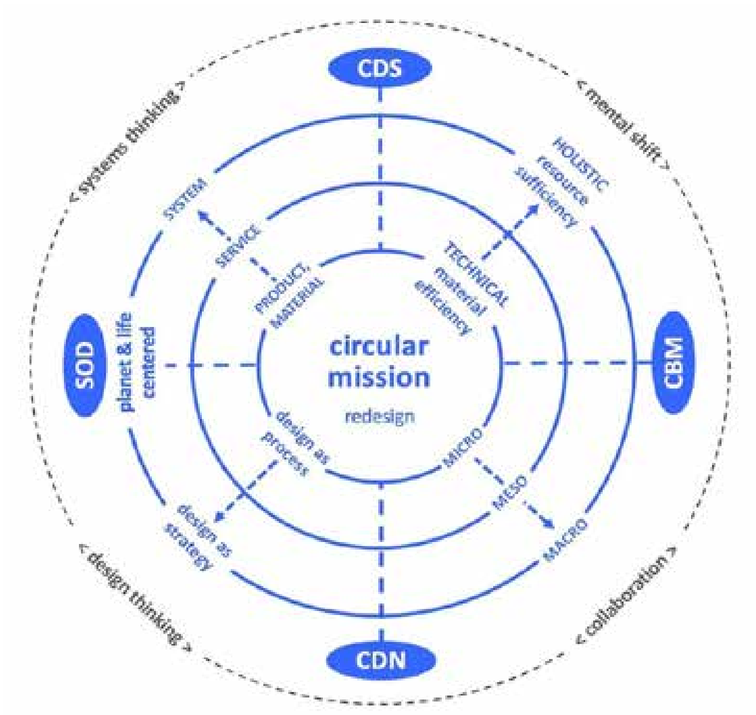

Figure 4. Design for circular business models conceptual framework (source: author).

The framework helps to define the relationship between the complexity of elements and conditions to be considered while designing for the CE, thus helping to foresee the potential circularity output of the innovation (i.e. material efficiency or resource sufficiency). It helps to capture the importance of a more holistic and systemic approach for many whose sustainability efforts are mainly related to the technical approach, i.e. solving issues related to innovation within the material and product level, leaving out systems change, which is essential for CE. It also explains the role of design in circular innovation. The more strategically design is applied within the organization, the easier it is to implement circular business models. Seven essential aspects are presented below to consider while designing for circular business models:

1. Design as mission-oriented – a design-driven approach should be built on the mission.
2. Design as process or strategy – circular design is applicable, and circular innovations are possible only if the company uses design as a process or strategy. Applying design within a strategic level helps to close the loops.
3. Systems thinking and systems-oriented design – continuous redesign across micro, meso, and macro levels.
4. Shifting from user-centered to planet and life-centered design.
5. Design thinking is aligned with systems thinking and systems-oriented design – uncontrolled improvisation during the process, like in jazz.

6. Mental shift – from technical to holistic, from material efficiency to resource sufficiency, i.e. think about design for "systems change" when considering any circular design strategy. This mental shift will lead to more circular business models and higher product integrity.
7. Collaboration within cross-disciplinary networks and across micro, meso, and macro levels. Design intervention is not limited to the company's micro level but should consider the system at meso and macro levels and a wide range of stakeholders across various fields.

Conclusion

This paper provides a synthesis and clarification of the emerging research theme of circular design and its relation to the circular business models. The value of the work lies in the proposed framework and seven essential aspects outlined to consider while designing for circular business models. The conceptual framework is aimed to guide and inspire designers and innovators to look beyond "business as usual" and get familiar with the main drivers for the transition towards business for circular economy and design of the "born circulars." Nevertheless, the framework is limited by a "state-of-the-art" understanding of circular design strategies and business models because it is built upon the existing theoretical research. Empirical application of the framework could bring a new understanding of whether there is more opportunity beyond the design and business models already recognized as successful cases for CE.

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DESIGN FOR CONSERVATION (D4C): A TOOLKIT THAT ENABLES SUSTAINABLE, COLLABORATIVE, AND DISTRIBUTED INNOVATION

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Abstract

Our planet is currently facing urgent, systemic, global challenges that require new collaboration paradigms for radical innovation in the ways we relate to our environment. As the window of time to address climate change shrinks, it becomes imperative for distributed, placed-based communities to quickly develop conservation strategies independently and autonomously, making use of their available resources.

Although the need for local communities to be total participants in developing environmental conservation solutions is well recognized, such solutions are often designed by and with external expertise and resources. This approach broadens the suite of stakeholders beyond the community (e.g., conservation practitioners, scientists, funders) and frequently focuses on narrow outcomes without considering community narratives, resource use, economic needs, and cultural sensitivities, which can result in community disenfranchisement and low levels of engagement. Without community support, these solutions are unsustainable, short-lived, and in most cases, do not fully address local needs.

As design strategists, this led to asking the following question: How can design methodologies support the achievement of sustainability goals by facilitating collaboration, structure, agility, engagement, and innovation within conservation projects?

Our main objective was to co-design conservation-centered tools that are adaptable and versatile enough to fit any project and context while allowing customization concerning place and culture. In the first phase of this research, our team conducted a literature review to explore, compare, select, modify, and adapt strategic design methodologies, as well as new overarching methods that operated in the mindset levels. The second phase of this project has been the testing and validating of these tools against real conservation challenges involving university students and external stakeholders (representing but not limited to the sectors of science, industry, policymakers, Indigenous tribes, and local citizens who are affected by the selected conservation problem). The D4C methodology has been validated through direct observation of the participants and in-site focus groups.

After two consecutive full-cycle iterations, we have published a methodological toolkit comprising five stages, offering a user-friendly step-by-step “agile-to-deep” approach

that includes 21 tools for sustainable innovation within the environmental conservation sector. These tools foster transdisciplinary collaboration, allowing multiple types of knowledge to be expressed through highly visual, collaborative graphic canvases.

Author Keywords
Design for conservation; D4C; design for sustainability; biomimicry; transformative change; systems thinking; regenerative design.

Introduction

Wicked Problems and the Role of Design

In 1973, Rittel and Webber assigned a peculiar name to humanity's complex, systemic problems: wicked problems. The term "wicked" denotes problems for which it is impossible to define optimal solutions because of both uncertainties about future environmental conditions and intractable differences in social values (Shindler & Cramer, 1999). Building upon these reflections, Buchanan (1992) published a journal article titled "Wicked problems in design thinking" where he argues that designers, by the bridging nature of their practice, have been finding partial solutions to wicked problems all along. Design problems have always been "indeterminate" because design has no particular subject matter apart from what a designer conceives it to be: the subject of design is universal in scope (Baron & Ghelich-Khani, 2021). To simplify the main characteristics of wicked problems, we have proposed six descriptive categories based on the concepts presented by Rittel and Webber (1973), Buchanan (1992), Irwin (2011), and Duckett et al. (2016), shown in Figure 1.

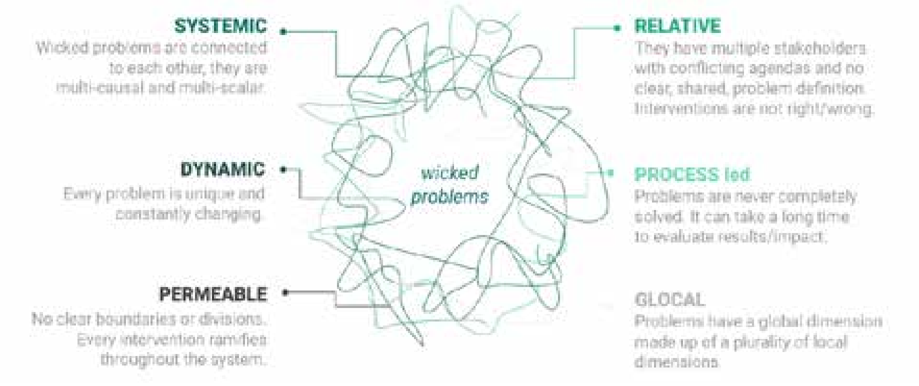

Figure 1. The six characteristics that describe the complex nature of "wicked" problems (Baron & Ghelich-Khani, 2021).

The central wicked problem that has guided this research is "biodiversity loss" which has traditionally been tackled by the discipline of environmental conservation, which focuses on the protection of ecosystems from a biological perspective. *Encyclopedia Britannica* states that conservation seeks to protect life's variety at all levels of biological organization (Pimm, 2021). However, because the underlying cause of biodiversity loss is increasing human activity, conservation must inevitably involve human interactions involving economics, law, social sciences, and religion, among others (Pimm, 2021). Following this last point, while scientists can focus on the biological aspect of conservation, we can assume that non-scientists have successfully carried out many other aspects of conservation for the last 100 years. In fact, from Indigenous peoples that have embedded conservation in holistic worldviews to families that organize to clean the neighborhood's stream, conservation is done at many non-professional levels.

Biodiversity loss is an urgent, global challenge that requires new paradigms of being and relating to each other and our natural environment, and in doing so, operating from a foundational level (mental models) through a relational level (human connections, interdisciplinarity) and into a practices level (technical/tangible solutions). Kania et al. (2018) use an iceberg model to discuss the root and visible dimensions of a problem, stating that conditions holding human systems in place are structured within three levels of change from structural to transformational. Figure 2 shows that what is visible above the waterline, the tangible 20% of an environmental project, can only be sustainable in time if what lies below the surface, 80% of the system, supports the surface actions.

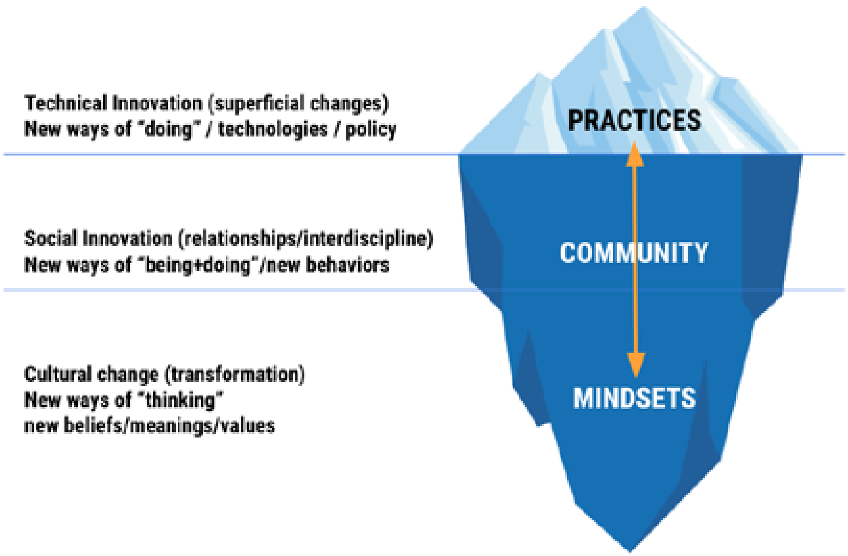

Figure 2. New paradigms of being, relating to each other, and in doing so, operating from foundational levels (mindsets or mental models) through a relational level (interdisciplinarity) and into a practices level (actions). Source: Gabriela Baron, 2021.

Traditional Western approaches to environmental conservation operate at the surface level, offering technical solutions independent from the relational and attitudinal causes. However, this notion is currently being challenged with an emergence of more solutions that incorporate the relational levels and some that extend all the way to the mindset levels. This is the case with the methodology we will present in this paper, which aims to operate vertically across all three levels and incorporates tools to facilitate this integral, transformative change-making.

The Rise of Design Thinking in Non-Design Fields
The notion of design as a "way of thinking" can be traced back to 1969, when the value of the methodology for wider audiences was identified (Simon, 1969; Cross, 2007). The use of design methods and models in fields that are not traditionally within the design realm is widely known as design thinking (Baron & Ghelich-Khani, 2021). In the last decade, designers' models and methods for creative problem-solving have been captured and systematized for their implementation by other professionals in diverse disciplines.

Design thinking (DT) can be defined as a process for creative problem solving traditionally used by designers to solve problems in a creative and innovative way (Friis Dam & Siang, 2020). DT methodologies have proved to be highly successful for addressing complex issues that are often beyond the domain of one discipline, problems that are multi-faceted/ multi-scalar, comprised of many stakeholders with conflicting agendas, and because their "parts" are interconnected and interdependent, there is no single solution (Irwin et al., 2015).

DT makes space for ambiguity and uncertainty, adapting the project through a process-led transformation. By involving many stakeholders in defining the problem and developing solutions, design thinking fosters organizational buy-in and external commitment to change. Testing reduces the fear of change and provides valuable insights. Failure is embedded in the method, lowering costs and risks. This is how the structure of design thinking creates a natural, iterative flow from research to rollout (Liedtka, 2018).

Design thinking has not yet been widely adopted in the conservation field. Although sporadic projects have made initial efforts, these have not rendered meaningful outcomes for non-scientific bottom-up conservation groups. Several authors have argued that we require more compelling future-oriented visions to inform and inspire conservation projects in the present (Tonkinwise, 2014) and that the design solutions in the present need to be informed by longer-term visions of sustainable futures (Dunne & Raby, 2013; Manzini & Jegou, 2003). As design strategists, this led to asking the following question: how can design methodologies support the achievement of sustainability goals by facilitating collaboration, structure, agility, engagement, and innovation within conservation projects?

Methodology
Initially, our team carried out a literature review that would allow us to understand the benefits and limitations of existing toolkits. We identified three main methodological approaches. The first refers primarily to practitioners with DT training who use one of the popularized DT models to solve a conservation challenge without adapting or changing this initial model. The second refers to a sub-group of toolkits that have been customized for sustainable development considering its environmental, social, and economic aspects. These present specific tools aimed at sustainability that are born from customization and adaptation of tools from the main methodologies. Even though there are some sustainability-oriented tools, these are not specific and are insufficient for the field of environmental conservation. The third group consists of toolkits for conservation practitioners that allow for more "agile" innovation within the conservation field. These include agile and visual approaches that design methods have influenced. Although there is an apparent effort to make these tools more user-friendly, we observed that this second group of methods was still heavily oriented to conservation professionals (scientists) and was still highly

complex for bottom-up, community-led conservation. All these models are non-linear, exploratory, and iterative in nature (Lockwood & Walton, 2008). In general, these models are better approached with adequate mindsets that, whether explicitly or anecdotally stated, provide guidance on "ideal" cognitive, attitudinal, and behavioral components to foster creative problem-solving.

The main methods consulted have been summarized in the following list:

1. **Design thinking methodologies**: Innovation models characterized by a set of explicit steps, using divergent and convergent cycles iteratively.
    - Human-Centred Design (Ideo, 2015)
    - The Loop (IBM, 2018)
    - Framework for Innovation or "Double Diamond" Methodology (Design Council, 2018)
    - The five stage-model (Interaction Design Org, 2020)
2. **Design for sustainability methodologies:** This is a sub-group of DT that has customized models and tools for sustainable development.
    - SDO sustainability design orienting toolkit (Vezzoli et al., 2017)
    - Collective action toolkit (frog, 2019)
    - The circular design guide (Ellen MacArthur Foundation, 2017)
    - The biomimicry toolbox (Biomimicry Institute, 2017-2022)
    - Beyond net-zero – A systemic design approach (Design Council, 2021)
3. **"Innovative" conservation methodologies:** Conservation methodologies which provide a step-by-step process, together with tools for each step. The Miradi software can be complementary to the Open Standards for the Practice of Conservation or used independently.
    - Conservation by Design (The Nature Conservancy, 2016)
    - Open Standards for the Practice of Conservation (Conservation Standards Organisation, 2020)
    - Miradi Software (Conservation Measures Partnership, 2004)

While each of these methodologies provided inspiration and insight for our research, no single approach was entirely adequate for the grassroots conservation community. The toolkits from the third group were too complex and required specialist knowledge while those from the second group proved non-specific enough for conservation purposes.

One of the central deficits we found was the lack of space for non-dominant worldviews. The surveyed methods did not provide enough openness to alternative ways of knowing and being characteristic of Indigenous communities with a deeper, spiritual relationship with the land.

This led us to design a new methodology that would follow a "pluriversal" approach (Escobar, 2019) which would hold space for connection and provide easy-to-follow steps specifically tailored for conservation projects. Finally, we proceeded to select, refine, mix, and adapt some of the existing tools and design new tools that would adequately fit each design phase. The resulting new toolkit has been called "Design for Conservation."

The Design for Conservation Methodology
Design for Conservation (D4C) is a systemic approach to innovation that draws from design methodologies to find solutions to challenges that arise from the interaction between people and the natural environment. Figure 3 shows a visual representation of the five stages of the D4C methodology: (Re)Connect, Understand, Propose and Validate, Plan for Impact, and Deploy Sustainably. These stages are non-linear and are structured as a spiral, with the (Re)connect stage at the center as it acts as a "guiding star" for all other steps.

Figure 3. Visual representation of the Design for Conservation methodology, presenting five stages in an iterative, agile, deep spiral with the (Re)Connect stage as the "guiding star."

D4C Stage	Rationale	Tools
(Re)Connect	By re-connecting participants to themselves, their community, and their land through empathy, D4C fosters the necessary mindsets for genuine, committed, creative, and adaptive problem-solving.	• D4C mindfulness opening exercise • Reconnection rituals canvas • Reconnection stories canvas • Maramataka: Environmental calendar • Embody the D4C mindsets • Botanical empathy
Understand	Understanding environmental issues requires systems thinking, embracing ambiguity, and re-connecting to the sources. To do unbiased research, we have to unlearn our preconceptions and understand that the experts can be the people closest to the land, the species, and the problem.	• Conservation challenge canvas • Stakeholder characterization • Stories as insight • Agile interviews • Immersive field trip
Propose and Validate	Getting inspiration from natural systems is one of the oldest approaches to problem-solving. Sourcing in slow, ancestral knowledge while using the latest technologies can yield highly innovative yet resilient ideas. Rapid prototyping can cut costs on testing, learning from early failure and iteration, evolving while doing, and adding definition to initial ideas.	• Inspired ideation lotus • Idea selection checklist • Feedback and iteration tool • Service delivery blueprint
Plan for Impact	Measuring impact is one of the most critical tasks in environmental projects. Here, the agile-to-deep approach provides a realistic path, allowing teams to use agile versions of impact measuring techniques that require fewer resources.	• Sustainability radar and checklist • Impact planning tool • Unintended impacts canvas
Deploy Sustainably	Deploying means further defining your ideas in order to bring them to effective action. This activity is comprised of tools that will help materialize your project. Whether for-profit or non-profit, most of these ideas start locally and small before scaling and replicating.	• Contextual system map • Stakeholder motivation matrix • Sustainable growth plan

Table 1. Rationale and tools for each of the Design for Conservation steps.

Each stage presents a set of tools, where the difficulty, allocatable time, materials, and paper templates are presented in the online platform. The aim and steps of each tool are explained as well. Table 1 shows each stage, its rationale, and the available tools. Users can choose to follow all steps in order, with the advice of returning to the (Re)Connect stage in between the other steps to avoid losing sight of the project's purpose and values. More experienced users can use the tools from one phase only, combine stages, and adapt or change tool templates as needed.

The agile-to-deep iterative approach consists of a spiral pathway where users can choose how deep they can go based on their availability of resources and time. This way, users can plan some short-term and longer-term goals that are flexible and based on feedback loops. This means that a team can start small with an agile design thinking approach to solving a problem. After each problem-solving cycle, the team will start gaining more and more insight into the issue and its complexities, so they will feel confident in allocating more funding, calling in specific experts, and learning from feedback. At this point, the team might iterate by going deeper into one particular aspect, using the original model on which the agile tool was based. These cycles of iterations would cover different aspects of the problem if such depth were needed.

Decolonizing Methodologies and Indigenous Perspectives

The D4C methodology was born as an effort to decolonize dominant social paradigms (DSP) in conservation practices. A society's DSP represents the values, beliefs, institutions, and habits that combine to create the lens through which its people view, interpret, and understand the world around them (Kilbourne et al., 2002). The current DSP in most Western cultures has a deep belief in the value of economic growth, has faith in technological solutions to wicked problems, understands well-being as increasing levels of consumption, and places the individual needs, rights, and freedoms of consumers above the welfare of other species and future generations, amongst others (Upreti, 1994). In synthesis, we refer to the mainstream, Western, Northern, patriarchal, and colonial approaches prevalent in industrialized countries. The different stages and tools of the D4C process aim to highlight the importance of decolonial and pluriversal approaches to solving grand challenges.

Throughout this project, we have intended to create a methodological bridge that enables collaboration between different stakeholders, understanding that they might come from diverse backgrounds, races, cultures, and systems of knowledge. The method acknowledges and celebrates that these diverse groups will have various motivations and specific agendas responding to their own community priorities. As a result, we mean to offer structure but allow for this structure to be modified and adapted to serve specific demands and contexts. This has been partially achieved by designing highly visual "canvases" where ideas can be presented and shared in many expressive formats (e.g., text, drawings, acting, etc.). The visual language has intentionally been disruptive from main Western graphic styles and has sought to incorporate the spiritual dimension through semiotic elements. A set of adequate mindsets were also created to provide overarching values to guide the process (Baron & Ghelich-Khani, 2021).

This method is expected to open the methodological conversations to different voices and literacy levels. Specifically for New Zealand, the D4C workshops seek to build transdisciplinary knowledge between Western scientific paradigms and Mātauranga Māori, hopefully opening the path to other Indigenous approaches, worldviews, or knowledge systems.

The Mindset Cards tool is one example of how the proposed methodology promotes a more holistic approach and creates space for other types of knowledge. Using bio-inspiration, we have defined seven mental models that are coherent with the principles that govern both natural systems and humans as an integral part of these systems: honest, positive, balanced, humble, cyclic, systemic, and relative (Baron & Ghelich-Khani, 2021). This tool is a central part of the (Re)Connect stage and aims to help teams adopt new mental models that are coherent with the principles that govern both natural systems and themselves as an integral part of these systems.

Figure 4. Mindset Cards present seven mental models that are coherent with the principles that govern both natural systems and humans as an integral part of these systems.

The "Balanced" card aims to promote balance between soft and hard approaches, as they are complementary, interconnected, and interdependent in the natural world. This card explains balance using the principles of Yin (feminine, moon) and Yang (masculine, sun). Yin and Yang represent the concept of duality balanced in an indivisible whole, describing how seemingly opposite or contrary forces may actually be complementary, interconnected, and interdependent in the natural world and how they may give rise to each other as they interrelate to one another. Yin refers to the feminine energies in life, and Yang refers to the masculine energies in life. Feminine energy is about being, waiting, and caring while masculine energy is about doing, efficiency, and results. Masculine qualities are dominant, strong, independent, assertive, brave, disciplined, rational, etc. Feminine traits are emotional, collaborative, nurturing, vulnerable, caring, humble, intuitive, creative, understanding, etc. When looking at the feminine – the Yin – it becomes evident why the natural realm is traditionally presented as female, why mother earth is a mother and not a father, and the qualities we need to foster within projects to restore balance. These

Figure 5. The Balance Mindset card that explains the benefits of hybrid methodological approaches.

Tool Validation and Outcomes

The D4C methodology was used by students of the course *Design for the Natural Environment* at the University of Auckland for two consecutive years. This Bachelor's level 2 course runs for one semester and has an enrollment of roughly 50 students per semester. It is essential to mention that most design students at the University of Auckland are part of conjoint studies, which means they integrate another discipline into their degree (such as science, psychology, business, etc.).

For the first year, we decided to focus on the Hauraki Gulf[1] Ecosystem restoration because it is geographically close to the university campus and because we collaborated with experts from the marine sciences program.[2] We collaborated with the Hauraki Watershed Group,[3] which had just run a series of community consultations that captured the voices of community stakeholders such as Iwi (Māori tribes), policymakers, citizens, scientists, industry, and academia. This document and a scientific report describing the material state of the gulf[4] provided high-quality secondary data for students to frame their design challenges. Finally, we collaborated with the Hauraki Gulf Forum[5] secretary, an Auckland Council subsidiary. Students worked in groups of four to five people and went through the five steps of the D4C methodology (see Table 1), consulting with the stakeholders listed above. As part of the process, students made field trips to appropriate natural locations and conducted further interviews. Students' concept solutions were pitched to the external stakeholders and refined on the basis of the pitch feedback to be finally presented for course evaluation. One remarkable student project was later presented at the Hauraki Gulf Forum assembly. This project introduced a product stewardship scheme focused on commercial fishing nets and promoted accountability for discarded nets (ghost nets) and a reward system for distributed retrieval.

For the second iteration, we decided to work on terrestrial ecosystems and chose the New Zealand Bush. The process followed was similar to the first iteration but invited a suite of terrestrial ecosystem stakeholders. Both years we had some in-person and some remote sessions with students and stakeholders due to the impacts of Covid-19.

This methodology was also remotely presented and partially tested during a four-hour workshop at the Sustainable Development Summit in Aotearoa[6] and other scientific and non-scientific conservation events.

Students and external stakeholders provided feedback regarding the methodology, which allowed for the constant adjustment of the method, the creation of new tools, and the fostering of adequate mindsets. In general, the methods were broadly celebrated. The teaching team's biggest challenge and most significant learning opportunity were to make the toolkit inclusive of Indigenous perspectives. Concerning this, some points were carefully considered:

- **Connecting to oneself, the team, the community, and the environment:** The (Re)Connect stage[7] was enjoyed and praised, highlighting the importance of fostering trust and genuine care relationships. The Mindsets card also helped frame the attitudes expected from the teams in terms of worldviews and balancing different ways of knowing.
- **Supporting Mātauranga Māori (Maori knowledge) through tools:** After collaboration with an indigenous scholar, we were kindly allowed to add a Māori environmental calendar – the Māramataka[8] – to the toolkit as part of the (Re)Connect stage.
- **Storytelling as insight:** We decided to include storytelling as a valuable way of learning, both through the (Re)Connection stories canvas and through the stories as insight canvas.[9]
- **Personhood of non-human beings:** We have made space for non-human personas[10] to be represented as stakeholders in the process: not only animals and plant species, but also rivers, mountains, and any other physical or metaphysical being that deserves consideration within the project context.
- **Qualitative/experiential value:** The Impact planning canvas[11] encourages participants to determine non-quantitative measures of impact that are in line with spiritual perception (such as the Mauri[12] or of a place).
- **Pace/timing:** One of the main limitations of Western DT methodologies is the "agility" of the method. Sprinting through stages does not leave room for individual self-reflection or meaningful engagement with others. This has been a difficult adaptation since institutions keep pushing for a faster pace and quick results, time being a scarce resource. This is why we have proposed cycles of iterations that go deeper, making the engagement long-term and broken into smaller working stances.

- **Inclusive ways of learning**: Finally, the overall language of the templates is still quite academic and complex; simplifying the language would allow more people to feel comfortable with this method. We are now creating short tutorial videos[13] explaining each tool to provide clear examples and making learning more inclusive through visual prompts.

These are just some relevant examples of how this toolkit aims to embrace pluriversal worldviews. Note that the addition of Mātauranga Maōri is culturally adequate and appropriate to the country of Aotearoa, New Zealand, and that international participants are encouraged to explore other Indigenous worldviews from their context or genealogy.

Conclusion and Future Steps

Conservation issues are complex and multi-layered; in many cases, small grassroots organizations closest to the problem do not have the tools to design a plan of action that could lead to the desired conservation outcomes with the available resources and within a reasonable time frame. The general objective of this research was to co-design conservation-centered tools that are adaptable and versatile enough to fit any project and context while allowing customization concerning place and culture.

Design for Conservation seeks to promote collaboration between different stakeholders where "experts" in the conservation field might be scientists. However, "experts" are considered the people closest to the land and are most affected by the local consequences of global problems. These partnerships between local community members, scientists, educators, policymakers, etc., enable an adequate transdisciplinary approach. When running D4C workshops, organizers should identify members of these sectors and try to bring them to work together to find solutions to the unintended local consequences of the grand challenges.

The method acknowledges the importance of a local (decolonized) approach to solving grand challenges and the diversity of small solutions that will aim to address these challenges as a resilient network, making "global" a network of "locals." The relation to place provides not only valuable insights but also the motivation and commitment to look for long-term solutions that do not deplete the environment, that source on local know-how, and that can adapt quickly to disruptions through decentralized, bottom-up decision-making. This method is explicitly versatile and adaptable, inviting participants to define their own roadmap. Figuratively speaking, the D4C strategy aims to provide structure as a common ground for participants to stand in, not a ceiling limiting possible outcomes. There is no ceiling: the method is open. It provides tools, not solutions. It is aimed to enable and empower any diverse group to find their own answers.

As the window of time to address environmental issues shrinks, it becomes imperative for communities to quickly develop conservation strategies independently and autonomously, using their available resources. Design methodologies can support the achievement of sustainability and conservation goals by facilitating collaboration, structure, agility, innovation, and community engagement. However, for this change to be transformative and resilient, we need to collaborate as an interdisciplinary community, from the mental models to the practices level.

After two consecutive full-cycle iterations, we have published a methodological toolkit consisting of 5 stages, offering a user-friendly step-by-step "agile-to-deep" approach, including 21 tools for sustainable innovation within the environmental conservation sector.

The D4C process can be learned and facilitated by anyone. As in any learning process, while results can be immediately seen, it takes time to master this process and its methods. Anyone can think like a designer, but we must not forget that designers are specialists in the design thinking field. While designers are optimal facilitators, they are not specialists in all the environmental and social areas that need to come together to tackle these complex, wicked problems we are dealing with. Similarly, experts do not need to come from academic fields; usually, the people more connected to their land (such as Indigenous communities) can provide the critical knowledge and experience required for innovative solutions to arise.

This project was born in an effort to provide solutions to grand challenges, enabling collaboration through a pluralism of context-related approaches. One of the characteristics of grand challenges is that they do not have a beginning and an end; they are continuous and cyclical. Therefore, an essential aspect of the method is that it is designed to continue the partnerships that might have been initiated throughout the workshops to ensure long-term reciprocal benefits. The proposed collaboration should not end when the project ends; it should be a genuine, mutually benefitting partnership that sustains efforts after the project has finished. Because of the nature of these grand challenges, a key element is the maintenance of natural human alliances in a collaborative ecosystem.

We expect the impact of our toolkit to be represented by the projects that different groups can effectively and collaboratively carry out and sustain. Another broader impact is that this project will evidence the benefits of acknowledging the scientific value of hybrid methodologies within traditional Western institutions.

The final version of the D4C toolkit will be open access, uploaded into a digital platform for anyone to download, use, share, adapt, and re-share. The aim for this is fast dissemination and further collection of feedback. Users will be encouraged to have transparent, open conversations about case studies and experiences with the method. Future steps consist of further dissemination of the current toolkit and periodic revision and cyclic adaptation to the needs of the context.

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[7] See more in https://www.design4conservation.com/d4c-toolkit

[8] Tool available in https://www.design4conservation.com/maramataka-environmental-calendar

[9] Tool available in https://www.design4conservation.com/stories-as-insight

[10] Non-human persona canvas https://www.design4conservation.com/stakeholder-characterisation

[11] Tool available in https://www.design4conservation.com/impact-planning

[12] (Noun): Life principle, life force, vital essence, special nature, a material symbol of a life principle, source of emotions - the essential quality and vitality of a being or entity. Also used for a physical object, individual, ecosystem or social group in which this essence is located (*Te Kōhure Textbook*, 2nd ed., 227-228).

[13] See pilot video in https://www.youtube.com/watch?v=WUbv5hBOn6Y

DESIGN FOR SYMBIOCENE. HYBRID MATERIALS AND SYMBIOTIC OBJECTS – IN-BETWEEN THE GROWN AND MADE

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Abstract
This professional paper is a part of ongoing experimental design research aimed at examining the conditions under which living materials combine with human-made materials and designed objects, potentially creating hybrid materials and symbiotic objects. The research combines biology, microbiology, and mycology knowledge into the experimental design practice. Research results contribute to applying existing scientific knowledge to design practice, eventually making it possible to apply to a novel chapter of symbiotic design.

Rapid technological progress and the culture of "materiality" drive a growing demand for materials. Plastics, synonymous with materiality, symbolize anthropocentric civilization where the biological habitat (including the human body) is gradually becoming a hybrid of living and synthetic materials (i.e. hybrid materials). There are various bacteria, fungi, algae, and other microorganisms with whom we might codesign new hybrid materials and symbiotic objects. It proposes a new idea of "materiality." It opens symbiotic design opportunities (i.e. design within nature) that eventually might contribute to the transition from the Anthropocene, where human activity has a dominant influence on climate and the environment, to Symbiocene, where human action is exemplified by mutual interdependence and benefit for all living beings, species, and health of ecosystems.

To explore the opportunity, design experiments are carried out by selecting three types of living materials: wheatgrass, mycelium, and bacteria. The following materials are tested in terms of two growing condition types: 1) *growing mediums* – learning from natural sciences and adopting scientific methods for an artistic research practice by transferring the laboratory to the designer's studio; and 2) *designed structures* – trying to expand the scientific research on growing specific living materials by searching for different application methods in a design environment and observing how different surfaces and structures influence living materials to grow into symbiotic objects.

This research provides insights on enabling and limiting conditions for designing hybrid materials and symbiotic objects which can have practical implications for developing

more circular products and public spaces. Further theoretical research on material and circular design might also explore these results.

Author Keywords
Symbiotic design; symbiotic products; material design; hybrid materials; design for circular economy; circular products.

Introduction

According to Berrien Moore III (2000), in the Anthropocene, the so-called new everyday life is characterized by uncertainty, unpredictability, chaos, and relentless change. Should we not think of this era as the new abnormal? The Anthropocene thus should be addressed, together with sustainable forms of producing (less), recycling, and co-existing with other species, in line with a socio-political and cultural shift: a passage from humanism to post-humanism, here underlined in its specific meaning of post-anthropocentrism. At this stage, the survival of the human species is related to the environment's well-being. Therefore, the existence evolves in relational, symbiotic, entangled interacting processes (Ferrando, 2016). Environmental philosopher Glenn Albrecht (2020) argues that humanity needs to move on from the story of the Anthropocene and proposes an idea for the next era: the Symbiocene (from the Greek symbiosis, or companionship). The scientific meaning of the word "symbiosis" implies living together for mutual benefit (Smith & Douglas, 1987).

The core concept of the Symbiocene is that life is interconnected, where the idea of autonomous individuals is mistaken. The Symbiocene represents a form of green thinking that is anti-growth in all contexts that fail to respect the symbiosis but pro-growth for new types of enterprise that do respect it (Albrecht, 2019). While there were attempts to build a new and viable society around concepts such as democracy, sustainability, sustainable development, and resilience, all these terms have been corrupted by forces determined to incorporate and embed them into the Anthropocene, where they become normalized – i.e. business as usual. The question of the survival of humanity and the perception of the whole ecosystem is not only technological but also cognitive, emotional, cultural, and philosophical. As our species increasingly invades the planet's wildlife, destroying entire ecosystems, natural climates, ecology, and other naturally occurring mechanisms, a people-centered – anthropocentric — approach cannot be further promoted and tolerated. So, in today's ecological crisis, the search for design materiality oriented to nature becomes extremely important and turns against anthropocentrism as initially, human beings and nature are co-evolutionary (Du Plessis & Cole, 2011; Zhang et al., 2015).

The collaboration with living materials might help to implement the idea of symbiomimicry proposed by Albrecht (2015) as a new practice in design, which means a mixture of symbiosis and biomimicry when learning from nature does not benefit humanity but promotes reciprocal interactions between all life on the planet.

Bio art and living material design are increasingly evolving and gaining popularity around the globe as a new field of alternative art and design practice (Lapworth, 2016). In this artistic research, the living materials and microorganisms are invited to join as creative assistants and co-authors, analyzing the relationships between the grown (by nature) and made (by humans). The following questions are addressed by practical experiments:

- How might different object shapes designed by a human being affect the "choreography" of living materials, and how might they influence the reaction (adapt/do not adapt) of these materials to the new structural reality?
- Which properties of materials are created, and which are lost?
- How might the limits of already studied material parameters be pushed?

It is assumed that raising these questions and incorporating living substances and microorganisms into experimental design processes might yield new practical knowledge valuable in the symbiotic design practice.

Wheatgrass, mycelium, and bacterial cellulose (Acetobacteraceae) are materials growing in different mediums and specific conditions (Wigmore, 1985; Antinori et al., 2021; Iguchi et al., 2000). These types of living materials are used in art and design, such as jewelry, building materials, and paper as well as in medicine as a source of drugs and psychoactive substances (Flannery, 2007; Jami et al., 2019; Ververis et al., 2004; De Smet, 1997). Further uses include the production of sustainable packaging; thermal and acoustic insulation materials and architectural elements (Abhijith et al., 2018; Jones et al., 2017; Pelletier et al., 2013; Soh et al., 2020; Attias et al., 2017); and vegan leather and temporary substitutes for human skin burns (Jonas & Farah, 1998; Gupta & Dave, 2021). Still, these materials are not widely researched in terms of the growing process and growing techniques, recognizing the natural growth of these materials as the design process. It limits the possibility of developing complex shapes that could expand the range of applications for wheatgrass, mycelium, and bacterial cellulose growing into new designed objects.

This has led to launching the experiments while collaborating with the living materials mentioned above and searching for untested ways to grow them using biological, mycological, and microbiological research methods. An overview of the living materials application in contemporary art and design (Wright & Baracco, 2018; Zhou et al., 2021; Vartiainen, 2018; Maurer et al., 2019; Heisel et al., 2017; Bandyopadhyay et al., 2018; Gazzar, 2021; Pasquero & Poletto, 2020) allowed the authors to identify the gap within the present body of knowledge on different cultivation techniques and provided inspiration to start the growing experiments. Although there is much scientific knowledge about living materials and their growing mediums, applying this knowledge in design is still limited. The scientific findings are not necessarily applicable to the product design, as the theoretical findings are barely tested in the design practice. Testing scientific knowledge within the experimental design practice might provide exciting insights into growing/designing symbiotic objects. In addition, the current research describes only some of the possible application/cultivation technologies.

To fill this gap, this experimental study aims to use the existing knowledge about cultivation media and expand the "cultivation" technique during the design experiment. The aim is to experiment between the scientific laboratory and the designer's studio, testing the available scientific knowledge about the growing mediums for living materials in the design process and observing the enabling and limiting conditions for the co-design of hybrid materials and symbiotic objects, capturing the set of circumstances that is most suitable for design. The co-design process is understood as designing together with living materials.

In the following sections, the practical research on the cultivation of living materials will be presented in terms of two growing condition types: 1) *growing mediums* and 2) *designed structures*.

Growing Mediums

In this research, the living substances are distinguished by their ability to move and reproduce, but they are limited to living organisms that do not have a central nervous system and therefore cannot feel pain: plants, fungi, and bacteria. The test conditions were experimental, without any high-quality technological equipment, instead of trying to test and apply the scientific knowledge under the designer's studio environmental conditions. The mediums selected for the experiments were those in which, according to the research mentioned above, wheatgrass, mycelium, and bacterial cellulose grow the best. The iteration process to generate a sequence of outcomes took around six months.

Wheatgrass

This experiment tests various growing mediums and growing living materials at a designer's studio. First, the aim was to find out which medium wheatgrass likes the most and how it influences the forming of the plant root structure. Two human-made structures – (1) metal mesh and (2) woven linen cloth – were used in the experiment as the growing structures. The objective was to find out in which conditions the wheatgrass would grow fastest with no additional growth; root development was used as the main criteria for success. Different mixtures of growing media were made from:

- soil,
- white clay,
- potato starch bioplastic,
- soil mixed with potato starch bioplastic,
- white clay mixed with potato starch bioplastic, and
- recycled cellulose fiber with potato starch bioplastic.

Wheat cultivation samples were watered every other day and stored at room temperature without using any additional light or heat source. The results of the cultivation experiment showed that wheatgrass did not germinate in the samples with potato starch bioplastic and the mixture of processed cellulose fiber and potato starch bioplastic, while in the samples with white clay and soil with potato starch bioplastic, it germinated only partially. Although the growth of wheatgrass on a metal wire mesh in a mixture of white clay and potato starch was adequate, the wheatgrass germinated very sparingly on the linen fabric structure. The best results of the experiment were shown when growing wheatgrass on both structures in a soil mixture.

Mycelium

During mycelium growing experiments, oyster mushroom spores (Pleurotus ostreatus) were purchased from an online store. It is a species that can bear fruit bodies almost all year round. The culture is easy to grow indoors, making it perfect for beginners. In these experiments, the focus was not on the fruit bodies but mycelium – the root system of the fungus. The spores were mixed with different substrates: fibrous hemp, sawdust, spent grain, and wheat, to find out which fungus best binds cellulosic material. Although the suppliers' page says that oyster mushrooms grow well on straw, it turned out that straw is much more challenging to sterilize well without autoclaving, so the straw was given up and all the other substrates were sterilized in a very primitive way – by boiling. Theoretically, such a method of sterilization is not indicated as an effective one, as most of the sources mention the need for a sterile environment for growing mycelium and that this is the most significant technological challenge for their cultivation (Vallas & Courard, 2017; Ghazvinian et al., 2019; Dessi-Olive, 2019). It was decided that a growing box could help in this situation, so a greenhouse was built, providing at least a little more sterile space and a dark environment. It is not precisely known if it was due to the greenhouse, but the fungus started to grow very rapidly and aggressively on all substrates. When mixing mushroom substrates, the new technological possibilities of cultivation were captured, as the mushroom root system is mainly used for solid object production, and other cultivation alternatives are just starting to be explored.

Bacteria

The combined mass of all bacteria on Earth is about 1,166 times that of humans (Bar-On et al., 2018), and the trillions of microorganisms in the adult body account for up to 3% of body weight (Sender et al., 2016), potentially indirectly affecting our well-being, emotions, or perception of the world. Bacteria provide other life forms with the necessary nutrients by converting dissolved compounds into energy (Kennedy, 1999) and live in symbiotic and parasitic relationships with plants and animals (Boursaux-Eude & Gross, 2000), which encourages not only deepening the knowledge of existing relationships but also analyzing the relationship between bacteria and the human-made environment. Analyzing the target literature and looking for specific properties of different bacteria (Xu et al., 2018; Hastings et al., 1985; Ghasemi et al., 2020; Gupta et al., 2021), well-known bacterial cellulose (Acetobacteraceae) was found. It was perfectly suitable for this research, as it is safe to work with and grow in a studio or home. This type of bacteria oxidizes sugar or ethanol and produces acetic acid during fermentation, making it widespread and playing an essential role in the production of food and beverages such as vinegar and kombucha (Gomes et al., 2018).

According to the recommendations, a more considerable amount of nutrient medium for symbiotic culture of bacteria and yeast (SCOBY) was produced: two tablespoons of green tea leaves were poured into a liter of hot water and mixed with four tablespoons of sugar. The tea was strained and poured into a larger container to cool down, and this process was repeated for a couple of hours until two kilograms of sugar and a whole packet of green tea were consumed. The 80 liter container (710 x 460 x 300 mm) was filled almost halfway and left to cool down overnight. The next day a SCOBY culture with some kombucha fluid was placed into a container. The container was covered with a cotton cloth and left to grow. After two weeks, the first sample of bacterial cellulose was removed from the medium and dried on a plywood sheet for a couple of days following recommendations (Lazaro Vasquez et al., 2020). This process should help it absorb excess water and dry evenly. The first sample was relatively thin and stuck to the plywood, making it difficult to peel off the sheet. Finally, a thin but robust, semi-translucent, and moisture-resistant sample of bacterial cellulose material was grown. For the second time, it was decided to extend the fermentation process and try to grow a thick sample of kombucha culture. It took one month to grow, but it was thick enough, even heavy, and difficult to transport from the fermentation container to the metal mesh surface prepared for drying. The exact process was followed the third time, but the fermentation period was shortened to three weeks.

Findings on the Growing Mediums
Although the growth of wheatgrass on a metal wire mesh in a mixture of white clay and potato starch was adequate, the best results of the experiment were shown when growing wheatgrass on both structures in a soil mixture. The experiments with growing mycelium helped the authors discover that a sterile environment is not always necessary and that the oyster mushroom (Pleurotus ostreatus) can grow rapidly and aggressively on all substrates. While growing the bacterial cellulose, many samples were ruined because the mold grew on top of a SCOBY culture. The most helpful finding was the non-intervention method – the samples molded when the designer was always around the studio, but the materials grew significantly better when left alone for two to four weeks.

Designed Structures
The metal chair constructions were used as designed structures in this part of the research. They were chosen not by chance but to show an iconic everyday object functioning as a symbiotic design. The constructions were donated, so the objects are also based on the upcycling concept. The test conditions were experimental, without any high-quality technological equipment, rather than trying to test and apply the scientific knowledge under the designer's studio environmental conditions. The iteration process of different experiments took from two days to one month.

Wheatgrass
After the initial growth of living materials in different media on a linen cloth and metal mesh structure, the wheatgrass started to grow directly on metal frames, observing how the shape of a designed object affects the choreography of wheatgrass and how the material adapts to the new structural reality. The wheatgrass was grown a) on a metal structure in a mixture of soil and potato starch, b) on a linen cloth attached to a metal structure, c) on a metal wire mesh in a mixture of soil and potato starch, and d) on a linen cloth which at the beginning was placed on a flat surface and only after the germination was attached to a metal structure. Frames with wheatgrass seeds were watered every other day and kept at room temperature without additional light or heat.

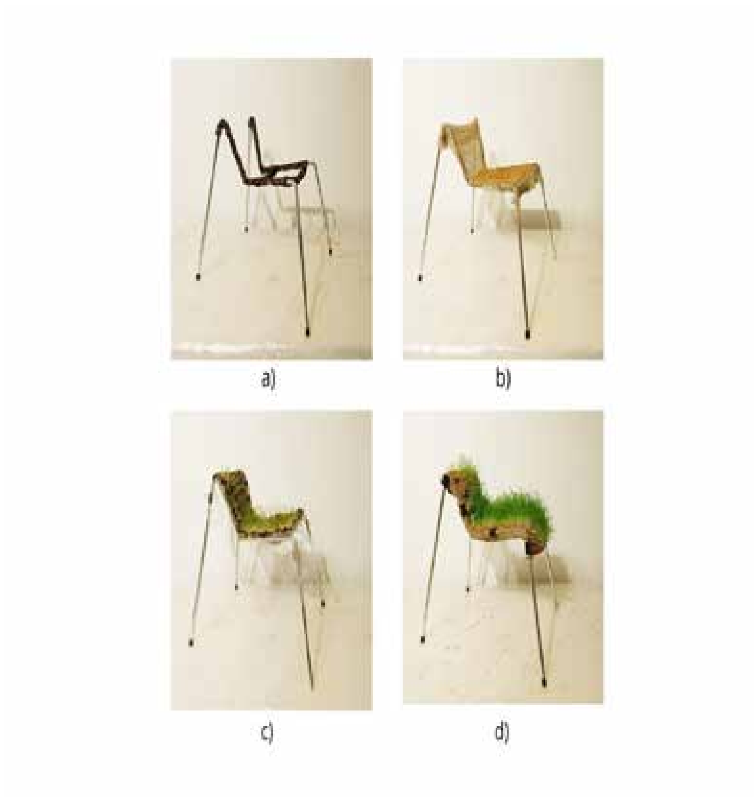

Figure 1. Creative wheatgrass growing process (source: personal album).

The results showed that test a) did not work, and the wheatgrass did not germinate because the roots of the plants were missing an additional structure to take root.

Experiment b) was only partially successful. In this case, the wheatgrass placed its roots, but the seeds showed no signs of life. During the experiment, it was realized that the roots need to lean somewhere – they cannot just hang in the air and grow in different directions. After one week, the support base was made from a plastic film, and a few days later, the plants started to grow. Unfortunately, the wheat germinated only in the middle of the seating plane, as the marginal seeds received less moisture due to the diagonal angle.

The third experiment c) showed better results than the first two experiments, but the wheatgrass seeds were germinated in advance. The seeds were grown in a hybrid soil and potato starch bioplastic medium, which was formed by applying the material to a metal mesh structure. In this case, the wheatgrass roots also had nowhere to rest, but the grasses grew efficiently enough. The growth of wheatgrass seedlings in the vertical position was much worse than in the horizontal position.

In experiment d), wheatgrass seeds were laid on the linen cloth without an additional medium, first waiting for the wheat to germinate and take root in the tissue. After the grass and roots sprouted, the fabric was transferred to the metal frame structure and fastened with clamps. The wheat was lush, growing rapidly and efficiently, although a weaker growth trend could still be seen at the top of the vertical plane. However, the root growth was so aggressive that it has overgrown additional parts of the metal construction to form bulky parts of the root structure. This sample was removed from the construction and dried.

This experiment showed that wheatgrass could not adapt to growing under all designed conditions, but example d) demonstrated the best growth results. Currently, the wheatgrass experiments are being continued with the cultivation of the root system in special molds to form solid object elements based on Charles Darwin's theory of plant root behavior (Darwin et al., 2010) which says that roots do not grow passively down but move and observe.

Mycelium

After testing various mushroom growing media, the unique bag for growing mycelium was designed, placing it directly on a metal frame and shaping a soft part for the seating object. Just a few days later, it could be seen how the white root system colonized the entire volume of the bag and gradually bound parts of the hemp substrate together. Although no memorable holes were left, mushrooms began to grow through the cracks in the edges of the bag.

Figure 2. The creative process of growing mycelium. Living hybrid with a grown seating part (left) and the fruit bodies of the fungus Pleurotus ostreatus (right) (source: personal album).

After removing the object from the bag and seeing the initial results, it can be stated that allowing the object to grow fruiting bodies can weaken the fungal root structure. It is also noticed that when the fungus encounters the plastic film, the surface of the fungus is smooth and nicely formed; when encountering the paper adhesive tape, the fungus structure is relatively weak. Growing the fungal substrate directly on a metal frame revealed much new information that could be applied in further research on fungal cultivation in a design studio environment and developing the living hybrids.

It is assumed that to grow living structures on the human-made matter, it is appropriate to use modular elements that allow the substrate to fuse into a homogeneous object following the tendency of the fungus to grow and thus naturally connect individual parts of the object (Yang et al., 2021).

Bacteria
After the preliminary experiments on bacterial cellulose growing within a specific medium, the wet culture was transferred to the surface of the metal mesh and a metal seat frame to see if it adapted to a non-planar shape.

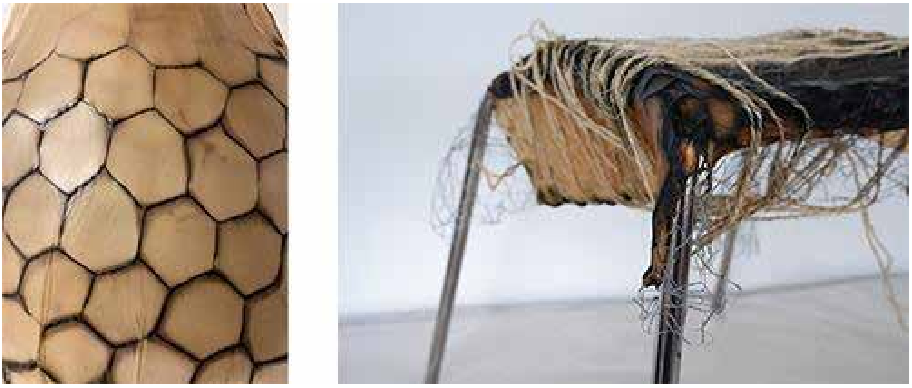

Figure 3. Creative bacterial cellulose growing process (source: personal album).

After three weeks of growing, the sample was dried for two weeks on a metal mesh which reacted to the metal and oxidized – the sample completely changed color and was opaque but strong enough for further shaping by bending.

The second bacterial cellulose sample was placed on a metal mesh and a seat frame. After about a week of drying, the SCOBY culture dried entirely and seemed to "overshape" the mesh structure, thus forming a living hybrid. In places where the metal frame and wire had the most vital contact with the surface of the bacterial cellulose, it repeated the surface of the metal mesh, suggesting the possibility of creating various patterns or drawings with metal pigments directly on the kombucha mushroom. Further experiments with bacterial cellulose will complement the study of hybrid living materials and focus on using SCOBY culture as a waterproof layer in creating living hybrids and symbiotic objects.

Findings on Designed Structures
During the experiment of growing wheatgrass on a metal construction, it was realized that the roots need to lean somewhere and have a support base to grow. The growth of wheatgrass seedlings in the vertical position was much worse than in the horizontal position. An experiment on growing wheatgrass on human-made structures showed that wheatgrass could not adapt to growing under all conditions, and it is necessary to germinate the seeds on the flat surface first. Only after that is it possible to apply the living material to designed objects. After the experiments with the mycelium growing on a designed structure, it can be stated that allowing the mushroom root system to grow fruiting bodies can weaken the mycelium structure. It is assumed that to grow living

structures on human-made matter, it would be appropriate to use modular elements following the tendency of mycelium to connect individual parts of the object. While experimenting with bacterial cellulose drying on a metal mesh, it was found that the SCOBY culture reacts to metal and oxidizes. It can be said that the technique of drying on a metal mesh can be applied to design various patterns or create drawings with metal pigments directly on the kombucha mushroom. After drying the living culture for one week, it can be assumed that it over-shapes the mesh structure, thus forming a living hybrid very well.

Conclusion

After the experiments with wheatgrass, mycelium, and bacterial cellulose in two growing conditions, a set of enabling and limiting conditions are identified for designing hybrid materials and symbiotic objects. *Enabling conditions* for the design of hybrid materials and symbiotic objects: the mediums used for growing living materials are easily adapted for preparation in a low-tech scientific environment; the materials are not overly picky, so they can be adapted to grow in an experimental process to gain insights; there is no need for a very sterile environment as described in most scientific articles; and the discovered artistic cultivation methods create suitable conditions for the growth of living materials in a designer's studio. The *limiting conditions* are that living materials could not adapt to grow under all designed conditions and the long growing process in terms of time led to testing only a limited number of conditions and growing living materials only on one type of design structure.

Based on these research results, while living materials combined with human-made structures, creating hybrid materials and symbiotic objects, a set of recommendations for symbiotic design was generated to assist designers, artists, and innovators on their creative path towards the concept of symbiotic-centrism and a healthy environment for both human and nature while designing circular products. The recommendations are presented below as a set of six points to consider when creating a symbiotic design for a circular economy.

1. Design by thinking that life is interconnected and that the idea of autonomous individuals is mistaken;
2. Create a nature-oriented design instead of a human-centered design;
3. Practice symbiomimicry in design when learning from nature does not benefit humanity but promotes reciprocal interactions between all life on the planet;
4. Represent a form of green thinking that respects symbiosis;
5. Design by thinking that humanity and the perception of the whole ecosystem is not only technological but also cognitive, emotional, cultural, and philosophical; and
6. Design natural habitats for living organisms and ignite symbiotic relationships, contributing to a healthy environment for humans and nature.

The research results can contribute to better application of existing scientific knowledge to design practice, eventually making it possible to further work on a novel symbiotic design chapter. The obtained results supplement the existing knowledge with a comprehensive understanding of the technology for growing the living materials into specific artistic environments and symbiotic design objects. The results might be used for future research by applying the same experimental process to a more considerable number of design structures to build a broader follow-up study on designing symbiotic objects. The findings on the cultivation possibilities of living hybrids might inspire the design of natural habitats for living organisms and ignite symbiotic relationships contributing to a healthy environment for humans and nature.

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DESIGNING SYSTEMIC CHANGE FOR URBAN ECOSYSTEMS: A FRAMEWORK FOR ASSESSING SOCIAL INNOVATION

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Abstract

Developing systemic changes for decarbonization and adaptation to climate change at the urban level is a complex challenge which requires considering a systemic approach. Numerous cases, frameworks and theoretical models are described in the academic literature, starting to create a relevant body of evidence that designing social innovations at the urban level can change citizens' mindsets and behaviors toward more sustainable practices, at both social and ecological levels. Yet this rich and important body of knowledge is scattered across different fields and not yet systematized in a comprehensive framework that can provide actionable knowledge for social innovators, designers and policy makers aiming to design and assess social innovations. Based on a systematic multidisciplinary literature review, we develop a framework for the design and evaluation of social innovations in climate ecosystems, which comprise the consideration of key main categories of indicators: context, input, social innovation (SI) actions (capacity building, SI top-down/bottom-up initiatives and scaling) and outputs (short-term results, medium-term outcomes, long-term impacts). This framework has both theoretical and practical relevance as it can be utilized for managing complexity and for clustering social innovation initiatives and related indicators, which can be deployed for measuring the effectiveness of actions and policies in municipalities.

Author Keywords

Climate neutrality; framework; systemic design; city; classification; social innovation.

Introduction

Social innovation is emerging as a relevant category of innovation that can change people's behavior and mindsets (Gregg et al., 2020) and reconfigure socio-technical systems (Geels, 2020) for supporting climate neutrality. Such social innovations tackle problems in the society with a human-centered approach, prototyping new products and services that are social in the means and in the ends, and improving them through rapid experimentation cycles. The contribution of social innovation to climate neutrality, includes – but is not limited to – reducing consumption by establishing opportunities for sharing, repairing and reusing practices (Schanes et al., 2016), creating capacity building so that citizens and other stakeholders can solve environmental and social problems (and create related jobs and economic opportunities) and build contexts and platforms to support change through the engagement and upskilling of networks of actors within communities (Diepenmaat et al., 2020; Gregg et al., 2020). The potential impact of deliberately designing the emergence and scaling of social innovations in cities for the wellbeing of communities seems particularly relevant (Hoppe & De Vries, 2019). Yet policy-makers might still find it challenging to understand how social innovation can contribute to decarbonization, specifically because of the challenge of measuring social innovation's impact. While several scientific articles have provided theoretical support and empirical evidence of the benefits of deploying social innovation for tackling climate changes, a comprehensive framework that organizes existing knowledge and indicators is still missing. Indicators of social innovation effectiveness, for climate change in particular, are scattered across papers, projects and disciplines. We propose to fill this important gap, performing a multidisciplinary literature review and organizing existing scientific knowledge into a comprehensive framework of dimensions that is theoretically grounded and practically useful.

The methodology is based on a systematic literature review of social innovation in the context of climate neutrality from the fields of sustainability, energy, climate change, management and public policy. The review was conducted by searching for relevant keywords in Google Scholar and includes the results of government-funded research projects. The search resulted in 267 papers that were processed and categorized according to their relevance for the identification of social innovation indicators (Unceta et al., 2016; Hewitt et al., 2019; Cantafio & Ryan, 2020; Lukesch et al., 2020; Andion et al., 2021; Baer et al., 2021; Sörgel et al., 2021).

The systematization of such a large body of literature led to the identification of an overview of approaches to the evaluation of social innovation in climate ecosystems, which comprises the consideration of key categories of indicators: context, input (or resources), social innovation actions (capacity building, top-down/bottom-up initiatives and scaling) and outputs (results, medium-term outcomes, long-term impacts). This general framework structure is based on the logic framework (Knowlton & Phillips, 2012): context, input, actions, outcomes, impacts. We expanded the logic framework categories to account for the specific dimensions of social innovation identified through the literature review, including also learning cycles for the development of a continuous prototyping mindset, which is a typical design competency relevant for developing adaptation and resilience (Stocco et al., 2021).

We make a contribution to theory by providing a systematization of literature from related fields, intersecting social innovation and climate change with a focus on potential assessment, thus providing a framework for design-led research for sustainability. From a pragmatic perspective, this paper provides a specific contribution by proposing a usable framework for researchers and policymakers aiming to select, design and measure the effectiveness of policies and actions that support the co-creation of social innovations with multiple stakeholders.

Literature Review: Social Innovation Contribution Toward Climate Neutrality

Methodology

With the aim of identifying scientific papers from diverse disciplines that address social innovation for climate neutrality and decarbonization, we searched scientific databases and key scientific journals. We started by performing keyword searches in Google Scholar with a broad set of keyword combinations in order to identify articles from related fields that might use different terminologies. Specifically, we performed multiples searches in the databases by combining one keyword related to social innovation (social innovation, social innovation action plan, social impact, social value, social innovation ecosystems, wellbeing, social impact assessment, social innovation metrics) and a keyword related to climate neutrality (decarbonization, environmental sustainability, climate change, climate neutrality, carbon neutrality, net zero, carbon footprint, ecology, circular economy). In a second phase, key journals related to the topic of interest were manually scanned, specifically the scientific journals *Nature Climate Change*, *Sustainable Cities and Societies* and *Sustainability* for the last three years. This search resulted in the identification of 267 articles from 2008 to 2022, which included two special issues: "Social innovation and the energy transition," published in the journal *Sustainability* in 2018, and "The dynamics of sustainable innovation journeys" published in *Technology Analysis & Strategic Management* in 2008.

All articles were processed by reading the abstract and keywords in order to understand if the paper contained a relevant contribution to answer our research question in the form of a theoretical model, a framework or indicators related to social innovation for decarbonization. When the contribution was not clear from the abstract, the entire article was processed. The analysis of the abstracts led to the identification of 31 articles from the fields of sustainability, energy, climate change, management and public policy. An additional 10 relevant papers were identified from the reference list of the 31 identified articles, which contained dimensions relevant for the research question. All 41 articles were read and analyzed, and their outcome systematized in the following sections: providing the motivations for considering social innovation in the context of climate change; theoretical models and frameworks; and development of a comprehensive framework to classify indicators.

Motivation: Why We Should Consider Social Innovation for Climate Neutrality

According to identified articles, there are multiple reasons for considering social innovation a relevant lever for decarbonization. We can group the motivation into five progressive categories: from the most basic and necessary levels of (a) acceptance and (b) behavior change to (c) the systemic consideration of socio-technical systems and (d) empowerment, which (e) influence wellbeing.

At the most basic level, it was outlined that if there is no acceptance by organizations (in particular, incumbent firms), local governments, citizens and the various actors, energy transitions will fail (Nakano et al., 2018; Gregg et al., 2020). Social innovations can provide a relevant contribution for climate neutrality by bringing behavioral change toward more sustainable practices (Schanes et al., 2016; Grottera et al., 2020; Loyarte-López et al., 2020; Mukai et al., 2022). Schanes et al. (2016) quotes Edenhofer et al. (2014, p. 20) that

> [t]he mitigation report of the Intergovernmental Panel on Climate Change (IPCC) states that behaviour, lifestyle, and culture have a considerable influence on energy use and associated emissions and that stabilizing or lowering consumption, transitioning towards a sharing economy and adopting other behavioural changes have a high mitigation potential. (p. 1033)

Thirdly, a relevant number of reviewed articles discussed how socio-technical systems can be disrupted by niche innovations that can reconfigure the system. In fact, "[s]uch transitions not only entail new technologies, but also changes in markets, user practices, policy and cultural discourses, and governing institutions" (Geels et al., 2008, p. 521). In a highly cited paper published in *Science*, Geels et al. (2017) discuss socio-technical transitions for decarbonization, offering an overall framework which takes into account technical and social aspects, including people's behavior and the relevance of framing the discourse based on the case reported by Rosenbloom et al. (2016) that discusses and analyzes solar electricity in Ontario through a "discursive approach to understanding multi-dimensional interactions within socio-technical transitions" (p. 1275) with a new analytic approach that connects discourses and storylines to transitions.

The most discussed reason for paying attention to social innovation when addressing carbon neutrality seems to be found in its ability to empower supporting actors to take action to tackle climate issues. Diepenmaat et al. (2020) published a theoretical paper with the eloquent tile "Why sustainable development requires societal innovation and cannot be achieved without this" in which they describe the business perspective on transitions and discusses societal innovation as a distinct innovation type by proposing an "innovation cube" and discussing the "need for broader partnerships for societal innovation based on multiple value creation" (p. 1270). They outline that sustainable development needs collective action for creating new systems, which in turn requires social innovation. Furthermore, citizens need to take up a new role for finding and sustaining new business models for a circular economy (Diepenmaat et al., 2020). Wuebben et al. (2020, p. 567) conducted a systematic review of "citizen science and citizen energy communities" for sustainable development goals (SDGs) and call for citizen science to supplement typical citizen participation formats in energy communities, as it engages citizens in research and increases their literacy regarding energy systems. Providing concrete examples through the case of Scotland's journey to decarbonization, Ostfeld and Reiner (2020) report on the effects of citizens' juries and focus groups. Agarwal et al. (2012), based on an analysis of climate adaptation policies in 47 least developed countries, provide key lessons for adapting such plans to local needs, such as increasing local autonomy, creating "mechanisms for information sharing among decision makers across sectors and levels of decision making; and (4) improve accountability of local decision makers to their constituents" (p. 565).

Finally, three recent papers focus on wellbeing, since it is (or should be) the final goal of all social and technological innovations. Engelbrecht (2018) highlights the need to consider wellbeing when assessing technological and social innovations because we cannot assume that innovations are desirable, per se. We should rather keep focused on the final desired societal outcome. Also, Hoppe and De Vries (2019) focus their work on wellbeing, arguing that "[i]n the context of energy transition, social innovation can be defined as empowerment and social goals pertaining to the general wellbeing of communities" (p. 141). Creutzig et al. (2022) demonstrate that demand-side solutions for climate change mitigation are not only useful to support decarbonization but also to increase levels of wellbeing. Specifically, they propose a classification of three "mitigation potential of demand-side options: avoid, shift, improve" (p. 36) which seem relevant for classifying social innovations, in particular for the context of the circular economy.

Theories and Frameworks

Framing the Context of Energy Transitions

After establishing the key contribution that social innovation can provide for supporting the transition to carbon neutrality, we outlined the theoretical models, and frameworks emerged from the literature that can be relevant for social innovation assessment.

As the aim of the literature review is to develop a pragmatic framework for designing and assessing social innovation policies and initiatives that can contribute to climate neutrality, we review models and frameworks that have relevance in particular for local governments. We describe such models and frameworks, starting from the broad context of transitions to climate neutrality, then narrowing the focus to social innovation specificities.

In their paper published in *Science*, Geels et al. (2017) invite the public to go beyond individual elements and consider socio-technical systems, that is, the interlinked mix of regulations, markets, infrastructures, technologies and user practices, which in combination deliver value for society (Figure 1). They present the multi-level perspective (MLP) framework for understanding the complex causal mechanisms that characterize systems transitions for deep decarbonization. The authors map socio-technical system elements: (i) market and user preferences, (ii) science, (iii) culture, (iv) technology, (v) policy and (vi) industry. They explain how niche innovations can bring radical breakthroughs which trigger the adjustments of socio-technical systems. In the paper, the authors argue that the acceleration of transitions

> involves three mutually reinforcing processes: growing internal momentum of niche-innovations, weakening of existing systems [...], and growing exogenous pressures. The resulting socio-technical transitions go beyond the adoption of new technologies and include investment in new infrastructures, the establishment of new markets, the development of new social preferences and the adjustment of user practices." (Geels et al., 2017, p. 1244)

In particular, it is argued that to motivate citizens to change practices, beliefs, conventions, skills and purchase decisions, information about climate change threats and financial incentives should be complemented by positive discourses about the benefits of innovations for decarbonization. Business and citizen support for decarbonization can be built "through bottom-up learning processes, participatory governance and polycentric stakeholder" (Geels et al., 2017, p. 1245).

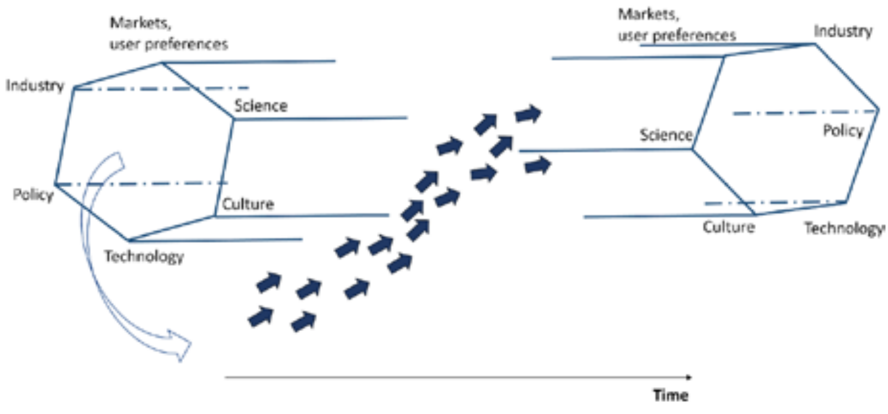

Figure 1. Socio-technical system elements.

In a more recent paper, the same author (Geels, 2020) further developed a "multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory" (p. 1). He reviewed the strengths and weaknesses of each of the three theoretical perspectives, highlighting their complementarity. Some of the identified strengths of social constructivism are, for example, the "interest in the shape and design of artefacts and patterns of use" and the "focus on cognitive processes." Among the weaknesses – or less elaborated topics – of the social constructivist approach, Geels (2020) identified the "idealist bias (limited attention for competition, markets, financial resources)" and "limited link to broader social sciences (due to dominance of micro-interactionism)" (p. 11). Regarding the second theoretical perspective, evolutionary economics, he identified among the strengths, the "deep understanding of 'material' processes (market competition, resources, performance, investment) and knowledge/capabilities," while among the weaknesses of the approach, we find the "limited understanding of institutions (as exogenous regulations)" and "limited interest in technical details (due to primary interest in economic implications of technology for firms/sectors)" (Geels, 2020, p. 11). Finally, the third theoretical perspective of neo-institutionalism has the strengths of showing "relational, processual understanding of institutions" and "recursive interactions between local practices and organizational fields" but the weaknesses of having a limited focus on "technology and 'material' dimensions" and "economic processes" (Geels, 2020, p. 11).

In "Why sustainable development requires societal innovation and cannot be achieved without this," Diepenmaat et al. (2020) review multi-disciplinary perspectives related to societal innovation for sustainable development, in particular the business literature on value creation, the literature on business model innovations, sustainability strategy and sustainability transitions, adding the "recursive perspective on innovation and society" (p. 2) applied to societal innovation. The authors are critical of the triple helix models "because these underestimate the importance of disinterest and conflicts of interests to be managed via multiple value creation on the basis of recursive multi-actor intentionality"

(Diepenmaat et al., 2020, p. 1). They propose the need to acknowledge that "actors require each other in realizing their own needs and wishes and may help each other in this respect. Contextual aspects enter via the improvement perspectives" (Diepenmaat et al., 2020, p. 13). Their work presents an historical discussion of modalities in which business addressed sustainability, and offers a systematic approach to innovation types. In particular, it provides a "co-evolutionary understanding of innovation-based transformations, based on a recursive relationship between innovations, improvement perspectives and socio-economic transformations, including the transformation of modernity" (Diepenmaat et al., 2020, p. 3).

In the paper, they specifically review societal innovation, framing it as a systemic type of innovation which requires design thinking and system building. They further argue that "Societal innovation involves social innovation in the form of cross-sector partnerships (resulting in new value chains) and possibly changes in ownership (energy cooperatives for renewable energy to heat and powerhouses)" (Diepenmaat et al., 2020, p. 16). The focus on design thinking is justified by the ability of the method to find configurations that are suitable for several actors (users, governments, finance). They base their argument on the work Ceschin and Gaziulusoy published in *Design Studies* in 2016 in which the authors visually presented the evolution of design for the field of sustainability, from the level of product design, to the level of product-service system, to the spatio-social level and finally to the socio-technical system level (p. 17). Thus, more recently, the focus of design broadened to include socio-technical system innovation, focusing on transforming systems by supporting the development of long-term visions and linking those visions to strategic decisions of design and innovation teams (Ceschin & Gaziulusoy, 2016, p. 31).

Creutzig et al. (2022) analyzed mitigation solutions in terms of effects on human wellbeing. Although such mitigation solutions are usually evaluated in terms of greenhouse gas (GHG) reduction, they systematically assessed the potential of demand-side solutions in terms of avoiding, shifting and improving consumption, and calculated the link to human wellbeing. With a methodology based on expert judgment and an analysis of extant literature, they evaluated "306 combinations of wellbeing outcomes and demand-side options" and found that "bridging socio-behavioural, infrastructural and technological domains, can reduce counterfactual sectoral emissions by 40-80% in end-use sectors." (Creutzig et al., 2022, p. 36). In terms of solution categories, they identify: (1) building: sufficiency, efficiency, lower carbon and renewable energy; (2) food: food waste, overconsumption, animal-free protein; (3) transport: teleworking and online education systems, non-motorized transport, shared mobility and BEVs; (4) urban: compact city, circular and shared economy, systems approach in urban policy and practice, nature-based solutions; (5) industry: using less material by design, product life extension, energy efficiency and circular economy (Creutzig et al., 2022).

Framing Social Innovation

According to Unceta et al. (2020, p. 908), social innovation (SI) "measurement and socioeconomic impact have been for a long time a required and challenging area of research inside SI studies, acknowledged by the research community, policymakers, social investment funds, practitioners, social entrepreneurs and social innovators themselves. However, there is still a lack of consensus on what are the major and determining methodological tools and indicators involved in its measurement and impact assessment. Despite this difficult task, there are three approaches that can be identified in the academic field which seek to build a system of indicators for SI measurement: "the individualistic approach," "the organizational approach" and "the regional/national approach" (Unceta et al., 2016). In this paper, we focus mainly on the urban level, but take into account all levels of complexity.

In the special issue "Social innovation and the energy transition," published in the scientific journal *Sustainability* in 2018, 20 articles contributed to the topic from different academic disciplines. The editors (Hoppe & de Vries, 2018) categorize the contributions into key topics relevant to social innovation:

> (i) technological innovation leading to new market models, actor configurations, and institutional settings creating room for social innovation; (ii) new governance arrangements; (iii) community energy, its impact, implications, and social incentives and policy to empower it; (iv) new participative research approaches to test and learn from livings labs and best practices; (v) "green nudges" to stimulate behavioral change; and (vi), serious energy games. (p. 141)

In a recent literature review on "social innovation related to ecological crises," Haskell et al. (2021) analyzed the 40 most relevant articles related to the topic and found that only five of those articles explicitly aligned with strong sustainability. For the literature analysis, the authors deployed the framework developed by Howaldt et al. (2017), which combines innovation studies and theories of social change. The framework was developed within the E.U.-funded project SI-DRIVE; it has a focus on social practices oriented toward societal challenges and it has already been applied specifically to environmental challenges (Schartinger et al., 2017). The framework is composed of five dimensions that can guide stakeholders in facilitating social innovation development. The focus is on an audience of policy makers and actors within the civil society, with the aim of assessing the potential for diffusion when social innovations are imitated and diffused across contexts (Haskell et al., 2021). The five dimensions of the the framework (Figure 2; Howaldt et al., 2017) are: (1) concepts and understanding; (2) addressed societal needs and challenges; (3) resources, capabilities and constraints (capacity building, empowerment and conflict); (4) process dynamics (mechanisms of diffusions, imitation, social learning, relationship to social change); and (5) governance, networks, actors (functions, roles and new concepts). Based on data and insights from both the SI-DRIVE (reviewed above) and SIMPACT E.U.-funded research projects, Terstriep et al. (2020) reflect on social innovation ecosystems. Their results suggest that to establish a social innovation ecosystem, it needs

> 1) a mode of governance that integrates actors from civil society, and the social, economic and academic field; (2) social innovation hubs, labs and transfer centres as intermediaries that accelerate social innovation activities; and (3) the integration of different modes of innovation in transformational innovation strategies. (p. 881)

More specifically, within the analyzed SIMPACT project (Rizzo et al., 2020; Unceta et al., 2020), a practical framework is proposed (Dhondt et al., 2016; Castro-Spila et al., 2016) for policy makers and social innovators to forecast ex-ante the potential impact of social innovation options. Such a framework is based on five steps: (1) determining the goals and socio-economic outcomes; (2) determining causal relationships between inputs, outputs and outcomes; (3) determining the role of stakeholders; (4) calculating the impact; and (5) the decision process.

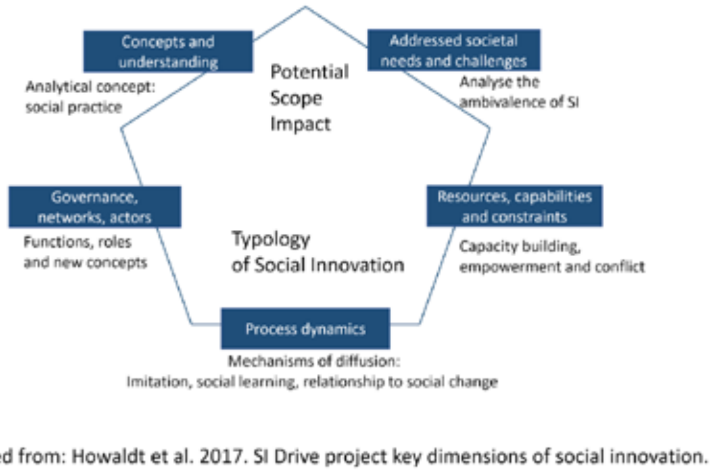

Figure 2. SI Drive framework adapted from Howaldt et al. (2017).

A comprehensive framework for evaluating social innovation initiatives has been developed by Secco and colleagues (Secco et al., 2019) and applied to a variety of contexts, from forest-dependent rural communities (Secco et al., 2019), to social farming, community energy and food cooperatives. The framework is the backbone of the E.U.-funded project SIMRA (Social Innovation for Marginalized Rural Areas) and has been utilized for the assessment of social innovations across Europe. It was derived from a literature review of over hundreds of existing frameworks (Secco et al., 2019) with the aim of developing a method and categories for evaluating social innovations. The resulting SIMRA framework builds in particular on the approach of the theory-of-change, detailing the causal mechanisms that led to changes, the base of any evaluation approach. More specifically, it outlines the intervention logic (logic model) that provides the causal link from inputs to activities, leading to outputs and culminating in outcomes and impacts, with the additional contribution of feedback and learning processes that loop back. The comprehensive SIMRA framework (Figure 3; Secco et al., 2017) includes an analysis of the context, and this takes into account nine main elements: (1) the trigger (that is, individual and collective needs); (2) the perceived context at international, national, regional and local levels; (3) the agents (ideas, values, willingness, reflexivity, capacity for change) which influence the context; and (4) the preparatory actions for collective benefit; which in turn affect (5a), the reconfiguring of the system. The (5b) reconfigured systems (new networks, new government arrangements and new attitudes), lead to (6) project activities with specific procedures and practices. Such social innovation activities produce (7) outputs in the form of identifiable products and services, which in turn produce (8) outcomes and impacts (positive or negative) on economic, social, environmental and governance/institutional aspects. Finally, (9) the learning processes provide feedback loops and multiplier effects to inform the context and social innovation activities. In practical terms, these nine key aspects are assessed with a mixed quantitative-qualitative methodology (Secco et al., 2017) and a combination of expert and participatory-based evaluations (Secco et al., 2019).

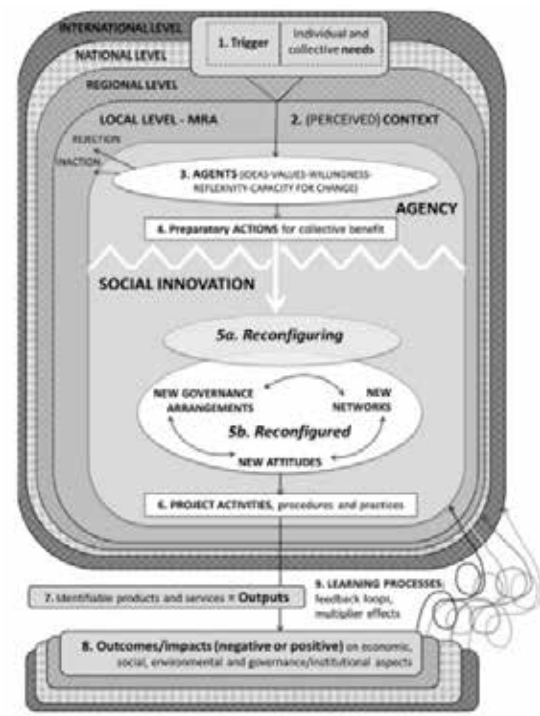

Figure 3. The SIMRA framework (source: Secco et al., 2017).

The Regional Social Innovation Index (RESINDEX) Model (Unceta et al., 2016) adds a further level to social innovation indicators, comparing the potential capacity to the realized capacity. The model was developed within a research project funded by Innobasque, the Basque Innovation Agency, and comprises a series of indicators grouped in three indexes: (1) capacity for potential innovation – composed of (1a) capacity for knowledge, (1b) capacity for learning, (1c) capacity for socialization, (1d) capacity for development, (1e) capacity for association; (2) realized capacity of social orientation index – composed of (2a) knowledge acquisition, (2b) development of social projects, (2c) impact of social projects, (2d) governance and (3) realized capacity of social innovation index – composed of (3a) knowledge acquisition, (3b) development of innovative social projects, (3c) impact of innovative social projects and (3d) governance.

In an analysis of social innovation ecosystems and sustainability in cities, Andion et al. (2022) proposed five dimensions that reinforce or hinder social innovation in cities, based on the case of the Brazilian city Florianópolis. The dimensions are categorized according to the scale of analysis: macro, meso and micro level. At the macro level, they identify the "institutional" dimension; at the meso level, they identify the level of "SIE supply – network of support actors," "SIE demand – network of social innovation initiatives" and interaction and governance. At the micro level, they identify the dimension of "practice and consequences – social innovation initiatives and their actions in [the] public arena" (Andion et al., 2022, p. 1276).

Angelidou and Psaltoglou (2017) investigated social innovations for sustainable development at the urban level. They explored the characteristics of social innovation across "the three basic and distinct dimensions of social innovation, as they are put forward by a large body of literature: i. Content, ii. Process and iii. Empowerment" (p. 113). They analyzed the literature to categorize domains of social innovation for sustainable urban development clustered into content (principal subject, sustainability challenge, urban setting characteristics), process (organization type, innovation mechanism, and ICT component) and empowerment (type, beneficiaries, outcome). They further focused on the human agency level, providing a categorization of "four primary citizen profiles in social innovation for sustainable urban development: the 'citizen-sensor,' the 'sharing citizen,' the 'collaborative citizen' and the 'entrepreneurial citizen'" (Angelidou & Psaltoglou, 2017, p. 113).

Finally, Baer et al. (2021) developed a categorization of approaches to social innovation related to Positive Energy Districts by comparing three in-depth case studies in Norway. The three dimensions that emerged from the case studies are: (1) citizen involvement, (2) stakeholder interaction and (3) capacity building and education.

Toward a Multi-Disciplinary Systematic Framework of Social Innovation for Climate Change

All the dimensions identified in the above reviewed literature have been included in a comprehensive map and organized according to the well-established logic model (Knowlton & Phillips, 2012) as the underpinning structure (Figure 4).

Given the broad number of dimensions identified, in particular for the category of social innovation actions or initiatives, some of the original categories of the logic model have been expanded. In particular, the social innovation actions are organized into three sub-categories: social innovation capacity building activities, (top-down/bottom-up) social innovation initiatives and scaling strategies. While we are aware that the sub-dimensions are not mutually exclusive, we find the clustering useful to organize the multitude of social innovation approaches and initiatives sourced from the literature review. Capacity building seems to emerge as a prerequisite for supporting the emergence and scaling of social innovation initiatives, thus indicating a pathway.

The categories related to the results are defined according to the newest labeling adopted by the European Commission (Horizon Europe Key Impact Pathways): results, output and impacts. Mapping the existing knowledge on the topic provided a complex and multi-faceted overview, indicating the variety of levels and perspectives adopted by researchers in diverse fields. The framework could thus provide guidance to researchers and practitioners to be aware of the many levels of complexity and the potential impact of deliberately designing the emergence and scaling of social innovations in cities for the wellbeing of communities (Hoppe & De Vries, 2019).

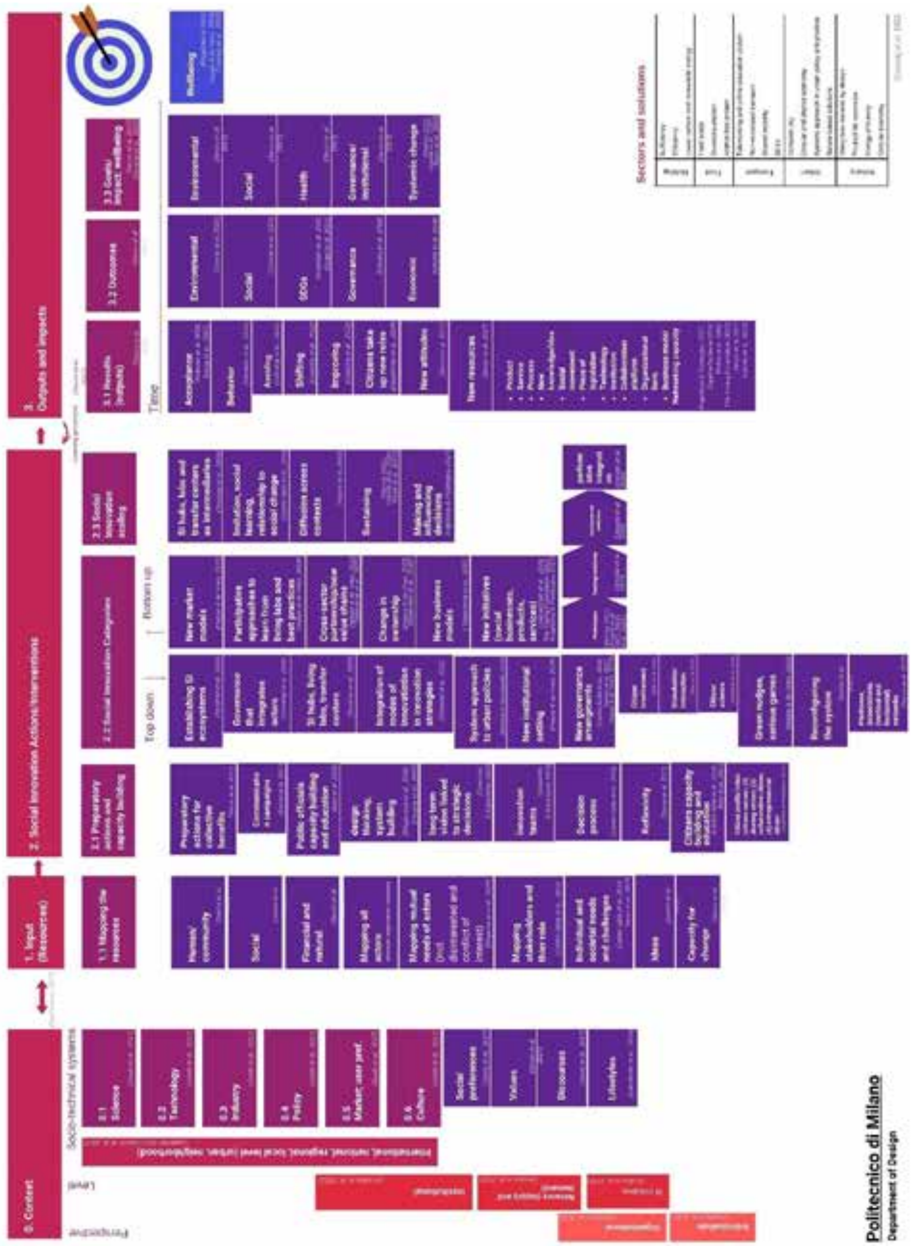

Figure 4. A comprehensive framework of social innovation for climate change (source: Knowlton & Phillips, 2012).

Implications and Conclusions

With the aim of developing a comprehensive framework for the assessment of social innovation initiatives for climate neutrality, we conducted an extensive multi-disciplinary literature review. We presented models and frameworks from extant literature, then aggregated and categorized the dimensions that emerged.

The resulting framework is theoretically based and comprehensive; it can be utilized to categorize social innovation initiatives and actions and related indicators for their assessment. Given the wealth of knowledge sourced in the literature review, it seemed that the time for a comprehensive framework had come for coping with the complexity of the challenge and for categorizing the hundreds of indicators scattered across several projects and papers. Our work contributes to theory by systematizing the available knowledge on the dimensions that influence social innovation specifically for climate neutrality. The comprehensive multi-disciplinary framework has practical implications for selecting, designing and assessing social innovation's impact toward a sustainable society. In future research, we aim to compare this theoretically-grounded framework with existing cases of social innovation for climate neutrality and with municipalities' needs (in particular with the city partners of the H-2020 NetZeroCities project), and then to categorize SI initiatives and related indicators (of results, outcomes and impacts). Such work would provide an actionable set of indicators for designers, policymakers and all stakeholders to design a solid SI policymaking and evaluation framework that can be general enough to be comparable across contexts and specific enough to adapt to local (urban) contexts.

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EXPLORING A NEW MODEL OF GREEN RETAILING: COMMERCIAL BRANDS PARTNER WITH MULTI-STAKEHOLDERS TO BUILD A SUSTAINABLE RETAIL ECOSYSTEM

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Abstract
Due to the prominence of climate change and ecological adaptation issues, more and more companies are emphasizing the circular economy concept under the framework of sustainable development. However, most of them are studying sustainability from product production and raw materials. This paper, however, examines a coffee brand that has created its first eco-friendly experimental store in Shanghai. It also introduces how it uses brand influence to connect multiple stakeholders, including designers, to spread the concept of sustainability and create a more adaptive green retail model. As we all know, the root cause of unsustainability in the Anthropocene is the lack of sustainability in human social development itself. Therefore, if we want to achieve maximum sustainability in the Anthropocene and the development of new sustainable materials in the field of science and technology, we need to influence people's thinking and lifestyle to adapt to the changing earth.

In this paper, we analyze the contribution of a new sustainable retail business model and operational framework to climate change mitigation through a study of a coffee brand's new retail pilot store. The retail store's sustainable business model framework is based on four main aspects: 1) complete recycling of waste materials to extend their life cycle; 2) reduction of environmental impact through product development and renewal of packaging materials; 3) collaboration with designers to develop a sustainable co-creation workshop system; and 4) development of a "green store" assessment system that covers the entire life cycle with audits and certifications in eight key areas, including energy conservation, water consumption management, and waste disposal.

The coffee brand hopes to build a sustainable new retail network that adapts to the current development. The new retail business in a point of distribution impacts

people's lifestyles, thus promoting the adaptation of the whole society and achieving more sustainable development.

Author Keywords
Green retail systems; sustainability; business models; co-creation; adaptive design.

Introduction

Ecological Impacts Since the Anthropocene

The Anthropocene is a potentially revolutionary concept, not only because it has become synonymous with the unprecedented global environmental impact of humanity, but also because it has long guided the fundamental scientific, social, and academic framework of Western intellectual thought. Philosopher of science Latour (2014) points out that it subverts a traditional notion of an external objective world devoid of human beings because human action is visible everywhere. These statements underscore the need to assess how we understand human social action on a planet transformed by humans, particularly about the historical relationships between humans and other organisms and the material processes and related discourses that shape the environment (Bauer & Ellis, 2018).

> Human activity has transformed between a third and a half of the land surface of the planet; many of the world's major rivers have been dammed or diverted; Fertilizer plants produce more nitrogen than is fixed naturally by all terrestrial ecosystems; Humans use more than half of the world's readily accessible freshwater runoff. (Crutzen, 2002, p. 23)

The Arctic ice sheet is receding, and the polar climate is changing rapidly; the Antarctic ice cap appears to be receding with it soon. The potential for massive disruption has accelerated recent discussions about the Earth's temperature and the sustainability of anthropogenic interventions explored (Burns & Strauss, 2013).

The Anthropocene era has introduced sustainability considerations in a new direction which requires not only adjusting social systems to the limits set by the biosphere but also recognizing the boundaries of the planet. Climate change, droughts, fires, food insecurity, water scarcity, and the resulting social unrest are urgent signs of the Anthropocene era (Hoffman & Jennings, 2015). When we are backcasting at these unsustainable phenomena, we find that the root cause of most of the chain reactions caused by environmental pollution is human behavior and perception.

The Rise of the Circular Economy

The Concept of Circular Economy

The circular economy is literally understood as the economy of recycling and regenerating materials, which essentially belongs to the economic model of resource recycling (Chen, 2018). In general, the circular economy concept aims to improve the efficiency of resource application and achieve reuse while not destroying the laws of natural environmental development so that all kinds of material energy can operate naturally.

In the specific application process, introducing the concept of the circular economy can help people accelerate economic development while minimizing the damage to the ecological environment and ensure the synergistic development of social economy and ecological and environmental protection (Liu & Wang, 2021). Therefore, the role of the circular economy can make the socio-economic development present the development form of "resource-product-renewed resource," which effectively reduces the waste of resources, improves the efficiency of resource utilization, and does not have an enormous impact on the ecological environment in the process (Zhao & Wang, 2021). The concept of the circular economy and the concept of recycling are the most critical factors in developing the circular economy. Therefore, it can be seen that the circular economy concept is consistent with the concept of sustainable development, and it can guide the future retail industry to be greener.

The Need for a Circular Economy

Urbanization and climate change require cities to find new pathways to a sustainable future so that urban environments may accelerate the shift to a circular economy. Additional acts of commitment are reflected in multiple actions by citizens to address climate change and to ensure progress towards a circular economy by contributing to waste reduction, increased eco-shopping, increased environmentally friendly transportation, or reduced domestic energy. Therefore, considering the need to change citizens' attitudes toward climate change, much must be done to effectively address climate change and lay the foundation for a circular economy (Davidescu et al., 2020).

In the context of urbanization and excessive pollution, circular economy principles are becoming increasingly important and necessary in the path toward sustainable development. The circular economy implies reducing, reusing, remanufacturing, and recycling materials.

The Impact of Education on Sustainability

Education is not only a fundamental guarantee for technological progress but also a meaningful way to raise public awareness of environmental protection and scientific development concepts. Education on the environment and sustainable development can directly influence the lifestyle and consumption behavior of the educated (Sun & Wang, 2017). As the world pays close attention to achieving sustainable development, the "circular economy" is emerging and becoming an important goal in repositioning the global economy and society. Sustainable development is embedded in education and learning, leading to changes in human behavior, thus creating a sustainable society for all. Therefore, using education as a means of communication to introduce the concept of sustainable development to the general public can effectively lead to the establishment of greener lifestyles and habits, thus promoting sustainable development in society (Wang & Jing, 2015).

Framework Building for the New Green Retail

The coffee brand studied in this paper is committed to making visible actions for sustainability and has a simple vision: to grow sustainable coffee, operate sustainably, and strive to be a resource-active company that gives back more to natural resources than it uses. The sustainability strategy is implemented through four action paths: quantifying, reducing, engaging, and offsetting (Figure 1). The company has set a primary goal based on science to reduce carbon emissions, water use, and waste emissions by 50% each by 2030. In 2021, the brand combined the three goals of "reducing carbon footprint, water waste, and waste" with a sustainable lifestyle and, after more than 500 days of preparation, opened its first Green Experimental Store in Shanghai. The store explores a new model of recycled green retail and encourages more customers to join in a more sustainable lifestyle. The store is designed and built, operated daily, and experienced by customers throughout its life cycle, with sustainable concepts and initiatives running throughout.

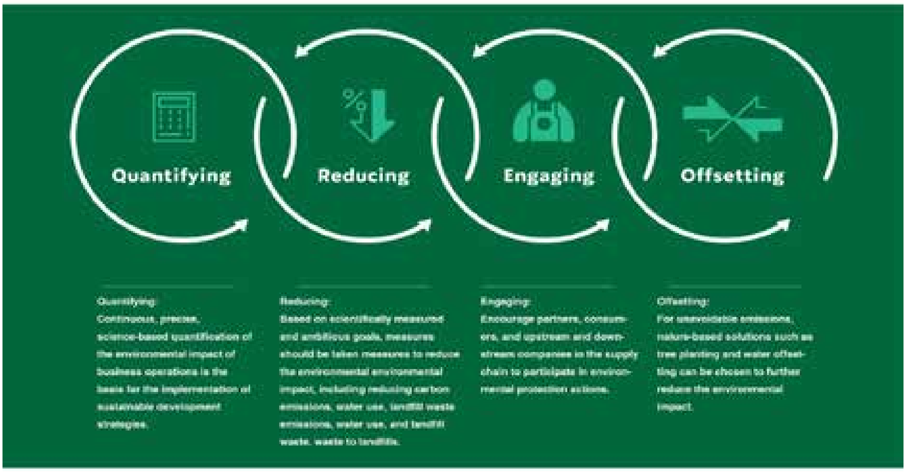

Figure 1. The sustainability strategy is implemented through four action paths.

The sustainable framework for the first green retail pilot store in Shanghai is based on four key aspects:

1. Recycling waste materials and extending their life cycle.

During the design and construction phase, the project team set an initial goal of ensuring that approximately 50% of the store's construction materials were expected to be recycled (Figure 2), upcycled, or degraded in the future (i.e. when the store was demolished or renovated). To achieve this goal, the project team used the RESET Materials Standard[1] as a framework for quantification and review. It uses a recycling strategy that includes a new modular design for the store's entire bar and back area, which can be disassembled and assembled as needed. If the store is remodeled in the future, the old modules can be "re-installed" in other stores. At the same time, the store uses a lot of recycled building materials. For example, solid wood coffee tables from other stores were recycled and composted to make door handles, bar tops, steps, and other facilities for the Green Retail Experimental Store.

The green apron worn by the barista is made from recycled PET bottles that are cleaned, processed, and recycled into polyester chips, yarn, and fabric and finally processed into a unique eco-friendly apron. This recycling program not only reduces the amount of waste generated from PET bottles but also reduces energy and resource consumption and the product's carbon footprint compared to traditional textile processes. A green apron can reduce greenhouse gas emissions by approximately one kilogram over its lifetime.

It is also the first coffee store in China to recycle 100% of the coffee grounds in the store. The coffee grounds are composted and used as organic fertilizer for crops and shopping mall gardens. Moreover, some coffee grounds are also used as raw materials for straws, food packaging, and store furniture.

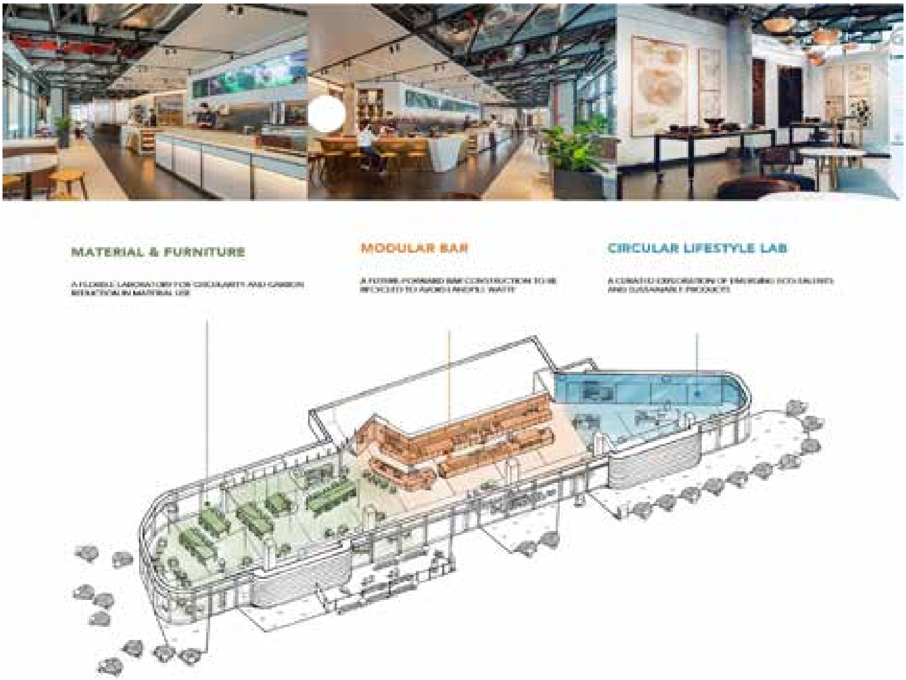

Figure 2. Interior layout of the new retail coffee shop.

2. Reducing environmental impact through product development and updating of packaging materials.

More than 50% of the food and dairy-based beverages in the coffee shop will be replaced with plant-based ingredients, and oat milk will be the default for dairy-based beverages. The store is also introducing fifteen new plant-based meal options, including various baked goods, sandwiches, and cakes, giving customers a richer taste and more sustainable consumption. Each oat milk chocolate muffin is estimated to reduce greenhouse gas emissions by sixty grams compared to conventional muffins containing animal fats and oils, equivalent to an electricity saving of 0.1 kWh.

Guided by the need to reduce plastic waste and promote a recycling lifestyle, the coffee shop has launched a reusable to-go cup and is encouraging dine-in customers to use store cups or bring their cups as much as possible to reduce the consumption of disposable tableware. All of the coffee brand's stores have stopped using plastic straws, reducing plastic use by approximately 200 tons per year. This includes the introduction of biodegradable lunch boxes, reusable plastic cups, and merchandise made from recycled disposable beverage containers.

Through plant-based food initiatives and the cessation of plastic products, the coffee shop is influencing the lifestyles of its customers, using sustainable living as an entry point and gradually influencing the sustainability of the entire ecology.

3. Coordinate stakeholders and develop a sustainable co-creation education platform for the general public.

For the first time, a co-creation education platform called "CIRCULAR LIFESTYLE LAB" (Figure 2) has been created in the coffee shop, which is open to the public for free. In order to spread sustainable ideas and expand its influence, the coffee company coordinates designers, artists, and doctors in the field of sustainable design as instructors of the co-creation platform. It cooperates with elementary and junior high schools to cultivate sustainable concepts for young people.

The platform is divided into two parts: an in-store sustainable mini art gallery and regular, sustainable public engagement workshops.

- The Sustainable Mini Art Gallery invites like-minded designers and artists to create sustainable-themed works using retail waste such as coffee grounds as the primary material. Artistically, the gallery gives unique meaning to the discarded materials. As customers view these artworks created from waste, they feel the value of discarded items and think about how waste can be reused.
- The Sustainable Public Engagement Workshop (Figure 3) is a co-creation platform established by the coffee shop in collaboration with designers, artists, primary and secondary schools, and other individuals and organizations. The workshops are organized weekly with different themes, but the overall direction revolves around the concept of sustainability and the preparation of waste and biodegradable materials as raw materials for creation. Workshop participants self-register and can personally create usable objects from waste materials during the workshops, such as candles, jewelry, and tableware made from coffee grounds. Through this workshop platform, the public can personally transform materials usually regarded as waste into everyday objects in their lives. With a bit of criticism, this educational platform stimulates the public to reflect on unsustainable behaviors and subconsciously motivates people to see sustainable behaviors as a new trend, gradually changing their lifestyles and consumption concepts.

Figure 3. The Sustainable Public Engagement Workshop.

4. Develop a “green store” assessment system covering the entire life cycle

The coffee brand officially launched the “Green Store” certification system. The brand and authoritative organizations developed the certification system, and the scope of examination covers the entire life cycle of the store.

For audit and certification, as many as forty indicators are focused on eight critical areas with the general categories of energy-saving, water consumption management, and waste disposal. As a new generation of brick-and-mortar store standards for the future, the “Green Store” system not only focuses on traditional store design and construction aspects such as water, electricity, and environmentally-friendly refrigerants, but also focuses on new perspectives related to store operations and consumer experience. For example, indoor noise reduction, indoor air quality, public transportation convenience, reduction of disposable packaging, and healthier and low-carbon plant-based meals reflect the coffee brand’s determination to invite more consumers to experience sustainable lifestyles.

Feedback from the Green Coffee Retail Experimental Store

Since the store opened in September 2021, it has received 120,000 visitors and has been disseminated online more than 3.5 million times, radiating to a wide range of people and a large audience. Meanwhile, this project was nominated by the *26th UN Climate Change Conference of the Parties (COP26) and included in the 2021 Business Climate Action Cases.*

Through proactive initiatives to improve the energy efficiency of its stores, the Green Store has been measured to reduce carbon emissions by an additional 15% per year compared to a similarly sized coffee store in 2019. The coffee brand plans to open sixty certified “green stores” in mainland China within the next year and gradually expand to the mainland market, inviting more consumers to join in practicing sustainable lifestyles.

In this way, it will form a new green retail ecosystem that will contribute to the low-carbon development path of the retail industry in China and globally.

Conclusion

Industrialization has accelerated humankind's destruction of the environment, and nowadays, sustainable development has become the primary development strategy for many countries and even companies. Therefore, this paper explores the future direction of retail development by examining the model of China's first green coffee retail store. Although it is only a little coffee shop that makes green action, the coffee enterprise cooperates with designers and artists and builds a perfect business model for a green retail store in terms of construction, user behavior, platform building, and evaluation system. The construction of an educational platform truly influences the sustainable behavior of the public subtly from the perspective of user participation.

The coffee brand hopes to use this green coffee retail store as an experiment to establish a new sustainable retail network and gradually impress the public's consumption concept and sustainable thinking. The brand hopes to promote sustainable and adaptive development of society, drive social innovation, and create well-being for generations of people.

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[1] The RESET Materials Standard is a data-driven standard for collecting and organizing materials data for the built environment.

MAPPING KNOWLEDGE, SKILLS, AND CAPABILITIES OF STAKEHOLDERS IN OPEN DESIGN-LED DISTRIBUTED PRODUCTION SETTINGS

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Abstract
Openly shared design knowledge and open-to-participate design processes present potential for empowering individuals to influence what is produced, democratizing innovation through espousing diffuse value creation networks that can diverge into different directions and design outcomes, transitioning towards sustainable futures through espousing socially, environmentally, and economically beneficial practices, and enabling new types of enterprise, new ways of manufacturing, and circular economy practices. Many researchers discuss these potentials of open design along with the distributed production paradigm that localizes production, closes material loops, and empowers communities to meet their own local needs as well as the needs of citizens in the future through open, adaptable solutions and knowledge sharing. The literature around open design and distributed production presents varying sustainable future visions in terms of decentralized governance and deploy varying assumptions about the roles of users, prosumers, makers, and producers. Stakeholders operating at varying scales (i.e. individual, local, regional, and global) and with different intentions for creating and recapturing value (i.e. for self and for others) can theoretically partake in such distributed, decentralized design, production, and post-use processes. However, the skills and capabilities enabling these stakeholders to engage in such processes also vary greatly according to the level of involvement and responsibility they intend to enact.

As part of a research project on exploring open design-led business models that can establish resilient and adaptive distributed value creation networks and localized circular economy loops, the author has mapped the skills and capabilities deployed to engage in distributed value creation processes according to life cycle stages, i.e. design, production, and post-use, and intentions for creating and recapturing value, i.e. for self and for others. This paper presents this initial mapping informed by a systematic review of the literature at the intersection of open design, distributed production, and business models, in an attempt to initiate academic discussion around the skills and capabilities required to transition towards distributed and decentralized value-creation networks in a comprehensive manner. This mapping addresses and formalizes what kinds of knowledge, skills, and resources responsible consumers, active users, makers/prosumers/do-it-yourself-ers, and local, regional, and global producers need access to, in terms of levels of engagement at design, production, and post-use stages by these stakeholders operating at varying levels. The author argues for a layered approach to designing products and services that

can accommodate all levels of engagement depending on stakeholders' capabilities and intentions, not only at the design and production stages but also at the post-use processes including repair, reuse, remanufacturing, and recycling. While the outcomes of such distributed production processes would be responsive to individual, local, and regional needs and adapted in a demand-driven way, the distributed value creation network would become resilient and quick to adapt to any imminent changes that require swift responses. Establishing such resilient and adaptive networks requires a detailed and in-depth understanding of accessibility to different kinds and levels of knowledge, skills, and capabilities.

Author Keywords
Open design; distributed production; makers; active users; business models; value creation networks.

Introduction

Open design, referring both to openly sharing design knowledge and to design processes open for participation, created much enthusiasm over the past couple of decades through various opportunities identified by many researchers (Gasparotto, 2020), such as empowering individuals to influence what is produced and facilitating socially, environmentally, and economically beneficial practices (cf. Manzini, 2015 by enabling new types of doing business (Gasparotto, 2017), new ways of manufacturing (cf. Raasch & Herstatt, 2011), and circular economy practices (cf. Hobson, 2020). These open practices are discussed in varying directions and in relation to open-source technologies, open governance, open innovation, open business models through value sharing, open access, and open production (Seo-Zindy & Heeks, 2017). The literature discusses openness in design from two perspectives. On the one hand, it is advocated by communities of like-minded people as an ideological stance for the democratization of knowledge and resources; on the other hand, it is regarded and utilized as a competitive business component by companies (Ferdinand & Meyer, 2017). Although such division helps us critically reflect on various practices deployed under the mantle of openness, it may point to different drivers/motivations of different stakeholders in distributed value creation settings rather than strictly separated communities of practice. Furthermore, deploying a categorization of stakeholders' roles in distributed value creation networks, rather than one based on perspectives on openness, presents opportunities for how open design can be realized and how open practices can be enacted in a more widespread manner. One such conceptualization of stakeholders was recently introduced by the author (Bakırlıoğlu, 2022), categorizing the stakeholders in terms of intentions for creating and recapturing value and into (1) the ones that create value for themselves and their communities, including responsible consumers, active users, prosumers, makers, and do-it-yourself (DIY)-ers, and (2) the ones that create value for others, including local producers such as crafts-practitioners and maker entrepreneurs, regional producers, and global mass-producers. These stakeholders can theoretically partake in such distributed, decentralized design, production, and post-use processes; however, the skills and capabilities enabling these stakeholders to engage in such processes also vary greatly according to the level of involvement and responsibility they intend to enact.

As part of the DF-MOD project on exploring open design-led business models that can establish resilient and adaptive distributed value creation networks and localized circular economy loops, the author has mapped the knowledge, skills, and capabilities deployed to engage in distributed value creation processes according to life-cycle stages, i.e. design, production, and post-use, and intentions for creating and recapturing value, i.e. for self and for others. In an attempt to explore alternative open design-led business models in distributed value creation networks, this mapping aims to formalize the knowledge, skills, and resources the stakeholders require to be able to participate in such processes at various scales of production. In the following lines, the rationale behind this endeavour is presented.

Background

Different approaches have long challenged the traditional distinction between users, designers, and producers, including participatory design (Björgvinsson et al., 2010) and codesign (Fuad-Luke, 2013), and the distinctions between stakeholders have become increasingly blurred over time, with hybrid roles and novel forms of collaboration (Stappers et al., 2011). By fostering transparency and access to design knowledge, open design suggests different forms of collaboration and co-creation among these stakeholders who have varying capabilities, skills, and resources, in order to formulate more accessible, participatory, and expansive processes (Bakırlıoğlu & Kohtala, 2019). Open design, accompanied by the distributed production paradigm, suggests a more democratized design and production process not only by geographically decentralizing these processes but also facilitating the participation of both the ones that create value for themselves and their communities, including responsible consumers, active users, prosumers, makers and DIY-ers, and the ones that create value for others, including local producers such as crafts-practitioners and maker entrepreneurs, regional producers, and global mass-producers (Bakırlıoğlu, 2022). These stakeholders are conceptualized according to the various, newly emerging forms of collaboration presented in the literature on open design, open innovation, and distributed production, following the technological advancements in production, communication, and automation technologies. Unsurprisingly, makerspaces, fab labs, and other similar collaborative spaces that bring people together, based on sharing space, high and low technology fabrication equipment, expertise, and knowledge are frequently mentioned in the literature as drivers of this change. Innovation spaces present a potential for impactful collaborative innovation through combining disciplinary knowledge and the development of new practices (Caccamo, 2020). Due to their accessibility, fab labs are perceived as democratizing innovation by bringing individuals together to espouse collaboration and providing the necessary infrastructure for them to pursue projects according to their needs, preferences, and wants (Beltagui et al., 2021; Mortara & Parisot, 2016). Various activities co-located in such spaces can initiate and facilitate knowledge exchange and collaboration among its users, primarily due to physical proximity (Santos et al., 2018). This is also thought to democratize innovation processes for disadvantaged DIY-ers and entrepreneurs, as such spaces initiate interaction among everyone in it and provide the resources for everyone to pursue their desires (Rezaee Vessal et al., 2021). Alternative forms of collaboration can emerge in such places befitting what is suggested by the democratization of innovation (Browder et al., 2019).

There are however concerns over whether such collaborative innovation places are actually encouraging such collaborations and if these collaborations evolve into entrepreneurship.

Vinodrai et al. (2021) highlight the lack of necessary training and infrastructure to support entrepreneurship in such places, although such places have gotten more and more widespread, especially in the Global North. Alternative forms of collaboration and innovative solutions can emerge, yet these outcomes might be disjointed from local economic development programs supporting local entrepreneurs. This actually impacts the diversity in such spaces, as they do not necessarily develop and deploy strategies or programs to engage diverse groups of people (Vinodrai et al., 2021). On another note, such places can easily become exploitative of the participants, since they are attracting increasingly more volunteer experts and espousing more innovative solutions, yet the participants are forced to do a lot more to stand out in such a crowd, gain reputation, and even turn their ideas into businesses (Browder et al., 2019). Similar concerns are also highlighted for online communities. These can be regarded as digital spaces bringing people together and espousing alternative forms of collaboration. From a design perspective, these communities can consist of designers and active users with a wide range of backgrounds, including different disciplines, that inform the design process through openly sharing knowledge and experience (Yang & Jiang, 2020). However, such communities may not be attracting an effective number of people to successfully proceed with the design and product development of different ideas shared in these communities (Bonvoisin et al., 2018), as can be observed through a large number of ideas shared that are not picked up by the community for further development and remain undeveloped (Coelho et al., 2018).

These potentials and barriers to alternative forms of collaboration in shared spaces and democratizing innovation, however, emerge from a particular definition of collaboration that is based on project-based thinking and reflects a process that ends by producing certain outcomes. Open design deploys an even looser and more diffuse form of collaboration that is governed by the openness of design knowledge and data and shared standards (Bakırlıoğlu & Doğan, 2020; Tooze et al., 2014). Open design can initiate such diffuse collaborations that would facilitate widespread distributed fabrication and enable alternative business models to overcome the barriers stemming from the physicality of open designs. Physical-digital divide in open-source design and hardware projects mostly stems from a lack of documentation, or rather, the fact that the participants of open-source hardware projects are not motivated to document their processes and outcomes in a way that allows those designs to be replicated or further iterated (Dai et al., 2020). There is also a lack of standardization or taxonomy of forms of contribution (Dai et al., 2020). Such barriers make it increasingly harder for horizontal management or governance of such communities, especially when they are espousing open-ended processes, rather than project- or product-oriented processes (Bakırlıoğlu & Kohtala, 2019).

The existing mode of production and consumption demonstrates the centralization of different stages of the product life cycle at different geographical locations, placing transportation in between each value creation process and resulting in large amounts of CO2 emissions (Diez, 2011). Furthermore, such accumulation of value in certain geographical regions further entrenches inequality in terms of accessibility to resources and wellbeing of people. Localization of design and production through integrating global, regional, and local scales for environmental sustainability has been discussed in the literature for a long while and conceptualized to empower local skills and improve the wellbeing of individuals (cf. Dogan & Walker, 2008). Distributed manufacturing presents an opportunity to bring production much closer to end-users through smaller and even micro-scale, flexible, and adaptable manufacturing units of digital fabrication (Srai et al., 2016), enabling the active participation of end-users and other stakeholders in design, development and production, personalization of products, and democratization of design (Ul Haq & Franceschini, 2020). Such processes can be supported by artificial intelligence for decision-making and enable individual, local, and regional stakeholders to devise their production and diffuse supply chains to be more responsive to environmental issues and social inequalities (Fox, 2017).

Outsourcing certain tasks to automated systems or supporting software can facilitate the involvement of larger audiences in design and production (Nilsiam & Pearce, 2017). However, there are also certain limitations of these technologies. For example, additive manufacturing technologies are not developed to a point where they can ensure no production defects (Baumers et al., 2017). Similarly, pre- and post-processing technologies are not as adaptive as additive manufacturing (Despeisse et al., 2017). The hybridization of production methodologies and value chains, where standardized, mass-produced parts are combined with 3D-printed components can exploit the potential opportunities enabled by local manufacturing (Rayna & Striukova, 2021). However, there seems to be a lack of standards or "plug-and-play" solutions for mass-produced components that would accommodate such flexibility (Chaudhuri et al., 2019). Nonetheless, such distributed processes present various opportunities, especially when local actors are engaged in them. Distributed production, especially with active, local production networks, can respond to global trends or barriers more easily thanks to shorter and more responsive supply chains (Freeman et al., 2017). Such scenarios require very small, local production units collaborating in shorter supply chains and undertaking peer production.

Since its earlier conceptualizations, open design's economic sustainability has been discussed with the modularity of the openness in parts and products (Balka et al., 2010). Partially opening parts while retaining others as "closed" and safeguarded has been discussed in literature commonly, as a way for the businesses that "open" their designs to economically sustain themselves (Bakırlıoğlu & Kohtala, 2019; Boisseau et al., 2018). While economic sustainability is indeed a concern, the democratization of not only the design knowledge but also the ways it can be used by other stakeholders is a crucial consideration often overlooked. Furthermore, even if designs are fully "open" and accessible, more often than not, there are only a handful of stakeholders that can actually realize – or produce – these designs, and even fewer stakeholders that are actually undertaking such endeavours. This paper recognizes the lack of knowledge, skills, and capabilities as a major barrier to the potential of open design and distributed value creation and puts forward a layered open design approach (Bakırlıoğlu, 2022). Layers here refer to conforming to the varying levels of skills, knowledge, and resources different stakeholders have – or are willing to deploy – to engage with open design processes, and layered design is about accommodating all these levels in open designs of things in an attempt to enable them to engage such processes at any of these levels. This requires an understanding of stakeholders' capabilities at design, fabrication/production, and post-use stages to accommodate them – as this paper aims to initiate a scholarly discussion around.

Methodology

The purpose of systematic literature reviews is to synthesize all relevant sources pertaining to a defined topic of interest (Pattinson et al., 2016; Pittaway et al., 2004). As part of the

DF-MOD project, a systematic literature review was conducted at the intersection of open design, distributed production, and business models in order to synthesize state-of-the-art novel open design-led business models that can enable distributed fabrication and value creation networks and can reveal opportunities for and barriers against their creation and implementation. The researcher initially identified various keywords related to open design and distributed production, and in a series of attempts, formed a search string to identify the peer-reviewed literature that clearly mentions business models and open design or relevant terms. The search string aimed to cover the fields of title, abstract, and keywords of peer-reviewed articles and was run in three academic databases (Web of Science, Scopus, and EBSCO Academic Search Elite) to provide a satisfactory snapshot of the existing literature – as of September 2021 – that clearly contains "business model" and "open design" or other terms presented. The author removed duplicates, manuscripts in languages other than English, and manuscripts other than journal articles. The author carried out an initial review of abstracts and also removed the articles that mention open design and other relevant concepts in passing in order to support their arguments about another approach, to identify different approaches in completely digital products and services, or to refer to other meanings of openness (e.g., unsolved processes, modular structures, etc.) not in the scope of this review. At the end of this process, a final list of 131 articles was identified.

The second stage started with the inductive coding of sources by the researcher without any previous categories in mind, revealing various thematic areas of analysis, including value creation processes; collaboration, people's involvement, and governance; intellectual property mechanisms; alternative, sustainable production and consumption; and life cycle stages addressed. The remainder of the articles were analyzed according to these thematic areas. This analysis revealed a conceptual divide between two types of stakeholders in terms of value creation purposes in distributed production settings (Bakırlıoğlu, 2022) and the knowledge, skills, and capabilities of these stakeholders that enable their participation. As a result of this analysis, the author mapped these knowledge, skills, and capabilities according to the type of stakeholders and design, production, and post-use stages, and revised this mapping through the insights of five experts in sustainable design, codesign, design management, and design-led businesses. The following lines introduce this mapping in an attempt to formalize the required knowledge, skills, and capabilities to participate in distributed value creation networks at different stages.

Mapping the Knowledge, Skills, and Capabilities of Stakeholders

This section presents the knowledge, skills, and capabilities of stakeholders in open design-led distributed value creation networks categorized as (a) value-creation-for-self, i.e. responsible consumers, active users, DIY-ers, makers, prosumers, and (b) value-creation -for-others, i.e. local producers such as maker entrepreneurs and crafts-practitioners, regional producers, and global/mass-producers. These were then mapped according to various roles possibly adopted by them at different stages of (1) design, (2) production/ fabrication, and (3) post-use. The following sections are structured as (a) a table of the mapping for each stage, (b) an introduction of roles and corresponding skills, capabilities, and resources for value-creation-for-self stakeholders, and (c) an introduction of roles and corresponding skills, capabilities, and resources for value-creation-for-others stakeholders. It should be noted that the author does not propose a strict separation of design, fabrication/production, and post-use stages; rather, these stages are used for mapping skills, capabilities, and resources while acknowledging that these stages are intertwined in terms of both decision-making and collaboration and with their realization by any stakeholder of distributed value creation networks.

Design sub-stages	Value creation for self		Value creation for others	
	Roles	**Skills, capabilities, resources**	**Roles**	**Skills, capabilities, resources**
Design research	Participate in user research		Conduct user research	• Design consultancy service (e.g., from a design consultancy firm) • In-house design team or department • Networking events with other local and regional stakeholders • Open access to information on other local and regional manufacturers open to cooperation • Open access to knowledge and skills of other local and regional manufacturers regarding the design and production processes • Developing open-source licensing strategies suitable for enabling collaboration
Co-design processes	Participate in co-design sessions		Participate in co-design sessions	
	Facilitate co-design sessions	• Knowledge/training on design processes and methods • Design visualization (e.g., drawing) knowledge/training • Technical drawings of parts • 2D computer-aided design knowledge/training • 2D computer-aided design software • 3D computer-aided design knowledge/training • 3D computer-aided design software • Computer-aided design models of parts	Facilitate co-design sessions	
Design detailing	Develop alternative part designs		Update designs based on others' designs	
	Develop additional parts			
	Change / adapt designs			
Open design sharing	Openly share own designs		Openly share design knowledge	• Horizontal management of licensing practices to be implemented • Open-source design platforms

Table 1. Mapping of the roles and corresponding knowledge, skills, and capabilities at the "design" stage.

Table 1 introduces various design stages such as design research, codesign processes, design detailing, and open design sharing to map the roles and capabilities of both types of stakeholders. For value-creation-for-self stakeholders, design research translates into participating in user research and requires no specific skills, capabilities, or resources. This is similar to participating in co-design sessions. However, the remainder of the roles involves a set of skills, capabilities, and resources applicable to all design sub-stages at varying levels. This set ranges from more general knowledge of design processes and methods to more skills-oriented knowledge on visualization, including hand drawing and 2D and 3D CAD. For facilitating co-design sessions, this might involve knowledge and skills about facilitation and resources for developing generative tools; for developing or adapting parts, this might involve knowledge about ideation and detailing as well as visualization of ideas. Open design sharing involves proper documentation of designs in terms of communicating design decisions and sharing adaptable drawings/models for others' use. For any of these, access to appropriate software and openly shared designs is required.

For value-creation-for-others stakeholders, the roles vary. These stakeholders conduct user research, participate in or facilitate co-design sessions involving value-creation-for-self stakeholders, and update their own designs based on the designs of both stakeholder types. Beyond the design capacity in the form of in-house design teams or external design consultancy services, they also require information about other local and regional producers' intentions for cooperation and their skills and capabilities in design and production to formalize distributed value creation networks. Furthermore, a barrier to overcome is novel open-source licensing strategies which are required to enable such diffuse collaborations. This also affects open sharing of design knowledge, as these licensing strategies should involve forms of horizontal management by all stakeholders and open-source design platforms enacting such management principles.

Roles and capabilities at the production/fabrication stage

Production/ fabrication sub-stages	**Value creation for self**		**Value creation for others**	
	Roles	**Skills, capabilities, resources**	**Roles**	**Skills, capabilities, resources**
Assembling parts	Assemble a set of parts Combine different parts	▪ Guides on assembling parts ▪ Access to hand tools ▪ Access to material resources	Openly share assembly information	-
Producing / fabricating	Fabricate co-designed parts Fabricate additional parts Fabricate own/ adapted designs	▪ Knowledge/training in craft practices (e.g., glass, ceramics, leather, fabric, etc.) ▪ Access to craft workshops and equipment (e.g., glass, ceramics, leather, fabric, etc.) ▪ Access to workshop and production equipment ▪ Production equipment use training ▪ Files ready for digital fabrication ▪ Access to digital fabrication equipment (e.g., 3D printer, laser cutter, CNC) ▪ Digital fabrication training	Openly share production information Co-produce with local and regional producers	▪ Standards for mechanical parts ▪ Standards for electrical parts ▪ Standards for designs ▪ Logistics service between stakeholders in the distributed production network ▪ Access to local material flows and supply chains information ▪ Access to stakeholders providing production/ fabrication services ▪ Having a say in the management of the distributed production network ▪ Quality control of production/fabrication outputs of different stakeholders

Table 2. Mapping of the roles and corresponding knowledge, skills, and capabilities at the "production/fabrication" stage.

Table 2 identifies two largely defined production/fabrication stages, i.e. assembling parts and producing/fabricating. Whether assembling predefined parts or combining different parts designed for different purposes, value-creation-for-self stakeholders need access to guides on assembling parts, hand tools, and material resources for assembly. As for fabricating co-designed parts, additional parts, their own designs or designs they have adapted, knowledge of craft practices, production equipment, and/or digital fabrication are necessary. In line with this, they might require access to relevant equipment (craft, production, and digital fabrication), which is still not immediately accessible to many value-creation-for-self stakeholders despite the global rise of coworking spaces providing these (e.g., craft ateliers, makerspaces, etc.). Finally, especially when using digital fabrication equipment, they might need access to digital files ready for digital fabrication, as these are different from CAD models and their preparation requires a different kind of knowledge (e.g., slicer software).

For value-creation-for-others stakeholders, other than producing and assembling parts, assembly information should be shared with other stakeholders, not only as a means of enabling assembly by others but also to ensure that parts are assembled correctly for longer product lifetimes. For producing/fabricating, they openly share production/fabrication information in a way that enables repetition by value-creation-for-self and other local and regional producers and co-produce parts and products with other producers operating locally or regionally. These require shared standards for electrical and mechanical parts and designs among value-creation-for-others stakeholders to enable interoperability of different parts designs, whether they are novel designs or adaptations of existing ones. It also requires additional services, such as logistics between stakeholders of distributed value creation networks and quality control of production/fabrication outputs. Furthermore, they need to have access to information on local material flows and supply chains as well as local and regional stakeholders that provide manufacturing-as-a-service (MaaS). Finally, they should be able to participate in the decision-making processes of such a distributed value creation network for the network's horizontal management.

Roles and capabilities at the post-use stage

Post-use sub-stages	Value creation for self		Value creation for others	
	Roles	**Skills, capabilities, resources**	**Roles**	**Skills, capabilities, resources**
Maintenance	Maintain parts and products	▪ Access to repair manuals ▪ Electrical and electronic parts (e.g., motor, key, circuit board, etc.) ▪ Mechanical parts (e.g., blade, beater, fan, etc.) ▪ Basic functional parts (e.g., pot, grill surface, etc.)		
Repair	Get parts and products repaired		Offer repair services	▪ Repair service or authorized service network provided by my company
	Dis- and re-assemble products		Openly share repair knowledge	▪ A repair platform where I can share repair information as open-source
	Repair parts and products		Sell spare parts	▪ A platform sales channel where I can sell spare parts or updated parts
Upgrading	Upgrade parts and products		Sell parts for upgrading	
Secondhand	Sell/give away no longer used products	▪ Reliable secondhand sales channels	Quality control of secondhand products	▪ A sales channel where I can sell the refurbished products
	Acquire secondhand products			
Shared use	Use products with others	▪ People with whom I can collaboratively use the product	Facilitate shared use	
Small-scale recycling	Recycle parts to produce other parts	▪ Access to shop floor recycling devices (e.g., Precious Plastics)	Collect and recycle parts to produce other parts	▪ In-house recycling equipment and system
Proper disposal	Properly dispose of parts and products		Openly share waste management information	

Table 3. Mapping of the roles and corresponding knowledge, skills, and capabilities at the “post-use” stage.

The post-use stage involves maintenance, repair, upgrading, secondhand sale, shared user, small-scale recycling, and proper disposal of parts and products (Table 3). Properly addressing these stages is crucial, especially in distributed value creation networks with potentially numerous stakeholders partaking in value creation processes and using different materials and production/fabrication methods for different parts. Value-creation-for-self stakeholders either carry out these stages themselves or get these done by third-party individuals or businesses. For maintenance, repair, and upgrading, these stakeholders require access to manuals for these practices as well as the availability of basic functional, mechanical, electrical, and electronic parts. They can acquire secondhand products or give away the products they no longer use; for both, there need to be reliable channels facilitating the exchange process. For shared use, they need others who are also willing to use the products in a shared way. For small-scale recycling, they can recycle their parts and products to fabricate new parts, at which stage they require access to shop floor recycling equipment (e.g., Precious Plastics). Finally, if the above practices are not viable, they dispose of the product properly so that other stakeholders – including but not limited to other value-creation-for-self and value-creation-for-others stakeholders – can recapture their embedded value.

For repair and upgrading, value-creation-for-others stakeholders can offer repair services through their authorized service network, or openly share repair/upgrading knowledge and provide spare parts and parts for upgrading so that other stakeholders, both value-creation-for-self and for-others, can undertake these processes. For sharing repair/upgrading knowledge, these stakeholders might utilize open-source repair platforms (e.g., iFixit and Motorola collaboration). They might also require additional sales channels for providing parts (spare and/or upgraded) in case they do not have the necessary sales infrastructure in place. For reuse of secondhand products, they can take on their quality control and refurbish as required, for which they might also require additional sales channels. On the other hand, they can also facilitate the shared use of products, simply by leasing products rather than selling them. If these stakeholders have in-house recycling equipment and systems, they can collect and recycle parts – properly disposed of by value-creation-for-self users – to produce new parts. This opportunity emerges when they openly share waste management information detailed enough not only for open-loop recycling but also for their collection systems.

Discussion

Open design, a diffused collaborative process through openly shared and accessible design knowledge, requires an accompanying novel production and consumption paradigm, such as distributed production, to realize its potential conceptualized for social, environmental, and economic sustainability. In such distributed value creation networks, all stakeholders from responsible consumers, active users, and makers/prosumers/DIY-ers (i.e. value-creation-for-self) to local, regional, and global producers (i.e. value-creation-for-others) act as nodes in value creation processes at varying levels, in cases where open designs accommodate their skills, capabilities, and resources at these levels. The layered design approach – suggesting not only the modularity of parts and components but also accommodating varying levels of participation to design, production, and post-use stages – puts forward the need for recognizing and responding to the diverse levels of engagement and intentions for creating and recapturing value in such networks.

As an initial framing, and in an attempt to initiate academic discussion around a layered approach to open design and distributed value creation, this paper introduces a mapping of skills, capabilities, and resources of two categories of stakeholders. The mapping involves various sub-stages of design, production, and post-use that these stakeholders can participate in and contribute to, and identifies the required skills, capabilities, and resources for such involvement in the literature at the intersection of open design, distributed production, and business models and refined through expert insights. The reader should recognize that the purpose here was not to claim a complete list of capabilities or stages; rather, this mapping attempts to formalize the numerous skills, capabilities, and resources to *enable* participation in various sub-stages of designing, producing, and post-use recapturing of value. As such, it does not involve what *motivates* these stakeholders to partake in distributed value creation processes, nor does it suggest forms of horizontal management of such diffused stakeholders. It simply proposes the need to consider what the stakeholders require to be able to participate in these processes for open design practitioners if they are to realize the potential for alternative and sustainable modes of consumption and production.

The above discussion lays the ground for future research on open design and distributed production, especially in identifying the gaps between the skills, capabilities, and resources all these stakeholders require to participate in distributed value creation networks and which of these they readily have. Similarly, more exploratory practice-based research can shed light on the gaps in this mapping, such as other sub-stages, skills, or resources. Beyond these, what would motivate all these stakeholders to participate in such distributed value creation networks in the first place remains the greatest question for such a paradigm shift from incumbent modes of production and consumption.

Conclusion

This paper argues for a layered approach to designing products and services in distributed value creation networks, which can accommodate all levels of engagement depending on stakeholders' capabilities and intentions, not only at the design and production stages but also at the post-use processes including repair, reuse, remanufacturing, and recycling. While the outcomes of such distributed production processes would be responsive to individual, local, and regional needs and adapted in a demand-driven way, the distributed value creation network would also become resilient and quick to adapt to any imminent changes that require swift responses. Establishing such resilient and adaptive networks requires a detailed and in-depth understanding of accessibility of different kinds and levels of knowledge, skills, and capabilities. This paper introduces an initial mapping of these, deployed to engage in distributed value creation processes according to life-cycle stages – i.e. design, production, and post-use – and intentions for creating and recapturing value – i.e. for self and for others – in an attempt to initiate academic discussion around the skills and capabilities required to transition towards distributed and decentralized value creation networks in a comprehensive manner. This mapping addresses and formalizes what kinds of knowledge, skills, and resources responsible consumers, active users, makers/prosumers/DIY-ers, and local, regional, and global producers need access to, in terms of levels of engagement at design, production, and post-use stages by these stakeholders operating at varying levels.

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MODELING GLOBAL ACTION FOR SUSTAINABLE DEVELOPMENT WITH EDUCATIONAL PARTICIPATION

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Abstract
Climate change is becoming one of the important challenges for human survival, and taking global collaborative action at the international level has become an important concern of the international community. In 2015, UNESCO released the *Education 2030 Framework for Action* (FFA), explicitly stating that education is an important pathway to promote sustainable development. In 2016, China issued *China's National Plan on Implementation of the 2030 Agenda for Sustainable Development*, in which the principle of "common but differentiated responsibilities" is proposed. This paper attempts to construct a model of "citizen responsibility" in the global action to achieve sustainable development through education from the perspective of sustainable development of the *Education 2030 Action Framework*. The model will effectively integrate the concept of sustainable development into citizens' lives through organizational actions, help citizens acquire the necessary knowledge and skills for sustainable development, and promote the implementation of concepts and policies. The project establishes or relies on a nonprofit international service organization with the goal of "effectively integrating the concept of sustainable development into citizens' lives," using education for sustainable development and global citizenship education as means, and using problem-based learning and case-based learning as methods to build accessible globally shared public welfare classes. Through course service, public welfare publicity, and design competitions, the model builds an effective bridge between citizens and decision-makers. In the era when everyone is a designer, we should form a global cross-cultural exchange and cooperation, build a "community with a shared future for mankind," and realize the sharing of responsibilities in sustainable development and everyone's participation. The main purpose of this model is to explore how human beings can break down cultural barriers and solve a complex and uncertain future through global collaboration, shared responsibility, and citizen participation. Further, it will try to provide a path that can be used for reference and to promote the cultivation of future comprehensive talents with a sense of international responsibility and mission through education so as to realize the shared responsibility of sustainable climate citizens.

Author Keywords
Educational participation; Education 2030 Framework for Action; global collaborative; citizen responsibility; organizational action

Introduction

Climate change is becoming one of the significant challenges threatening human survival. Especially since the Covid-19 pandemic, people have had to reflect on the relationship between human and nature. The *United Nations Framework Convention on Climate Change*, published in 1992, demonstrated the international consensus for collaborative global action to address the challenges posed by global warming. In September 2015, the United Nations General Assembly adopted *Transforming Our World: The 2030 Agenda for Sustainable Development* which sets out the 17 Sustainable Development Goals (SDGs). SDG 4 touches on one of the most important areas, namely inclusive and quality education, pointing to the important role of education in actions for sustainable development. On 4 November 2015, the 38th UNESCO General Conference launched the *Education 2030 Framework for Action: Ensure Inclusive and Equitable Quality Education and Promote Lifelong Learning Opportunities for All (FFA)*, which further clarifies that education is a key pathway for sustainable development. The ecological crisis is a common challenge for humanity and climate justice has become a topic of global discussion. However, due to differences in regional cultures and imbalances in economic development, the international community is divided on the assumption of responsibility and concrete actions. How can education work in sustainable development? This requires top-level design from a global level that cuts across the barriers of ethnic and regional cultural differences in order to achieve an awakening of sustainable development awareness among global citizens.

The Chinese government responded in the *National Plan on Implementation of the 2030 Agenda for Sustainable Development* published in September 2016, proposing the principle of "common but differentiated responsibilities," which was first proposed in the *United Nations Framework Convention on Climate Change*. As the largest developing country in the world, China has always given top priority to sustainable development. As early as ancient China, the ancient Chinese thinker Lao Tzu proposed the "unity of heaven and man," which emphasized the wisdom of humans and nature living in harmony. The concepts of green development, ecological civilization, community of human destiny, and sustainable development put forward by the Chinese government in the course of development have precisely absorbed the wisdom and experience of the ancient East and provided ideas for the solution of the climate problem. The climate issue is an intricate system that cannot be solved by the actions of a single citizen or a single country; only through global collaboration can the common good of all mankind be achieved. The reality, however, is that despite the international community having reached certain consensus or ideas, there is still a lack of a bridge or channel to communicate these ideas to the general public. Ideas are good, but they are difficult to translate into concrete action. This study seeks to develop a model of "civic responsibility" in global action for sustainable development through education. Through organizational action and global education for sustainable development, the concept of sustainable development is effectively integrated into the lives of citizens, resulting in an awakening of global citizenship that influences concrete behavior in their lives and makes development concepts and policies real in practice.

Background in Meaning Frame

Climate Ecological Crisis – A Major Challenge Facing the World

British Astronomer Royal Professor Martin John Rees delivered the keynote speech "Prospects for the Future of Humanity" at the *2019 Global Grand Challenges Forum* in London on September 8, 2019. In it, he stated that the earth in the twenty-first century will face two major challenges: population surges and climate warming (Rees, 2020, p. 110-114). According to projections, the world's population may grow to around 10 billion by 2050, and the planet will be very crowded; the second exact prediction is that the climate is warming. Rees (2020) pointed out that, unlike population issues, the reason for the continued deterioration of the climate is not a lack of discussion, but a lack of practical action. In a special report released in October 2018, the Intergovernmental Panel on Climate Change reiterated the urgent need for action. Professor Zhonghua He (2020) from Shandong University in China also pointed out that in today's era, we must face the two major issues of ecology and capital. Ecological imbalances, environmental degradation, and resource shortages have declared the fatal crisis of industrial civilization (He, 2020). The climate issue has become the hallmark ecological issue of our time. The warming of the global climate system is accelerating, and a series of climate problems such as extreme weather, melting glaciers, and rising sea levels have aroused people's alarm. The neologism "Anthropocene," coined by Paul Crutzen and Eugene Stoermer, has become one of the key words in academia, increasingly framing people's understanding of "the age of humans." In May 2019, the International Commission on Stratigraphy (ICS) Anthropocene Working Group (AWG) voted to use "Anthropocene" to name the current geological age of human beings, and set its start as the mid-twentieth century. At the heart of the concept of the Anthropocene is the impact of human activity on the planet. Transcending anthropocentrism and turning to post-anthropocentricity, human beings should learn to live in harmony with nature and adopt a low-carbon lifestyle to cope with environmental crises and achieve a historic transformation of civilization.

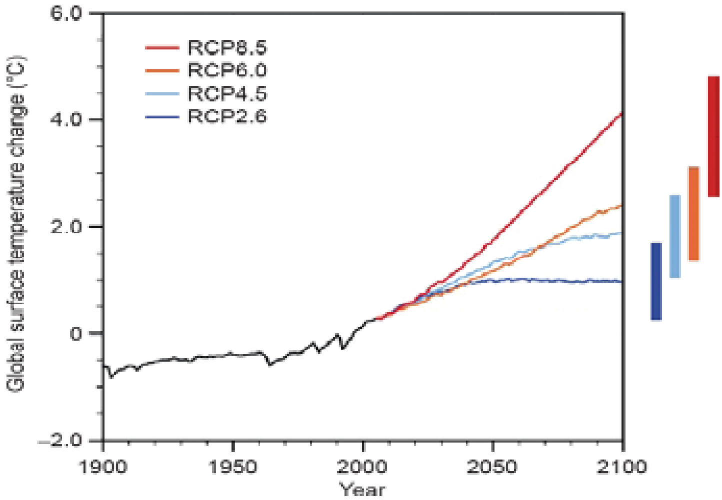

Figure 1. As annual global greenhouse gas emissions continue to rise, the world will continue to warm (source: Rees, 2020, p. 110-114).

The Gap – From Concept to Action Existence

As Rees said, climate change is not a lack of discussion, but a lack of action. Although green, ecological, and sustainability have become hot words in global academic and political circles, a series of documents and policies have been formulated to promote the implementation of the concept. However, for the average citizen, perhaps these terms are familiar, but they do not know exactly what they should do. Even though some people – such as designers – pay attention to these concepts, they are still at a loss as to how these concepts are reflected in the practice of designing products. Because sustainable development design is a system, just like ecology itself is a huge system, we must consider the perspective of systems theory and build a bridge that can effectively communicate between scientists, policy makers, educators, and the public in order to truly convey these advanced concepts to the public, which is what SDG 4 aims to do. Education for sustainable development cannot only take place in schools, but there must also be easy access to knowledge for the public in the family and society. Scientists, designers, and policy makers, while indispensable in top-down conceptual leadership, can only play a part in sustainable development. Only by arousing the broad participation of citizens can the concept of sustainable development be truly transformed into action. These awakenings from the public will also form value tendencies in the selection and use of commodities, thereby realizing an unstoppable sustainable wave from the bottom up. It is worth noting that there is a lack of an effective communication bridge between citizens and policy makers, so there is still a certain gap between citizens' real-life behavior and policy ideas.

Social Change – A Connected World in Transition to Sustainability

Climate and ecological issues are related to the survival and destiny of human beings. Professor Ezio Manzini (2015) from the Politecnico di Milano proposes a "connected world that is transforming towards sustainability" in which everyone has to constantly design and redesign their own way of being, whether they want to or not. Numerous projects are clustered here and have led to greater social change. The choice of design professionals is to nurture and support these individual or collective projects as well as the social changes the projects induce (Manzini, 2015). The elements of a social system are interconnected, and no country or individual can be independent of climate issues. The international community needs to reach a consensus on sustainable development at the cognitive level. In December 2015, nearly 200 parties to the United Nations Framework Convention on Climate Change reached the *Paris Agreement* at the Paris Climate Change Conference. This is the second legally-binding climate agreement after the Kyoto Protocol in 1997, making arrangements for global action on climate change after 2020. The agreement attempts to call on governments and all sectors of society to take immediate action to reduce greenhouse gas emissions and enhance their ability to respond to climate change through a relatively autonomous and fair approach. These measures reflect the progress of social civilization and the common actions that unite the world in saving energy and reducing emissions. The world is in transition; people and countries will be more closely connected to each other. Despite conflicts of interest and culture, we must clearly recognize that solving the problem of environmental degradation is a responsibility that humanity must share. On this issue, under the premise of respecting the economic and cultural differences between countries and regions, it is necessary to advocate on a more equitable basis for collective actions necessary to safeguard the common interests of mankind.

A Sustainable Education Model on Global Collaboration

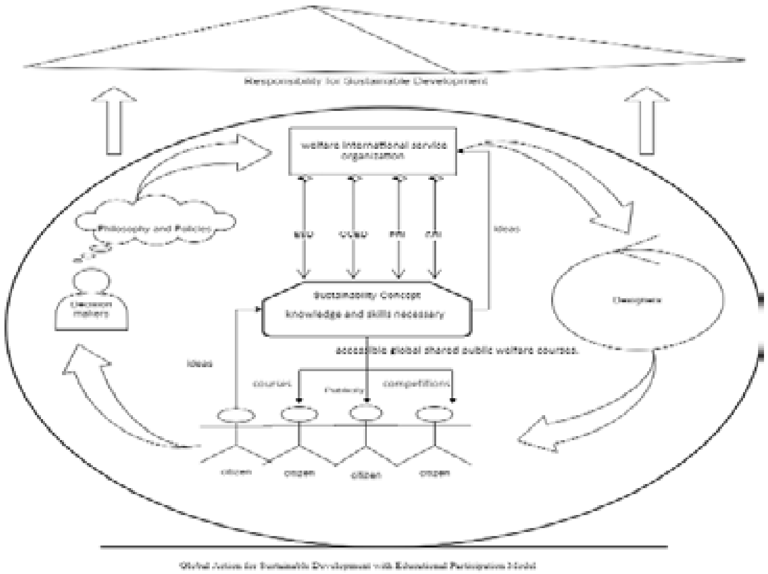

Figure 2. Model building – global action for sustainable development with education participation.

A Systems Perspective on Systemic Innovation

Buchanan (1992) calls a problem that cannot be clearly defined or completely solved a "wicked problem" (p. 5-21). Tim Brown, CEO of IDEO, reiterates this view in *Design Thinking for Social Innovation*. The problem of climate change is a multivariate and complex giant system which belongs to a typical "wicked problem." The development model derived from industrial civilization has created huge material wealth for human beings, but also brought a variety of problems such as those threatening the climate and biodiversity. Ecological civilization is a brand-new development concept and human civilization seeks a truly sustainable development based on the premise of respecting and maintaining natural ecology. Under the background of today's ecological civilization construction, all humanity is a community of destiny. Can humanity achieve sustainable development in a holistic sense? It depends on everyone's consciousness awakening and efforts as well as the systematic change and transformation of the usual mode of production and lifestyle. The various elements of these "wicked problems" are intertwined and interact with each other to form a series of systemic problems. Therefore, sustainable solutions to complex system problems must rely on systemic design, a cognitive approach that emphasizes universal connections and a holistic view. This model is based on a great transformation: humanity begins to come to terms with the limits of the planet, and this process requires us to have attainable connectivity. Based on the above observations, we try to build a culture that blends local and global and a distributed system that closely links production and consumption. This is the application of the concept of social innovation and well-being oriented to the specific path of sustainable development in the whole society. We need to rethink "game-changing" social innovation, re-examine global collaboration under the new network and ecosystem thinking, and use systems thinking to drive practical actions for sustainable development.

The Role of the Responsible Subject

Organizational Role – Idea Leader and Organizer

The core of our envisioned Global Action Model for Sustainable Development with Education Participation lies in a strong organizational guarantee. We hope that this organization will have a profound concept of sustainable development and be committed to contributing to the unity and happiness of all mankind. This organization should have four capabilities: the ability to acquire the latest international development ideas, the ability to speak and dialogue on the international stage, the ability to develop teaching courses and design teaching products, and the ability to introduce knowledge carriers to all citizens of the world. This organization can come from the government or the non-government, but it is very important that it must be not-for-profit, otherwise the judgment and behavior of the organization will be affected by the inclusion of too many economic interests. This sounds like a demanding assumption, but is there such an organization? It is understood that some people are working hard for the common destiny of mankind, such as UNESCO and OECD. The *Education 2030 Action Framework* and *Preparing Our Youth for an Inclusive and Sustainable World: The OECD PISA Global Competence Framework* are the results of their efforts. They have written the concept of sustainable development into official documents in the form of official organizations, and continue to promote them, changing people's ideas and behaviors with their powerful influence. There are also informal non-governmental organizations such as DESIS, which was jointly initiated by six universities, including Politecnico di Milano, Parsons School of Design, Tongji University, and Jiangnan University in 2014 and registered in Italy as a formal, for-profit organization.

DESIS is dedicated to building sustainable networks and uses society as a whole as "one giant socio-technical laboratory" to drive social change through design (Manzini, 2015). Of course, there are also organizations that promote interaction between sustainable ideas and citizens in the form of projects, such as The CIMULACT project, a European project running from 2015 to 2018 dedicated to turning citizens' visions into actions; and the BioKompass, a regional project running from 2017 to 2020 at the Senckenberg Naturmuseum, which tried to involve citizens in scenario development and promote the transformation of sustainable bioeconomy (Rosa, 2021). We hope that more responsible organizations will stand up and contribute to sustainable education for all citizens. We also hope that such organizations will have more and more international influence and play a well-known and important role. In the global action model for sustainable development with the participation of education, the organization assumes the role of leader and facilitator. It summarizes and develops sustainable concepts, and builds a platform for citizens to communicate with designers and decision-makers. On the one hand, designers and educators communicate concepts related to human survival to the public, and on the other hand, through building communication channels, designers turn civic wisdom into tangible actions.

The Role of the Designer – The Facilitator and Coordinator of Behavior

The goal of system design is not only to reduce the environmental impact of industrial products but, more importantly, to create a sustainable production and consumption system while promoting localized social, economic, and cultural sustainable development. For designers, it is not only to design attractive, environmentally-friendly products that meet market needs, but also to innovate more sustainable services, economic and production systems, and educational experiences. In the new age of civilization, designers should focus on post-anthropocentric design. Design for sustainability includes design for social sustainability, design for sustainable behavior, and innovative design for sustainable social systems. Designers in the context of sustainable development should possess four qualities:

- First, designers should have basic awareness and relevant knowledge of environmental sustainability.
- Second, designers should have a sense of responsibility to consider and make decisions for the interests of the entire region and the interests of different groups of people.
- Third, designers should also have the awareness and ability to think critically and have the courage to question prejudices.
- Fourth, system design needs to establish interdisciplinary work teams to generate more ideas and be able to observe and understand problems from different perspectives, thereby improving efficiency and optimizing results.

Design should be a bridge from social ideas to social actions. On the one hand, designers influence mass consumption through the products and services they design, and on the other hand, they transform mass needs and expectations into products. Designers should have a keen sense to discover and identify key issues in sustainable social systems, and make judgments about the products to be designed by combining literature and expert opinions. These issues may design environmental aspects, such as carbon emissions, energy use, etc., and may also include social aspects, such as cultural heritage protection, population growth, etc. These issues are intertwined and together constitute complex system problems. Identifying these issues is critical, and real system design begins here.

Designers are not only implementers of product design, but also collectors and disseminators of ideas. Designers not only undertake the responsibility of disseminating the concept of sustainable development advocated by international organizations to the public through the design of products and services, but also undertake the collection of real-life problems faced by the public and folk wisdom that can solve problems. Designers can be system planners, resource coordinators, participatory design coordinators, technical supporters, and tool developers. These roles require solid professional training in service design, space design, and visual design, but also require other capabilities far beyond design training. This is a higher expectation and requirement for future designers and a higher challenge for design education (Fang, 2021, p. 40-46). This is often described as a T-shaped education, where the learner has in-depth expertise in one area while possessing general breadth of knowledge in a range of other disciplines in an interdisciplinary manner.

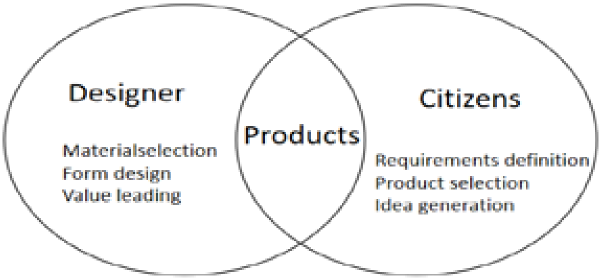

Figure 3. Product-based interaction diagram between designers and citizens.

The Role of Citizens – The Practitioner and Creator of the Idea
Manzini (2015) believes that the design of the future is a design that everyone can participate in, and a design that both expert designers and mass designers can use to construct meaning and solve problems. Sustainable social innovation must adhere to the concept of "decentralization," break through class restrictions, move towards flattening, change the traditional top-down model, and realize the interconnection of "top-down" and "bottom-up" to achieve equal sharing between citizens and decision-makers, between countries and between citizens. Qualified global citizens should regard the concept of sustainability as an inescapable responsibility and strive to practice this concept in their lives. The action of the organization is to encourage citizens to participate in sustainable development actions, and the responsibility of citizens is to develop their own level of concern, depth of understanding, and research and participation capacity. Citizens are the main body who implement the concept of sustainable development and discover sustainable development problems in real life. Future global citizens must understand the overall concept of sustainability from social, economic, and environmental dimensions so as to play an irreplaceable role.

Citizens are not only passive recipients, but also active creators. A designer's work affects a citizen's choice, and in turn, a citizen's choice is the first driving force for a designer's behavior – a citizen's literacy and aesthetics directly determine the designer's value judgment. By establishing effective communication channels, citizens' needs, wishes, and opinions are better integrated into mission-oriented social innovation systems while higher-level management entities can improve funding, policies, and their products (OECD, 2020). On the one hand, citizens influence the supply of products through their choice of commodities. Design is centered on user needs and user experience. Citizens who adhere to the concept of sustainable development will have a better impression of low-carbon and environmentally friendly designs. If a product with high energy consumption and heavy pollution loses the market, it will naturally bring about changes in the designer's behavior. Citizens, on the other hand, are the discoverers of ideas. Citizens have rich life experiences. They can directly feel the problems and needs in life, and can even construct solutions to the problems. Citizens with the concept of sustainable development will always connect their own life with the knowledge they have learned and form new ideas, such as the need for rational use of living space and solutions to water waste.

The problem of ordinary people is that, when they generate good ideas, they do not have the ability to directly translate them into products because of their own professional capabilities. This requires the coordination of organizations to provide smooth communication channels for citizens and designers. Of course, not all of these ideas are feasible, and designers need to use their own professional abilities to demonstrate and filter. In order to solve the gap between citizens, decision-makers, and designers, designers should assume the important responsibility for communication and guide citizens' participation in the policy itself through the collection of ideas and the expression of products. When they have good ideas, they cannot transform them into products directly because of their limitations of professional capacity. This requires organizational coordination to provide smooth communication channels for citizens and designers. Of course, not all of these ideas are feasible, and designers need to use their own expertise to justify and filter them. The global action model for sustainable development with the participation of education emphasizes the support and trust from citizens. Convenient and diversified "bottom-up" communication channels can facilitate the dialogue among citizens, designers, decision-makers, and other stakeholders. The idea is to ensure that citizens have an enhanced experience of participation and the opportunity to express their views and suggestions in a co-creation process geared towards sustainable development. In order to address the gap between citizens, decision-makers, and designers, designers should take on the important responsibility of communication. Through the collection of ideas and the expression of products, citizens can be better guided to participate in the policy itself.

Educators' Role: Curriculum Developers and Implementers

Education is key to the achievement of the SDGs, and educators play an important role in this education-participated model of global action for sustainable development as developers and implementers of their curriculum. Education is an agent of sustainable change and social progress. Educators should actively join in and use their professional knowledge to integrate the concept of sustainable development into teaching products. It is the responsibility of educators to create a diversified curriculum system to meet the learning needs of global citizens of different cultural backgrounds. In this theoretical model, educators incorporate sustainability issues into teaching and learning, while encouraging and helping learners to change behaviors and ways. The learners in our model are lifelong education systems for global citizens, which place higher demands on educators. They not only have the ability to disseminate knowledge, but also have the ability to design courses. The courses here are not courses in the traditional school sense – they have more diverse forms and more flexible methods, which makes knowledge a resource as easy to obtain as running water. Educators should realize that education for sustainable development (ESD) not only happens in schools, but also in spaces outside of schools. This starts the formulation of curriculum plans and the selection of teaching methods. The courses here will be broad courses, not limited to traditional classroom teaching methods. Curriculum services, public welfare publicity, design competitions, etc. can all become ways to carry out civic education.

Action Path and Method

Education for Sustainable Development (ESD)

In May 2020, UNESCO adopted the *Berlin Declaration on Education for Sustainable Development*. UNESCO has called for education for sustainable development to be a core component of all education systems at all levels by 2025. Audrey Azoulay, UNESCO

Director-General, declared that, "Education can be a powerful tool for transforming our relationship with nature. We must invest in this field in order to preserve the planet" (UNESCO, 2021). The rise of education for sustainable development was the result of the sustainable development movement of the 1980s. In 1987, the World Commission on Environment and Development (WCED) published the report *Our Common Future*. For the first time, the concept of *sustainable development* was put forward in the report: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

In recent years, the international community has made important commitments to education for sustainable development by organizing conferences or publishing important documents, regarding ESD as an important means to improve the environment and development of human existence. Examples include: *Agenda 21* reached in 1992; *Programme of Action of the International Conference on Population and Development* issued in 1994; International Conference on Population and Development in 2005; United Nations Decade of Education for Sustainable Development (DESD) in 2005; *Global Action Programme on Education for Sustainable Development (GAP)* in 2013; *Proposal for Sustainable Development Goals* in 2014; *Education 2030 Framework for Action: Ensure Inclusive and Equitable Quality Education and Promote Lifelong Learning Opportunities for All* in 2015 (Yang, 2019). In the face of severe climate challenges, the most important thing is to change the concept of global citizenship and realize the transformation of social civilization through healthy, green, and sustainable lifestyles. Education is considered a key path to achieving the SDGs because it provides knowledge, skills, values, and attitudes that can fundamentally change people's perceptions. Sustainable education design needs to consider the relationship between formal school curriculum education and informal school education. On the one hand, sustainable education must play a role in the formal school curriculum, and more importantly, it must leave school and play a role in the community, family, and social network so that more people can understand the environmental crisis facing the earth and let more people get involved in the defense of the planet. As Angela Merkel, German Chancellor said, "We need training for sustainable development not to be a privilege but accessible to all people. The success of the Education for Closer Sustainable Development Programme for 2030 will bring us to all the SDGs" (qtd. in UNESCO, 2021). The construction of a global action model for sustainable development with the participation of education focuses on establishing a learning network for global citizens outside of school so that more citizens can learn the concepts, knowledge, and skills.

Global Citizenship Education (GCED)

With the development of information technology, the world has become an interconnected whole, but human rights violations, inequality, and poverty still threaten peace and sustainable development. Global citizenship education (GCED) is UNESCO's response to these challenges. In the face of a shared human crisis, we should start by educating learners of all ages that these are global – not local – issues, and to be active advocates for more peaceful, tolerant, inclusive, safe, and sustainable societies. Global citizenship education is a strategic area of UNESCO's Education Sector that builds on the work of peace and human rights education. It aims to instill in learners the values, attitudes, and behaviors of responsible global citizenship, namely creativity, innovation, and a commitment to peace, human rights, and sustainable development. The current GCED curriculum and framework advocates enhancing global connections and cooperation through education in response to a rapidly changing and uncertain future world. OECD's *Preparing Our Youth for an Inclusive and Sustainable World: The OECD PISA Global Competence Framework* (2018) and UNESCO's *Global Citizenship Education: Topics and Learning Objectives* (2015) are both important documents on the qualities a citizen of the planet should have defined. PISA enumerates the capabilities that future citizens should have from four dimensions (OECD, 2018), including the abilities to:

1. Examine local, global, and intercultural issues.
2. Understand and appreciate the perspectives and worldviews of others.
3. Engage in open, appropriate, and effective interactions.
4. Take action for collective well-being and sustainable development.

Global citizenship education is an education for all citizens. Through the popularization of common knowledge, let more citizens take the environment and peace as their own responsibilities, cross the barriers of regional cultures, and act on cross-cultural civic values: "The citizenship of global citizenship stems from a sense of responsibility driven by global solidarity" (Kim, 2021, p. 129-141). Here, we should clearly address: under the Sustainable Development Goals, what is the GCED curriculum? Are we concerned with the form or the purpose of the course? If you focus more on the purpose of the course, then the form of the course is not limited to the traditional classroom form; it can be flexible, such as competitions that arouse public participation or more attractive micro-movies. The Covid-19 pandemic has made us realize the vulnerability of human beings to nature and the importance of digital means of information dissemination in the communication of culture today. The ability to use digital information has become an essential quality for future citizens. We should imagine the impact on human solidarity of the dissemination of common human knowledge, supported by the power of networks.

Problem-Based Learning (PBL)

In *Reimagining Our Futures Together: A New Social Contract for Education*, UNESCO (2021) emphasizes that "problem-based and project-based educational approaches can be more participatory and collaborative than conventional lessons offer." "Participation" and "collaboration" in the Global Action Model for Sustainable Development with Educational Participation are very important. Because our actions can only be meaningful if we mobilize the deep participation of global citizens, a problem-centered learning model provides us with a solution. Because our model is mainly oriented towards education outside of school, the curriculum design needs to be different from the traditional weekly repetition of fixed-time curriculum preparation and needs to establish a new dialogue mechanism between global citizens and policy makers. In our design, we focus on trying to build solutions around a problem in life. This method is more suitable for the dissemination of sustainable development ideas with the participation of designers. We can find issues that resonate easily around citizens and then choose a variety of learning methods to form cross-cultural exchanges. For example, the Collaborative Innovation Ecological Design Center of the Academy of Arts and Design of Tsinghua University in China established a toilet research and design project team in 2015, after realizing that the dirty and messy toilet environment in vast rural areas lacking a municipal pipe network brought a series of ecological problems.

It systematically integrates green recycling technology, ecological agriculture, humanized facilities and space planning, community building, and feasible business models, and proposes an integrated ecological toilet solution. At the same time, it has cooperated with many enterprises and foundations in recent years to carry out the system design practice of new ecological public toilets (Xin, 2018, p. 232-236). In such a practice, citizens are involved and we can organize and shape teaching materials. Focusing on the issue of ecological toilets, we can use various forms such as lectures, leaflets, and public service advertisements to engage more citizens in the practice of sustainable development. Problem-based or project-based learning has the commonality of focusing on problems in design and pedagogy, which can stimulate learners to acquire, apply, and generate knowledge in inquiry and action. This way of learning is also easier to disseminate widely in the community and society, making knowledge more accessible and increasing a sense of community and participation among citizens. Problem-based learning, with the authenticity of the questions and the relevance of knowledge, provides learners with real learning opportunities to better understand the ever-changing world we live in and establish new values. Problems are shared, solutions are collaborative, and knowledge is shared. Such an approach facilitates the creation of networks about common problems and integrates knowledge into dynamic problem-solving processes.

Case-Based Learning (CBL)

Case-based learning (CBL) is a traditional teaching method which was first adopted in the teaching of economics and law in some universities in Europe and the United States, then gradually applied to medical education. By guiding students to analyze typical cases, CBL teachers help students build image thinking and improve their ability to analyze and solve problems independently. The advantage of CBL is that it can combine the advantages of online learning, use multimedia, hypermedia, and various interactive functions to organically integrate in the design and development of teaching cases, and provide the potential for independent online case learning. With the increasing maturity of information technology and artificial intelligence technology, autonomous learning in an online context will become an important way for citizens to acquire knowledge. This provides ordinary citizens with lifelong learning opportunities and will also provide more open learning resources for future citizens. CBL relies on one or more specific cases to guide learners to study and explore the problems in the cases. PBL is the learner's direct participation in the real problem situation and the learning of direct experience. Unlike PBL, CBL is the learning of indirect experience from cases. CBL can provide learners with detailed learning materials in a short time to improve learning efficiency. In the global action model for sustainable development with the participation of education, PBL and CBL complement each other. PBL can stimulate citizens' awareness of sustainable development in the process of participating in problem solving while CBL makes knowledge more accessible, interactive, and inspiring, thereby improving the efficiency of learning. The advantage of CBL is that it can provide rich teaching resources, promote the exchange and connection of knowledge around the world, and make knowledge more accessible. When the excellent experience of sustainable development is rapidly disseminated, the thinking and action of sustainable development on a global scale will become more in-depth.

Conclusion and Discussion

The main implication of this study is to imagine the possibility of a global collaboration to face an increasingly complex and uncertain future. We emphasize the important role of education in the process of sustainable human development. As the *Education 2030 Framework for Action* (UNESCO, 2015) states, education is the secret weapon for realizing ideas into action. We try to use systematic and innovative thinking, relying on the power of nonprofit international service organizations to build an interactive network between decision-makers, designers, and citizens. This is a model for "citizen responsibility" in global action for sustainable development through education. Actively organizing actions to effectively integrate the concept of sustainable development into citizens' lives helps citizens acquire the necessary knowledge and skills for sustainable development and promotes the implementation of concepts and policies. The project establishes or relies on a nonprofit international service organization with the goal of "effectively integrating the concept of sustainable development into citizens' lives," using ESD and GCED as means and PBL and CBL learning as methods to build accessible, globally shared public welfare classes. Through course service, public welfare publicity, and design competitions, the method builds an effective bridge between citizens and decision-makers. In the era when everyone is a designer, we should form a global cross-cultural exchange and cooperation, build a "community with a shared future for mankind," and realize the sharing of responsibilities in sustainable development and everyone's participation. We try to break down cultural barriers through global citizenship education and achieve human unity and collaboration with nature through global collaboration, shared responsibility, and citizen participation. This is a hypothetical model. Of course, some organizations and individuals have been contributing their own strengths to the process of sustainable human development, such as UNESCO, OECD, DESIS, etc. We hope to see an organization that can have far-reaching influence in the world: whether in a remote rural area or a luxurious city, all should be able to easily obtain educational products. We hope to have the opportunity to turn our valuable environmental wisdom into actual products, and even have the opportunity to interact with top decision-makers. In this process, the designer will play an important role as a bridge and intermediary. Of course, there is still room for this research to be further explored, such as:

1. Why outside of school?

The educational behavior we envision is mainly oriented outside the school, not without school education but with more emphasis on education that occurs outside the school walls. Formal school education has a sound teaching system and a professional team of teachers. However, the global action model of sustainable development under the participation of education lies in the establishment of a lifelong education network for citizens from the perspective of the system and pays more attention to the convenience of obtaining public welfare education products outside the school.

2. Why is the nature of the organization nonprofit?

Sustainable development is the top priority for human survival and long-term development of human beings. The nonprofit service organization we envision must have a high sense of responsibility and mission, cross the barriers of culture and interests, and provide services and innovation to global citizens. In this case, the source of funding may be official sponsorship, the benefit conversion of green design products, or even more possibilities.

3. What is the specific form of educational products?

The educational products we discuss belong to a broad curriculum. This kind of course includes both explicit and implicit courses, such as digital products, public welfare courses, goods on the shelf, interactive game experience, etc. With the combined efforts of educators and designers, these can be seen as courses and lead to a revolution in the concept of citizenship.

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RISING WATERS: DESIGNSTORMING ADAPTIVE DESIGNS FOR COASTAL COMMUNITIES IN 2030, 2050 AND 2100

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Abstract
Life exists near water for many reasons, including access to food sources, waterway transportation and recreation; there are studies that also suggest psychological benefits to being near water (Mackerron & Maruto, 2013). Human development has been concentrated along these coasts and waterways, constructing residences, businesses and public spaces. However, the ocean is rising at a dramatically increasing rate, with the average rise along the United States coastlines doubling from about 0.06 inches (1.524 mm) per year prior to 1993 to 0.14 inches (3.556 mm) per year since (Sweet et al., 2022, p. 2). Together with damaging storms, this is causing water to move and surge into these areas and structures (Fleming et al., 2018). There is a need for strategies capable of mitigating climate change and helping people adapt to these new and imminent circumstances that threaten their homes, local economies and communities.

This paper explores methodologies, insights and design outcomes from an intensive three-day "Designstorm" workshop on preparing coastal communities for the impacts of sea level rise, and how this might serve as a model for both integrating climate issues into design education and for collaboration between designers and climate change experts. The workshop brought together subject matter experts from the City of Long Beach's Climate Action and Adaptation Planning team, the Aquarium of the Pacific and nonprofit The Nature Conservancy with transdisciplinary faculty and student designers from ArtCenter College of Design to address the anticipated consequences of rising sea levels. The scope of the workshop brief incorporated research into the science of climate change, global case studies of current methods being used to adapt to and prepare for environmental changes and personal stories from residents and business owners of three local, coastal neighborhoods in Long Beach, California. The brief called for solutions for three coastal neighborhoods using the National Oceanic and Atmospheric Administration's 2017 projected sea level rise in the next 10, 30 and 80 years (Sweet et al., 2017).

The subject matter experts facilitated pre-workshop research opportunities for the faculty and students, including lectures on climate data and research, tours of the three neighborhoods and the opportunity to interview people who depend on those neighborhoods for their homes, businesses and recreation. Over the workshop, student designers

collaborated with subject matter experts to develop five adaptive design planning models along with the short-, medium- and long-term solutions that incorporate temporary and permanent concepts to allow residents to remain in their homes for as long as possible while also planning for eventual managed retreat. A local company gave students access to their software using virtual reality (VR) headsets to combine aerial views of the coastal neighborhoods and climate data to create images showing future possibilities of the impact of sea level rise, in addition to showing how certain adaptation strategies like sea walls might reduce that impact.

The final models were presented by the students in an open town hall meeting as part of the learning outcomes, as well as in an outreach tool initiated by the City of Long Beach. This gave the students the opportunity to engage in public discussion with the residents of the community and demonstrate the possibility of adaptation through a variety of phased design approaches.

Author Keywords
Sea level rise; climate adaptation; resiliency; design education; partnerships; workshops.

Introduction

Sea Level Rise Overview

According to the National Oceanic and Atmospheric Association (NOAA), sea levels have been rising over the past century around the world, but that rate has dramatically increased in recent decades. In 2018, global mean sea level was 3.2 inches (8.128 cm) above the 1993 average – the highest average in the satellite record (1993-present). Overall, the sea level continues to rise at a rate of about .14 inches (3.556 mm) per year (Sweeting et al, 2022, p. 2).

Higher sea levels mean that storm surges push farther inland than they once did, which results in more frequent nuisance flooding. Disruptive and expensive, nuisance flooding is estimated to be from 300 to 900 percent more frequent within U.S. coastal communities than it was 60 years ago (Nuisance Flooding, 2014). In addition, many climate models show low-lying coastal areas will be effectively inundated or permanently underwater in the next century (Sweeting et al, 2017).

Sea Level Rise in Long Beach

Given their acute vulnerability to flooding, the City of Long Beach conducted a vulnerability assessment in 2018 to understand the short- and long-term implications of climate change on the city. The study was based on sea level rise projections for the California coast that indicate sea level rise in ranges of of 4.6 to 11 inches (11.6 to 28 cm) by 2030; 5.0 to 24 inches (12.7 to 61 cm) by 2050; and 17.4 to 65.6 inches (44 to 166.6 cm) by 2100 (AECOM, 2018, p. 7).

Based on these projections, the City of Long Beach is expected to experience devastating losses as early as the year 2030. By this time, the city is calculated to have lost 1.3 million square feet of privately owned (residential and commercial) buildings, 17 city parks, roads and several city facilities including fire stations, schools and facilities managing waste, electricity, gas and potable water (AECOM, 2018, p. 21, 22, 29, 40, 48). Flooding beyond 11 inches is expected to have devastating and irreparable damage to the City of Long Beach if mitigation and adaptation strategies are not implemented as soon as possible (AECOM, 2018, p. 8).

Partnerships and Project Brief

The Aquarium of the Pacific (AOP) and the design college had a history of partnership over a 10-year period, collaborating on projects around ocean exploration, climate change, resilience and marine defaunation. Because of its location on the Shoreline Aquatic Park in Long Beach, the leadership of the Aquarium has an economic and mission-driven interest in the issue of sea level rise in the City of Long Beach. Dr. Jerry Schubel, the CEO of the Aquarium at the time, pulled together a coalition of stakeholders, including experts from The Nature Conservancy, the U.S. Geological Survey (USGS) and the City of Long Beach, to explore how to communicate about and find solutions for the quickly approaching impacts of sea level rise on local neighborhoods. As part of that effort, Dr. Schubel approached ArtCenter College of Design to create an intensive workshop that would challenge students to address the impact of rising sea levels on three Long Beach communities. The intention was for the students' unique projects to create a sense of hope for solutions and visions for a new future while communicating the serious nature of imminent sea level rise.

For the three-day Designstorm experience, transdisciplinary design students were challenged to address the anticipated consequences of sea level rise for residents of specific Long Beach neighborhoods: Belmont Shores, Naples Island and the Peninsula, areas that contain residential properties, public recreational spaces and businesses. Students designed strategic, forward-thinking concepts for the years 2030, 2050 and 2100, incorporating temporary and permanent solutions to allow residential and public uses as long as possible while also planning for managed retreat.

Designstorm Methodologies

Pre-Designstorm

Prior to the start of the three-day Designstorm, students toured the Long Beach neighborhoods that will be among the first to experience dramatic effects from rising sea levels: Belmont Shores, Naples Island and the Peninsula. Students paid close attention to the physical landscapes and the types of residential homes and businesses that currently occupy the sites along with the infrastructure, city-owned open spaces, parks and community buildings. They met with local residents who shared personal stories and their deep sense of connection to their neighborhoods.

Dr. Schubel offered students a series of presentations at the Aquarium about the science of climate change, methods of preparing for sea level rise currently being employed and how urban areas are adapting to new environmental challenges. Case studies on recent responses to sea level rise were presented from the Netherlands and Indonesia. Students were directed to review scientific climate change reports from NOAA, the Aquarium, The Nature Conservancy and the Long Beach Climate Action and Adaptation Planning team to best prepare for the Designstorm.

Day 1 Designstorm: Icebreaking, Role-Playing, Ideation

The Designstorm opened with students sharing field trip observations and creating stakeholder maps to represent those affected by rising sea levels and included homeowners, government officials, tourists, companies and others. Participants beyond the students included the faculty leading the Designstorm and Dr. Schubel, AOP; Alyssa Newton Mann, Coastal Project Director at The Nature Conservancy; and Robert Groves, oceanographer and AOP docent.

Students introduced themselves via a prompt, an exercise that also fueled discussion on critical concepts about the nature of resiliency. Students described a personal story answering the question, “When did you find that you had to adapt to a situation that changed? How and what did you do?” Individual accounts of challenges, surprises and unexpected happenings dovetailed into bigger lessons about planning for emergencies and methods of adaptation. Some students from Pacific Island countries related personal accounts of how flooding has affected their homelands and hometowns.

Students discussed how transitional adjustments can be created and accepted when situations radically change and “normal” is not normal anymore. Conversations stressed the importance of understanding the difference between adaptation versus reaction, the resiliency of youth and methods to move people and projects into action, especially if imminent danger is not directly obvious.

Two presentations followed which offered students additional resources to inform their ideation. J. Calil, CEO and cofounder of Virtual Planet Tech – a company that translates imagery into 3-D representations – presented specific realistic aerial views of the Long Beach neighborhoods that were part of the Designstorm focus. Calil explained the process of marrying the photographic images with 3D models and data from USGS to create the images and forecast future possibilities. Additionally, this technology can take into account how certain known and tested strategies – i.e. seawalls, sand dunes – can mitigate and/or reduce the effects of rising sea levels.

A presentation by A. Newton Mann from The Nature Conservancy provided a general overview of the hazards of climate change along with nature-based solutions that have been proven effective. Newton Mann described impending disasters associated with increased flooding and wildfires and other climate related impacts, especially when it comes to coastal habitat. Newton Mann outlined ways that the Conservancy is advocating for resiliency as coastlines disappear and shorelines are submerged. Additionally, Newton Mann presented how the Conservancy is communicating and educating the public about the realities of sea level rise, offering methods for “managed retreats” in order to reduce risks, relocate strategically and effectively use natural solutions.

Newton Mann explained how seawalls have historically been used in California as well as the negative impacts seawalls can have on coastal access and ecologies; today more than 10 percent of the entire coastline is propped up by such reinforcements (personal communication, November 5, 2019). More natural solutions for combating the rising waves include: planting oyster reefs, revitalizing coastal marshlands and creating vegetative dunes (personal communication, November 5, 2019).

Students engaged in an exercise of roleplaying Long Beach stakeholders who will be affected by rising sea levels. In small groups, students assumed various identities: a longtime resident, Coastal Commissioner, city official, contractor, etc. Guests would play themselves (Newton Mann: Nature Conservancy, Dr. Schubel: Aquarium of the Pacific, etc.). Groups were given appropriate funds and policy options. The goal was to prioritize policy through negotiations and have everyone leave the table with a "sense of hope" and a deeper understanding of the needs of the stakeholders involved and the complexity involved in addressing them. In character, students argued, compromised, reflected and determined which policies to support with their assets. In timed sessions, the stakeholder proxies debated, discovered the ramifications of their actions on certain groups and considered worst-case scenarios.

After the exercise, the participants discussed the surprises and frustrations of working with individuals who have a diverse set of goals and aspirations. They realized that certain groups tend to compromise while other groups are more resistant to changes. Of the numerous insights gleaned from the exercise, the students concluded that considering multiple points of view can be overwhelming but necessary when conducting design research that potentially affects a broad spectrum of stakeholders.

In the afternoon, students brainstormed "What if…" concepts to reach highly aspirational ideas. Among other possibilities, students imagined coexisting with water, communities created around flood waters and floating cities. From the hundreds of potential concepts, students clustered similar ideas together and considered practical aspects of how the solutions address inequities, respond to new risks, change behavior, protect the ecosystem and improve infrastructure. Students were divided into five three-member teams and instructed to present three preliminary directions to investigate. Student teams presented their initial concepts to the guests, explaining the research supporting their concepts and outlining their strategies for implementation over the project's multi-year milestones.

Day 2 Designstorm: Research/Ideation, Journey Map

The day opened with a reminder of the specific parameters for the student teams: develop a concept that addresses sea level rise projected for the years 2030, 2050 and 2100 as it relates to the three Long Beach communities. Additionally, teams should use the high-range projected sea level rise of 11 inches (28 cm) for 2030, 24 inches (61 cm) for 2050 and 65.6 inches (166.6 cm) for 2100 (AECOM, 2018, p. 7). The overall goal was to create plans by which residents and visitors would be able to continue to live in and enjoy the neighborhoods for as long as possible and to create a plan for a managed retreat as sea level rise advances.

Figure 1. Projected sea level rise in the three Long Beach Neighborhoods of the Peninsula, Naples and Belmont Shores in 2030, 2050 and 2100. (credit: H. Huang, P. Karnchanapimolkul, & L. Mendez, 2019).

Students created a journey map outlining how and when residents will move, the physical and ecological transformation of the neighborhoods and coastline and how to employ nature-based strategies to temper the effects of rising sea levels. Rough models – along with sketches and plan layouts – were used to further develop their ideas and validate physical designs.

Day 3 Designstorm: Refinement and Presentations

Students completed their models, 3D representations, maps, small prototypes of structures and final presentations. Teams rehearsed their presentation and visual storyboard depictions of how communities would implement, use and benefit from their concept. As teams transformed their ideas into graphic 2D and 3D representations, the faculty continued to encourage, question choices, challenge their thinking and offer practical structural advice. The students presented the following five concepts to invited guests, which included Designstorm partners, Long Beach city planners and Aquarium staff members.

Adaptive Planning Models

Student Project 1: H2O Home: Helene Huang, Pitchamon Karnchanapimolkul, Lilibeth Mendez

The H2O Home concept begins with the premise of accepting the rising seas and building a coexistence model with the ocean. This three-tiered approach is capable of long-term adaptation, regardless of how high the waters may rise in the future. It stipulates that by investing in the future today, we can all live safely tomorrow. By the year 2100, the residents of Long Beach would be living in a city that embraces the water and features floating markets, amphibious housing and water-based transportation. The plan begins with an early communication campaign and community events to collaboratively prepare for the future of Long Beach. An Aquarium of the Pacific exhibit will outline plan details: the futuristic amphibious houses; "Sea Street," the new floating business/market sector; the new aqua farming endeavor; an underwater park at the oil islands; and how the shoreline's ecosystem will change.

In 2030, the residents most vulnerable to flooding are the first to be offered relocation housing in newly constructed inland highrises while the infrastructure in their area is improved.

In 2050, the first set of amphibious homes will be available in small pad-like configurations. Visitors and residents can use their own boat – or a water taxi – to shop and dine at "Sea Street," a floating business district that is moored to the area using concrete pillars over new aqua-farming areas. Off the coastline, the oil islands will transform into underwater parks under domes.

Figure 2. Rendering of the Sea Street floating business district and aquatic farms (credit: Helene Huang, Pitchamon Karnchanapimolkul, & Lilibeth Mendez, 2019).

In 2100, all residents are able to return to their old neighborhoods and move into a community of amphibious homes connected to each other on floating platforms. The now-empty highrise towers can be offered as affordable housing. The Peninsula's seaside will be transformed into a series of sand dunes which will naturally slow the eroding effect of waves.

Student Project 2: Tide Pool Terrace: Brittanie Gaja, Anyoung Roh, Amanda Sutanto
The Tide Pool Terrace is a design that aims to preserve most of the city infrastructure with the exception of the Peninsula, which becomes a living protective barrier for the rest of the city. Tide Pool Terrace will create a living seawall in the current community of the Peninsula that will provide a sturdy protective infrastructure, restore lost habitats and create community through interactive and educational public spaces.

The design of the terrace allows for the wall to grow as the sea levels continue to rise, providing a protective barrier as well as an educational public park for the residents of Long Beach. The structure will reduce the destructive power of the waves and encourage rich tide pool ecosystems to form on formerly sandy beaches.

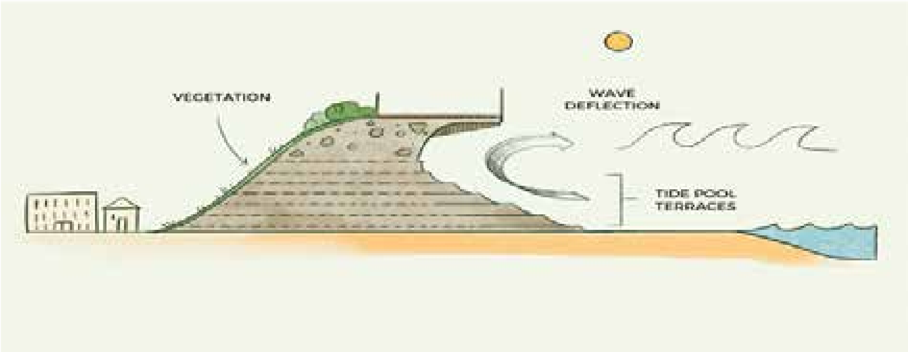

Figure 3. Drawing of the final stage of construction of the Tide Pool Terrace (credit: Brittanie Gaja, Anyoung Roh, & Amanda Sutanto, 2019).

In 2030, residents of the Peninsula are informed and prepared for their upcoming move to temporary floating housing. In the meantime, drainage and permeable pavements will be created in Belmont Shores and Naples to mitigate effects of flooding.

By 2050, residents will be rehomed in a series of temporary floating houses while the Peninsula is being restored to a more natural estuary. The demolished homes on the Peninsula will provide materials for the foundation of the seawall. Terraces will be created on the seawall.

By 2100, residents will be welcomed back to the area to inhabit homes, constructed with recycled materials, which are affixed to platforms below the water. Visitors and residents can take in the views from the boardwalk on top of the seawall and also explore the tide pool biodiversity hotspots that now line their natural and unique public space.

Student Project 3: Stay Connected: Anya Radzevych, Veilinda Rusli, Amanda Wallgren
Stay Connected focuses on the physical and economic development of the region by keeping residents connected to their emotional roots and adding financial opportunities for growth as well as creating immersive educational experiences for the community. Long Beach residents who have to relocate will be able to be emotionally and economically

connected to the shoreline through a restored natural habitat and to invest in an underwater aquaculture farm.

In 2030, a kelp farm will be installed along the offshore oil islands, providing new job opportunities in the area. Experience Park, located north of Belmont Shores, will be environmentally restored with native vegetation blocking winds, gray sand to slow erosion and coastal plants that fortify the shoreline. Through onsite exhibitions featuring augmented reality and VR technology, visitors will be educated about how the landscape will change because of sea level rise, and at night, guests can experience a light projection display on the rocks.

In 2050, the kelp farm will expand with multi-trophic aquaculture opportunities, and residents who have been displaced will receive stock in the growing company. Experience Park will expand (similar to the Highline in New York City) with walking paths that extend out to the water while the no-longer-functioning oil islands will be repurposed for wind energy generation.

In 2100, Experience Park will be a major center for tourism as well as a community center for residents; boats will be able to access and dock nearby. An underwater glass pavilion will give visitors views into the local farming aquaculture. Locals will continue to generate passive income from the nearby farming endeavors and stay connected with the community and area that they know and love.

Student Project 4: Peninsula Project: Adapting to Rise in Sea Level: Michelle Affandy, Derling Chen, Rose Zhang

This concept builds up and out using natural protection from rising sea waters as well as using older structures as foundational elements to retrofit existing structures, which allows residents to return to their original neighborhoods in new floating structures. This phased project employs a careful timeline that will move residents away from the area for restoration and then bring them back.

In 2030, a kelp forest and oyster habitat will be installed off the shoreline to create a living shoreline while the closed-down oil islands transition into water desalination facilities.

In 2050, oil islands will likely be underwater but will be the foundational support for the desalination pods. While homes are being retrofitted and built upwards, residents can relocate to temporary floating homes, which will serve as a base for future floating communities. These modular communities will receive power and water from the desalinization pods.

In 2100, floating home communities will expand and incorporate businesses. Residents will be back in their original and retrofitted homes as well as living in the floating homes now installed off the coast of the city. Submerged oil islands will continue to support the desalination pods that will provide power and water to the local residents. The aquaculture farming from the oyster beds will contribute to the local economy and provide food.

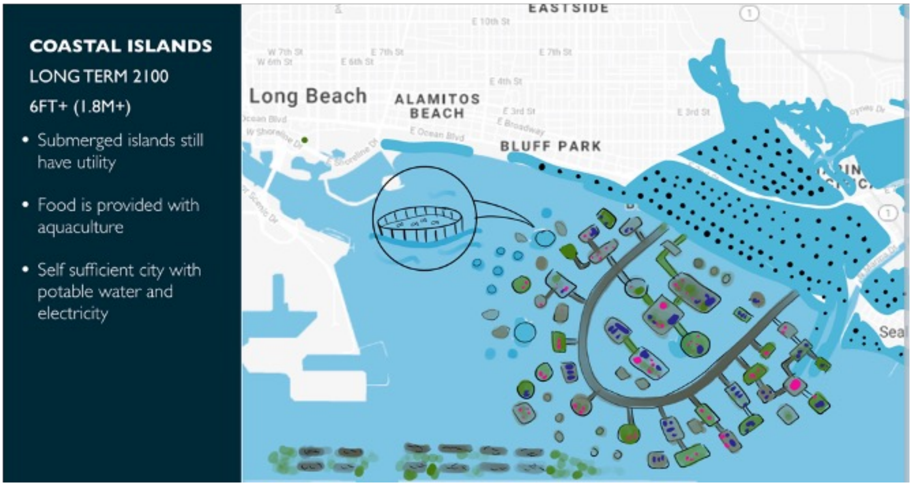

Figure 4. Map of the final stage of the floating homes, businesses and aquaculture in 2100 (credit: Michelle Affandy, Derling Chen, & Rose Zhang, 2019).

Student Project 5: Otter Homes: Brandon Camino, Seohyeon Lee, Cullen Townsend
The Otter Homes project is based on a hybrid model that designs current infrastructure to flood with minimal damage in order to prevent other areas from flooding. The areas that do flood are designed to house residents and commerce through water adaptive strategies.

The Otter Homes project begins with city infrastructure that is designed to be useful before and after flooding. Before the flood, they serve as public spaces, and once the water comes, they divert water away from key city areas. The plan includes dramatic visual demonstrations and systematic relocation of residents during the construction of reimagined beach bungalows (Otter Homes) and floating villas.

In 2030, the City will start a dialogue with residents about the upcoming relocation and housing options. Public work projects will be constructed across the city. These spaces will be first designed as sunken basketball courts. Once these spaces flood in the future, they will serve as a visual and dramatic reminder of the reality of sea level rise, while also providing temporary drainage and water holding tanks. Additional flood zones will be designed to become wetland restoration projects.

In 2050, residents will be moved into sustainable compact "otter" homes that can be placed on land or water. Land otter home sites are situated in open spaces and vacant properties outside of the three affected neighborhoods, minutes away from the water. Floating otter bungalows will be established around Naples Island in Alamitos Bay first and are capable of being either temporary or permanent structures.

By 2100, floating villas will expand the residential opportunities further into the water, welcoming residents back to their original locations, now with direct ocean views. These multi-level villas will be arranged to be interconnected and allow all residents to have private marinas for water vessels.

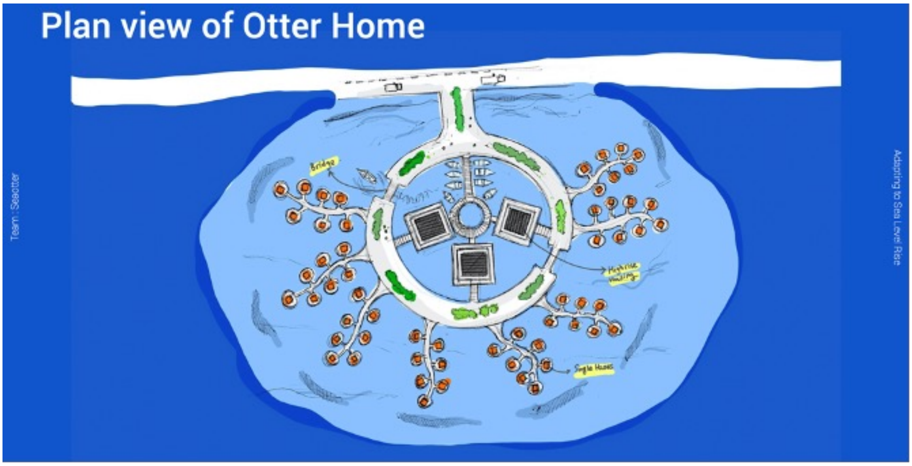

Figure 5. View of the final plans for the Otter Homes, a series of connected floating bungalows and villas that allow residents to move back to their neighborhoods (credit: Brandon Camino, Seohyeon Lee, & Cullen Townsend, 2019).

Conclusion

The Adaptive Planning Designstorm explored a significant aspect of the climate crisis: how do communities threatened by sea level rise respond to the loss of shelter and society, shorelines and ecosystems? The answer was not the result of a committee of scientific experts or governmental agencies. Rather, proposals were created by teams of student designers working in close cooperation with knowledge experts and community stakeholders over the course of three intensive days. This method of exploration was based on the hypothesis that design can bring a unique perspective that works most effectively when in close partnership with stakeholders and knowledge experts whose perspectives lead to inspiring and unifying proposals that serve as bold, yet achievable, visions of a collaborative future.

More specifically, five student teams led by three faculty studied climate change and focused on the projected rise of sea level in three coastal communities in Long Beach, California. Scientific evidence and projections, conservancy efforts, governmental responses, technological advances and resident concerns were available to students throughout the workshop. This exchange of information in an atmosphere of collaboration was a key element of the Designstorm process and outcomes. This provided an important stimulus for intense design exploration and allowed the students to explore and experiment with novel solutions from the start while also adhering to a brief providing common touchpoints.

Students uncovered different approaches to solving these complex problems that took technology, business, science and human behavior into consideration. Many projects embraced sea level rise as an opportunity to create new ways of living capable of adapting to rising seas indefinitely while recognizing the emotional and economic implications for stakeholders. These bold ideas require significant change and buy-in from the community as residents learn to coexist by adapting to a new relationship with the ocean. Other projects found the friction within the community and the ability to relocate residents to be a major barrier, and therefore prioritized maintaining as much of the land intact as possible and creating strong barriers that could withstand the rising seas by 2100. Overall, all student projects found that this challenge will trigger imminent change to Long Beach due to inevitable flooding and relocation. Most inspiring, students were able to find positive opportunities hidden within the threat of sea level rise and elevate them to bring new value to the community by providing new natural public spaces, sweeping ocean-front lifestyles, ocean-based income opportunities and modern forms of water-based transportation and housing.

Key Takeaways Based on Adaptive Planning Designstorm

The preparatory work and visit to the AOP and project site, and the three-day Designstorm provided an opportunity to utilize design to address a very real outcome of accelerated climate change. While there have been many design responses to sea level rise, few explicitly call for remaining in place as long as possible. This novel and very human-centric goal solicited new and unusual solutions. The success of the Designstorm as an instruction and learning method for design students was due, in no small part, to the close participation of experts in fields of science who provided a grounding and platform upon which the designers were free to create.

The key takeaways included:

- The Rising Waters Designstorm can serve as a model for integrating complex climate issues into design education and can provide learning opportunities for research, collaboration and design.
- Complex climate issues are more readily learned and integrated when given a real-world context; the reality of Long Beach and the people who live there introduced a sense of purpose into the design effort and advocacy for adaptation as a key strategy.
- The “fitness” of design research and ideation methods relative to climate issues was demonstrated, notably stakeholder research and skills such as sketching mock-ups.
- The value of partners and participants who commit time, resources and expertise in preparing students and faculty, and importantly, remain involved and available throughout the design activity, was amply demonstrated.
- Conversations and empathy-building with primary stakeholders (residents of Long Beach) was an important resource during research and validated the aspirational nature of the concepts; this also underscores the necessity to improve upon how stakeholder research is conducted in all areas of design.
- It is necessary to have a clear problem statement that establishes focus, is agreed upon by all partners and is stated in a design brief; for example, this project could have been given as “Addressing Sea Level Rise in Long Beach.” Instead, it was more prescriptive: a phased approach for adapting

to sea level rise in three Long Beach communities. Additional parameters were the timing of the phases (tied to NOAA data) and an emphasis on allowing the current residential and outdoor uses to continue as long as possible within an eighty-year timeframe.

- The Designstorm is a fast process that can deliver results in under a week, providing stakeholders with new information they can use for inspiration, planning and further development.

In summary, design education can contribute to building capacity for design for adaptation by engaging collaborators who are willing and able to engage fully throughout the process of the project, providing students with real-world projects focused on the impacts of climate change. The design brief and stated goals of such projects should take into account the needs of a broad spectrum of stakeholders and strike a careful balance between specificity of the challenge and openness to experimental and novel solutions.

Climate change is a global issue that demands the participation of us all. The Rising Waters Designstorm offers a model of collaborative learning in which design students learn by exploring and iterating solutions to a defined problem. The value of the Designstorm beyond the studio is in the experience of the process by stakeholders and the conclusions presented to them. In only three days, scientists, politicians, community members and other stakeholders are able to express their concerns, share their deep knowledge and have their voices heard independently while receiving an analysis of these thoughts through unifying proposals that serve as bold, yet achievable, visions of a collaborative future.

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RUDERAL MATERIAL PROJECT

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Abstract
What do the creeping thistle (*Cirsium arvense*), curly dock (*Rumex crispus*), and American pokeweed (*Phytolacca* americana) have in common? They are all ruderal plants that thrive within North American urban ecological wastelands. This community of wild, pioneering plants – a mix of native and invasive species – are the first to lay root to land that has been laid to waste by natural or man-made destruction. They are the change makers: adapting, surviving, and growing in the most barren of soils within our cities.

This paper reflects on the relationship between the material taxonomies of ruderal flora specifically colonizing Detroit's historic Belle Isle's Wet-Mesic Flatwoods – home to some of Michigan's most endangered plant species – currently disrupted by flooding, human disturbance, deforestation, and pollution. The methodology of the project focuses on observation through field work, cartographic snapshots, and material sample-making. The project explores how these disturbance-adaptive species integrate with native species to conceptualize future scenarios through a series of *material landscapes* to present a framework of opportunity, extinction, adaptation, and renewal.

If "environmental stability is an illusion, and an unpredictable future belongs to the best adapted" (Botkin, 1990; Del Tridici, 2014), what is the potential for these ruderal species to act as models to inform adaptive design practices? How could these design practices produce new material applications? And how do we – artists, designers, and humans – learn the ways of *ruderal thinking* to foster adaptive material systems? This project looks at these signals to coalesce into an interactive, bio-diverse dialogue designed around these inquiries.

Author Keywords
Ruderal plants; wastelands; disturbance-adaptive design; material landscapes.

Introduction

The Wet-Mesic Flatwoods is a unique ecosystem on the eastern side of Detroit's third largest island, Belle Isle, "a swampy type of forest that the Michigan Natural Features Inventory lists as 'imperiled' in Michigan" (Allnutt, 2020). The Flatwoods, as they are commonly referred to, are home to several colonies of native trees, including pumpkin ash (*Fraxinus profunda*), red mulberry (*Morus rubra*), and Shumard oak (*Quercus shumardii*), all currently on the Michigan Natural Features Inventory (MNFI) threatened species list, the last of special concern (Slaughter et al., 2010). Beneath their canopies lies a low-growing range of flora – a mix of species identified as native and non-native, the latter having the potential to be considered invasive if their growth causes harm to humans, the economy, or the environment. Due to natural and man-made disturbances – including flooding, human excavation, fires, and pollution – many native communities of plants have been removed or displaced, only to be replaced by the more adaptive colonies of *ruderal* plants.

Patches of native soil are still viable to provide support to the vestiges of a native ecosystem through dormant seed banks, but in the case of Belle Isle, large areas of non-native soil have been brought in as fill. The idea that communities can be restored to their original ecosystems by removing ruderal colonization and reseeding with native plants is an overly simplistic view (Del Tridici, 2014) in the wake of climate change, with rising waters, warmer temperatures, and continued human intervention to restore the environment to what it once was. Notable French biologist Antoine Laurent de Lavosier stated, "In nature, nothing is created and nothing is destroyed, but everything is transformed." If disturbance is a part of nature, learning to adapt is therefore the best way forward.

Adaptive Design Practices Through Ruderal Thinking
Ruderal plants thrive in anthropogenic habitats, pushing up through wastelands to colonize disordered communities, rising as the harbingers of changing ecosystems. As Susan Cowles (2017) states in *Brooklyn Says, "Move to Detroit": Ruderal Aesthetics*, ruderals are "metaphorically paradoxical: indexing catastrophe and abandonment, yet conversely representing resilience and renewal." The paradox of ruderal thinking permeates the work of contemporaries, seen in Ben Hartley's (2020) *Ruderal*, where he "explores the parallels between ruderal plant species with the processes of gentrification and urban renewal"; *Ruderal Consciousness*, a collection of works by artist Sam Schmitt at Hartslane Gallery, London, including an installation "encouraging plants to sprout in unexpected places" (Akriditis, 2020); and Margaret Haugwort and Oliver Kellhammer's (2021) *Ruderal Witchcraft*, a project that considers a "set of practices specific to planetary, weedy natures that work their way at edges and interstices of public and private property, and which are entangled with a range of other human and non-human outcasts of capitalist modernity." Designers and artists pursuing ruderal thinking in original design outcomes necessitate the creation of these new principles that exhaust all assumptions, whereby all solutions are measured. As a designer with a specific focus on natural or waste materials with a sense of place, "new materials can offer new, unique combinations of properties which enable original design" (Ashby, 1992, p. 5), yet initiating *small* modifications, shifts, and changes is the approach to considering larger adaptive material systems.

Throughout this project – uniting field study and exploratory creative practice – a collection of ruderal plant species has been observed, collected, and synthesized to create a series of hypothetical landscapes, speaking to the potential for adaptive, ruderal thinking in material design.

Methodology

Field Research
This project originated from the cartography of Belle Isle, observed prior to a guided walk hosted by the Belle Isle Nature Center in the fall of 2020. The *Ruderal Material Project* officially kicked off a few months later with an interview and guided tour of Belle Isle's Wet-Mesic Flatwoods with Amy Emmert, Director of Education at the Belle Isle Conservancy, in November of 2021. This was followed by repeated visits throughout the winter

to become familiar with the environment, document points of interest, and select sites for the spring of 2022.

The Wet-Mesic Flatwoods are cartographically divided into eight cells outlined by a series of winding "roads and trails that play a significant role in shaping the current characteristic of the flatwoods" (Slaughter et al., 2010). This mapping strategy presented eight unique contact points of discovery (Figure 1). Within each cell, a single one-foot-square site was selected based on 1) observed natural or human disturbance to the land and 2) the diversity of flora within the perimeters.

Figure 1. Map of Belle Isle highlighting the eight cells of the Wet-Mesic Flatwoods with sites marked. Map courtesy of Michigan Natural Features Inventory (MNFI).

Figure 2. Cell sites with material landscape snapshots. (left to right): Cell 3, Cell 5, and Cell 7.

Making Material Samples: Aerate, Perforate, and Disperse

The taxonomy of each ruderal plant sample was classified through a virtual dichotomous key – a combination of digital apps, including *PictureThis, PlantNet,* and *Seek by iNaturalist,* to identify, cross-reference, and archive each species. While every attempt was made to properly identify the species, this was an exercise in curiosity and investigation and was not intended to reflect the rigorous standards of scientific botany. Each material snapshot was used as a framework for conceptualizing mechanical attributes, material substance, color, and texture. Additionally, each material sample explored the strengths and weaknesses of the ruderal material to provoke concepts for adaptive outcomes.

A strength among the ruderal species became a common narrative: the ability to thrive in compacted, low-oxygenated soil. Heavy machinery used for building and paving leads to compacted ground, while flooding caused by climate change and human intervention can produce further oxygen deprivation in soil. Many ruderal plants have the ability to adapt to low soil oxygen by changing their root anatomy and architecture in a process called aerenchyma (Yamauchi, 2021). Using aerenchyma as a foundation for structure, a series of multi-material samples were ideated to show adaptation through perforation: foamed sponges for hydrophobic aeration, hydro-gels for protective organic films, and waxes for heat-triggered, form-shifting surfaces. This process of creating space – or pockets of air – was applied to all samples within the material landscapes.

Several methods were used to process the materials – drying, shredding, and grinding – to make pastes, powdered pigments, and shavings for dispersion within the samples. Each sample was bio-based, with the intent of reintroducing the material back into the landscape in its new form to modify, adapt, and decompose within the environment.

Figure 3. Ruderal material samples.

Results

Material Landscapes

The material samples and final material landscapes are abstract concepts for future artifacts and surfaces. They are considerations for opportunities and innovations for material adaptations. Of the eight cells, three were selected to create final landscapes: Cell 3, Cell 5, and Cell 7 (see Figure 4). Multiple experiments were performed to iterate a body of samples for consideration for each cell.

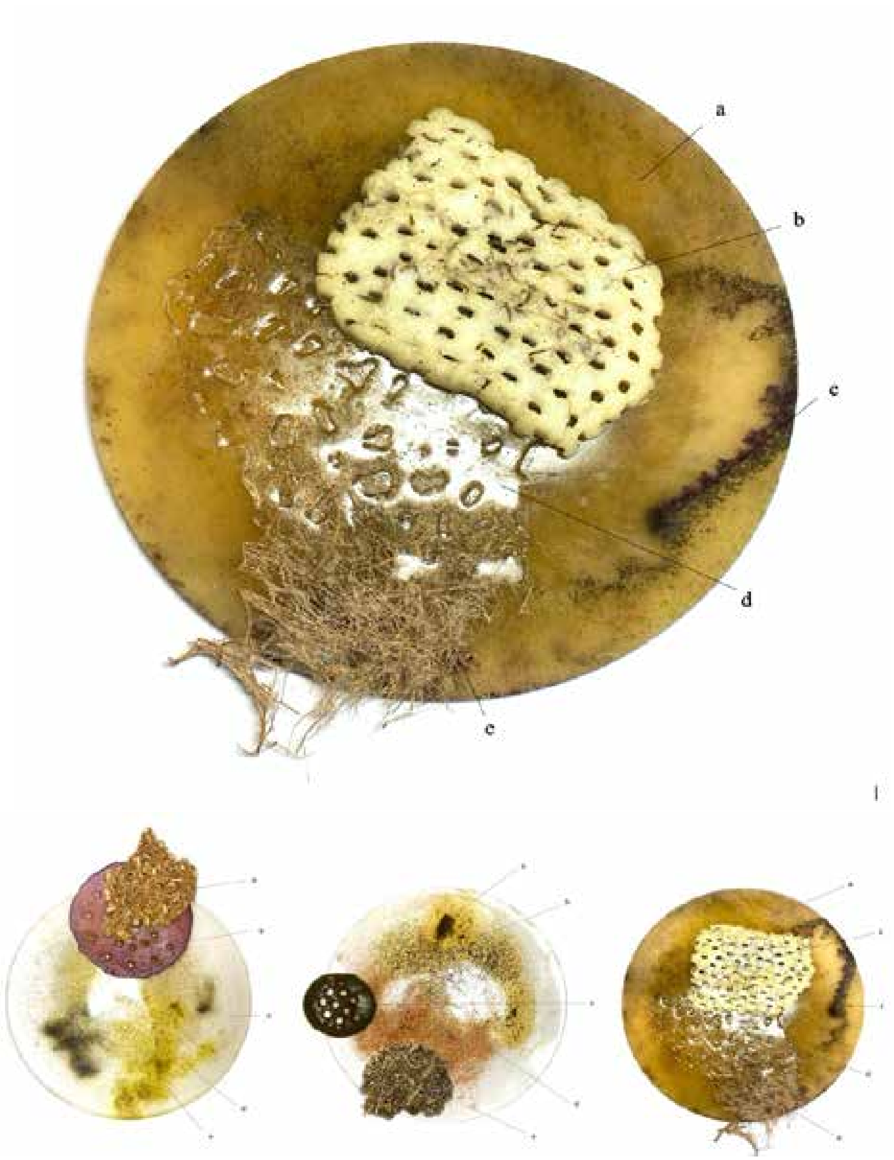

Figure 4. Ruderal Material Landscapes, Wet-Mesic Flatwoods. (top): Cell 7; (bottom, left to right): Cell 3, Cell 5, and Cell 7. Dimensions: original 7 inches, 6 inches after shrinkage.

Cell 3

Cell 3 is surrounded by Central Avenue, the Sylvan Canal, the Wildwood Pass, and the Oakway Trail. The Oakway Trail was paved until its recent removal in 2021 to increase hydrology and create a natural footpath. The site selected (42.346893, -82.965965) included lambsquarters *(Chenopodium album),* lady's thumb (*Persicaria maculosa*), field pennycress (*Thlapsi arvense*), cattail (*Typha*), fox sedge (*Carex vulpinoidea*), curly dock (*Rumex crispus*), and pokeweed (*Phytolacca americana*).

From these materials, several iterations were explored, with the final landscape represented by a brittle sponge of dried cattail (*Typha*) and curly dock (*Rumex crispus*); a perforated hydrogel of American pokeberry (*Phytolacca americana*), water, glycerin, and carrageenan; and a hydrogel slab, intended to protect and hydrate, with embedded powdered pigments of lambsquarters *(Chenopodium album),* lady's thumb (*Persicaria maculosa*), water, glycerin, and agar.

Cell 5

Cell 5 is located south of Central Avenue, where the soil has been disturbed by an unpaved road leading south toward Shadownook Street. The site selected (42.343686, -82.974061) included American burnweed (*Erechtites hieraciifolius)*, lady's thumb (*Persicaria maculosa*), yellow rocket (*Barbarea vulgaris*), lambsquarter (*Chenopodium album*), reed canary grass (*Phalaris arundinacea*), and creeping thistle (*Cirsium arvens*).

From these materials, several iterations were explored, with the final landscape represented by a perforated hydrogel – intended to protect and hydrate through fluctuating saturation and dehydration – with the embedded powdered pigments of American burnweed (*Erechtites hieraciifolius)*, yellow rocket (*Barbarea vulgaris*) flowers, and lady's thumb (*Persicaria maculosa*); a perforated bio-textile which dehydrates and re-hydrates to promote aeration, consisting of dried and powdered lambsquarter (*Chenopodium album*) leaves, water, glycerin, and carrageenan; and a brittle sponge made of shredded reed canary grass (*Phalaris arundinacea*), water, and carrageenan.

Cell 7

Cell 7 is located along the Hiking Trails Trailhead, surrounded by the Nashua Canal and Vista Drive. The site was selected (42.327425, -82.978987) for flooding due to a combination of natural and manmade disturbances. The ruderal plants include the invasive European honeysuckle (*Lonicera periclymenum*), annual bluegrass (*Poa annua*), lambsquarter (*Chenopodium album*), common dandelion (*Taraxacum officinale*), eastern annual saltmarsh aster (*Symphyotrichum subulatum),* Virginia creeper, garlic mustard (*Alliaria petiolate*), lady's thumb (*Persicaria maculosa*), and prostrate knotweed (*Polygonum aviculare*). The competitive saturation of flora in such a small footprint shows the potential for ecological succession, changing the environment for future generations.

From these materials, several iterations were explored, with the final landscape represented by 1) a hydrogel, intended to protect and hydrate, with embedded powdered pigments from the eastern annual saltmarsh aster (*Symphyotrichum subulatum)* powder (leaves), Virginia creeper (*Parthenocissus quinquefolia*) powder (leaves), lady's thumb (*Persicaria maculosa*), treacle mustard (*Erysimum cheiranthoides*), dried and powdered, prostrate knotweed (*Polygonum aviculadre*), dried and powdered, water, agar, and glycerin; 2) an herbal bio-foam made of common dandelion (*Taraxacum officinale*) seeds and pappas (fluff), water, glycerin, agar, and surfactant; 3) an embossed biofilm made of lambsquarter (*Chenopodium album*), water, agar, glycerin; and 4) a bio-textile – as a potential natural replacement for geotextiles – made of dried annual bluegrass (*Poa annua*).

Conclusion

The Ruderal Material Project was initiated to bring awareness to the unique ecosystem that is the Wet-Mesic Flatwoods through observing the attributes and relationships of adaptive ruderal plant species. The intent was not to create singular solutions, but to conceptualize potential ways of thinking and designing that could be applied to new artifacts, systems, and environments. Consideration of these material samples begins as starting points for adaptive future materials, ones that might require you to remain hydrated to fit, spend time in nature to shift color, or provide aeration where space is needed to breathe.

This project is an invitation to look at disturbance, wastelands, and weeds as indicators of change, considering these changes as potential for adaptation and innovation. Change does not require complete destruction, as disturbance is an essential part of the working order of nature: working incrementally forward, adapting through small shifts, and moving through extinction into the direction of renewal.

Future steps for the Ruderal Material Project include working with the Belle Isle Conservancy and the Department of Natural Resources to collect ruderal, non-native plants from each of the cell sites to curate a series of larger-scale material landscapes. The goal is for these landscapes to be exhibited within the natural landscape of Belle Isle for the purpose of education, discovery, and awareness of the changing environment, opportunities for adaptation, and recognition of resilience.

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ENCOURAGING ADAPTATION OF REUSABLE PACKAGING FOR FMCG PRODUCTS THROUGH E- COMMERCE DELIVERY

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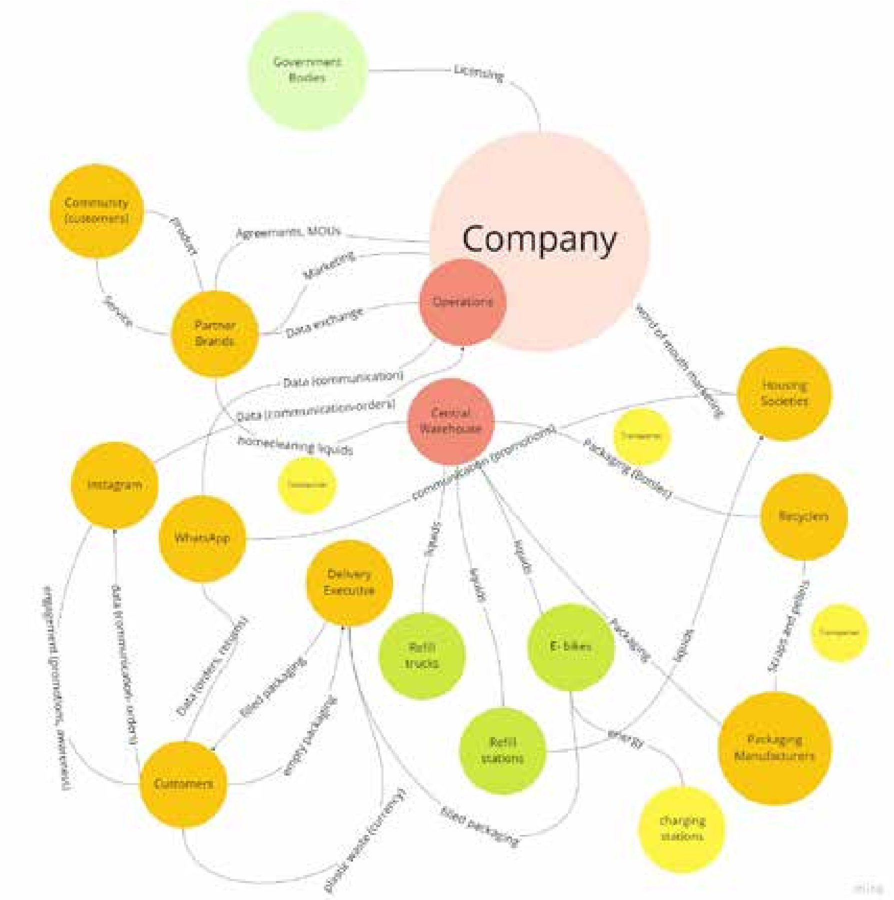

Abstract
E-commerce sales in India have seen a sharp rise in convenience to daily essentials, leading to an increased generation of packaging waste from FMCG products. Alternatively, governments worldwide are introducing policies to encourage the adoption of reusable and refillable packaging to combat the environmental and economic impact of single-use packaging. With this, it is essential now for brands and large conglomerates to adapt to closed-loop packaging systems at the earliest.

This project aims to understand the current buying behaviors and values of e-commerce app users for groceries and their views on the packaging. Getting know-how of the current market of reusable packaging and waste management infrastructure by interacting with experts is also essential to the study. Conducting an autoethnographic study through the lens of a researcher helped validate insights from in-depth user interviews. Post analysis of the collective qualitative data, an ecosystem model is proposed, which will help address the needs of consumers and companies through added transparency, human interaction, and communication strategies.

The model showcases how e-commerce companies and reusable packaging service providers must deploy communal-level interventions to drive increased adaptation of such packaging on a larger scale. By being a part of the system, each stakeholder contributes certain 'resources' and conducts 'activities' that are codependent on the other while looking to add value to and capture value from the system. It aims to ensure that all stakeholders involved in the ecosystem benefit from adapting to a systemic implementation of reusable packaging in the Indian market.

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FOSTERING CIRCULAR MATERIALS WITHIN THE DESIGN PRACTICE: MATERIALS AND PRODUCT LIBRARY SYSTEM

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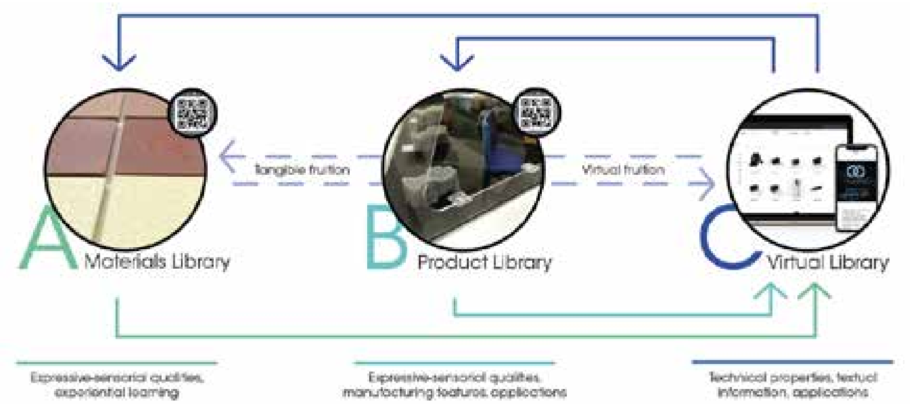

Abstract
New models of production and consumption should be investigated in the short and mid-term since the current resources' exploitation is overcoming the possibilities of our planet. Sustainable development and circular economy are assuming a crucial role, and several strategies for their implementation have been emerging in the last years. The individual contribution of new design strategies, circular materials, and digital technologies for exploiting circular economy practices is well-established. However, some issues still prevent the real implementation of those strategies. Designers are not fully aware of how to exploit them for real applications, although materials scientists and professionals are increasingly focused on the characterization of recycled and bio-based materials. This work aims to spread the use of circular materials amongst design practitioners by fostering the tacit knowledge of these materials through new experiential tools. This first design experimentation has been part of FiberEUse, a research project on exploiting new circular materials from recycled glass and carbon fibers. Starting from the concept of a "materials library," a new experiential tool has been designed to stimulate the exploitation of circular materials and reach a wider network thanks to a physical and virtual learning experience. A first demo of the "materials and product library system" was exhibited at Milan Design Week 2021, and the virtual part is visible at https://fibereuselibrary.com/.

This adaptive system is not only meant to collect materials samples since it also includes new products/applications and non-textual contents. Moreover, it can be used during the whole design process, facilitating the tacit knowledge transfer by direct experiencing physical and virtual contents, i.e., flat samples, product parts, pictures, and technical data. Materials and product library systems represent a potential way for design practitioners to discover new circular materials and speculate on possible applications for their exploitation within real contexts.

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