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DESIGN ACROSS BORDERS UNITED IN CREATIVITY

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DESIGN ACROSS BORDERS
UNITED IN CREATIVITY

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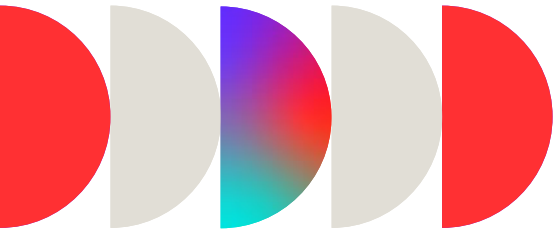
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Preface

In a world shaped by constant transformation and global interconnectedness, design emerges as a bridge between people, places, and ideas. Cumulus Monterrey 2024: Design Across Borders – United in Creativity invited the international design community to reflect on the profound potential of design to transcend cultural, geographic, and disciplinary boundaries, uniting us in the shared pursuit of innovation, inclusion, and positive change.

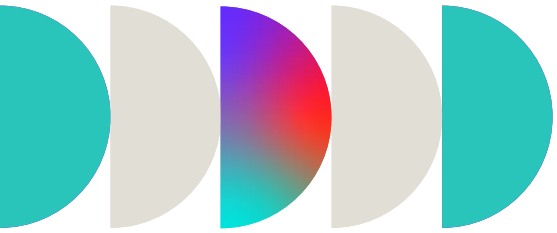
This edition of the Cumulus Proceedings gathers contributions that respond to urgent questions: How can design foster empathy and intercultural understanding? In what ways does it become a catalyst for social transformation in a complex, globalized world? Can design truly become a universal language—and what are the challenges in achieving that ideal?

The richness of perspectives represented in these proceedings speaks to the global nature of the Cumulus network. Authors, researchers, educators, and practitioners from across continents have come together to share insights, experiences, and provocations within four thematic tracks:

- Design for Change explores design's role in social innovation, sustainability, equity, and the circular economy—highlighting projects that place co-creation and inclusion at their core.
- Speculative Futures ventures into emerging territories shaped by technology, artificial intelligence, and immersive experiences, imagining the future of creative practice.
- Education in Art and Design focuses on pedagogical innovation, interdisciplinarity, and the challenges and opportunities of digital transformation in global learning environments.
- Translocality brings critical attention to issues of migration, decolonization, and the Global South, recognizing the importance of diverse voices and perspectives in shaping a more equitable world through design.

Together, these contributions reflect a collective commitment to harnessing creativity as a force that transcends barriers—linguistic, political, cultural—and brings people together around shared values and visions.

We are proud to present this volume as a testament to the power of design to imagine, inspire, and unite. May it serve not only as a record of this important moment in time but also as a spark for continued dialogue, collaboration, and transformation in the global design community.



Design Across Borders: United in Creativity

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

The Cumulus Monterrey 2024 Conference marked a timely and vital moment in the global conversation about the role of design in shaping a better world. Hosted at the prestigious design institutions of Tecnológico de Monterrey and Universidad de Monterrey (UDEM), the international gathering has been further enhanced by the unique Monterrey's rich heritage and cultural identity, contributing to a thriving ecosystem of creative exchange for scholars, researchers, and practitioners across various design disciplines.

The central theme of the conference, "Design Across Borders: United in Creativity," provided an inspiring gateway for exploring how design holds the possibility to transcend geographical, cultural, and disciplinary boundaries. In particular, the conference was framed by four imperative trajectories: "Design for Change," investigating how design practices can drive social innovation and sustainable development; "Design Futures," exploring the interplay between technology and creativity, immersive experiences, virtual realities, and the implications of artificial intelligence; "Education in Art and Design," investigating pedagogical approaches in the field; and "Translocality," addressing complex issues of migration, decolonisation, and North-South dynamics. Themes highlight the broad scope of contemporary artistic and design pursuits.

At the heart of the conference was a shared recognition that design can be a dynamic force for empathetic understanding and intercultural dialogue. Through a rich program of keynote lectures, panel discussions, workshops, exhibitions, and informal exchanges, the international community demonstrated determination to work collaboratively across geographical and cultural divides, confirming the foundational premises of the conference: that creativity knows no boundaries, and through design, we can forge connections that transcend the limitations of space, time, and cultural difference. In an era of unprecedented global challenges, from climate change to technological acceleration, from cultural conflicts to social inequities, designing without boundaries means identifying areas of commonality, intersection, and convergence, highlighting them in ways that resonate with and reflect the spirit of our transborder region. As traditional confines between nations, disciplines, and cultural contexts become increasingly permeable, the design community must find itself uniquely equipped to harness this fluidity. Rather than resisting uncertainty, design must embrace it, transforming constraints into opportunities for innovative problem-solving and cross-cultural exchange.

The proceedings collected in this edition offer an extensive variety of perspectives on the ideas and projects discussed at the event. They include case studies, speculative work, educational reflections, and practical strategies, all pointing to the evolving role of design to shape societal interactions, encouraging intercultural dialogue, and building a more harmonious and interconnected world. However, these proceedings capture only a portion of the energy and insight shared during the conference, with the remaining impact continuing to reverberate through ongoing collaborations and dialogues within our global community.

As we move forward, the conversations from Cumulus Monterrey 2024 remind us that creativity thrives not in isolation, but in community. And in a time marked by division and uncertainty, design, when practiced with care and intention, can truly serve as a bridge. One that brings us together to learn, to act, and to imagine a positive change.

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Index

PAPERS **21**

Ngaua Te Pae Hamuti: Rise To The Challenge: Tethering Commonality And Contrast To Create Opportunities For Positive Social And Environmental Change **22**

3D Printing Of Energy-Efficiency Windows **45**

Analyses Of Sustainable Development In City Visual Image Design: A Study Based On Citespace Knowledge Mapping Method **58**

“The European Fusilli Project In The City Of Turin: The Systemic Design Of Circular Agri-Food Proposals Involving Local Actors Of Mirafiori Sud District” **87**

An Analysis of Inclusive Design Integration And Intersectionality In Design Education Curricula **112**

A Contrastive Study of Service Design in Public Transportation System in Shanghai and Turin **136**

Collaborative Design Explorations With Augmented Reality **159**

Biomaterials and Biodesign Transferring Knowledge From Academia to Secondary Schools **179**

“The ‘Maraña’ as a Dysphoric Notion for Staying with the Troubles of Revolts”. **200**

Research on Fashion Clothing Design Strategies for the Young Elderly From an Inclusive Perspective **218**

Beyond Boundaries: Enhancing Human Experience Through Inclusive Design **239**

The Development and Logic of Digital Fashion From The Perspective of the Design **253**

Strategic Foresight and Worldbuilding With Companies **282**

A Design-Led System Towards Circularity **304**

Speculative Design Education: Identifying and Analyzing Critical Moments in the Process of Extrapolating Future Scenarios **326**

Design for Being Home and Connected: Emerging Types of Dwelling at Home Toward Smart Furnitures **352**

Adaptive Learning Experience for Art and Design Graduates in a Changing World **376**

“Deconstructing the Traditional Boundaries of the Automotive System Through the Recycling of Composite Materials in the Design and Production of the Future Car” **388**

Bridging The Gap: Linking Transferable Skills to Potential Futures in Graphic Design **410**

Design for Children's Active School Commuting Environmental Safety Empowered by Artificial Intelligence and Augmented Reality **432**

"Ensurance" Environmental Insurance: Research And Practice Based on Social Innovation Design **452**

Research on Health Detection Product Design Based on Affordance and Traditional Chinese Medicine (Tcm) Wellness Concepts **467**

Cross-Cultural Design Innovation Through Technology And Creativity **481**

Research on the Experience Product Design of Intangible Cultural Heritage "Song Dynasty Kites" Based on the Perspective of User Needs **501**

Research on Environmental Regulation Design of Sustainable Community from the Perspective of Thermodynamic System **522**

Extended Curriculum Programmes in South Africa: A Focus on Social Justice and Arts-Based Pedagogies **547**

Multidimensional Artistic Processes and Strategies for Conversational Practices Between Women **570**

Packaging and Cultural Accessibility. Designing Product Comprehensibility for All Users **586**

Research on the Emotional Value of Traditional Residences from the Perspective of Daily Life — Take the Example of the Eagle River Diaolou Group **607**

"Blockchain Applied to Systemic Design: Ensuring Project Authenticity Through Quantitative Report Verification" **625**

Untold Stories: The Graphic Design of Maria Keil and Cristina Reis During the Portuguese Dictatorship and the Path Towards Inclusiveness **640**

Cultural Dimensions in Design: Research on the Shifts of Interactive Relations **663**

Navigating Challenges in Participatory Design: Exploring Handover Tools when Designing for People with Dementia **688**

Time for (S)Heroes to Enhance Circular Fashion and Costume, Art Installations, Devising for Design, State-of-the-Art Technology, Inclusion and Diversity **713**

Data Sonification and the Power of Audio: Breaking Boundaries of Information Design with Creativity, Accessibility, and Innovation **737**

"Places to Learn – Cultural Heritage Enrichment Model (Chem) for Transformation and Innovation Through Art and Design" **763**

How can Generative AI Transform Smartphone Communication?: Exploring New Design Landscapes for Everyday Experiences **785**

Regenerative Design in Tibetan Regions: Place-Based Learning Through Storymaking **801**

Shifting Graphic Design Pedagogy: Co-Creating With Cancer Survivors for Inclusive Clinical Trials **824**

Research on Brand Experience Design Strategy for Mr Virtual Community Based on Ahp-Qfd Model **841**

Design and Biomaterials: Integrating New Models for Sustainable Design **863**

Cultural Regeneration of Domestic Wastes From Participatory Design Perspective **883**

Design-Driven Innovation (DDI) as a Catalyst for Transformation: A Case Study of the Air-Membrane Version of Huo-Yan Laboratory **914**

Pemo, Positive Emotion: A Gamified AI Journaling Website Centered on Facilitating Users in Developing More Positive Narrative Identities **936**

Puli Project Semillas Del Futuro: Implementing Design-Led Education to Transform Communities **957**

Design Futures for Traditional Craft: A Collaborative and International Approach **974**

A Study on Modular Concept Design for Street Vendor Markets in the Context of Consumption Downgrading **993**

Sustainable Choices, Fresh Approaches: Redesigning Meal Kits Using Activity Theory **1013**

Research on Daily Spatial Practices in Traditional Chinese Villages: A Case Study of Fujian Tulou Villages **1030**

Extending the Lifecycle of Designed Products for Sustainable Development: Insights From Zisha Teapot **1051**

“Designed By Women (DPM): Approaches for a Historical, Non-Sexist, and Co-Creative Study on Pioneering Women Designers In Chile” **1079**

“Co-Creation and Design of Tools for Cultural Mediations in Art Museum of Ciudad Juárez” **1100**

From Dystopia to Micro-Utopia: Societal Change Through Digital Design Innovation **1121**

Crafting Immigrant Narratives of Belonging: Art and Design for Social Innovation with the Latino, Latina, and Latinx Community of Iowa City **1137**

Artistic Resistance in the Post-Privacy Era: Reflection, Imagination, and Reconstruction Under Liquid Modernity **1153**

Empathy Engine: Using Game Design and Real-Time Technology to Cultivate Social Connection **1172**

Digital Droplets: Shaping the Appreciation Experience of “Spring Water” **1194**

Care of New Knowledges - Educene **1213**

Co-Designing for Equity: Addressing Anti-Black Racism in the Arts in Canada- A Working Paper **1232**

Experience prototyping with an Educational Robot Platform: Development and Pedagogical Reflection from an Interaction Design Course **1256**

Onlife. Exhibit Design in the Time of the Mangrove Society **1276**

Aigc and Vernacular Creativity: A Study of Chinese Rural Children’s Aesthetic Education From the Perspective of Capability Approach **1295**

‘Re-Wilding’ The Cultural Landscape. Breraplus, an Ethical and No Borders Museum Experiment **1318**

Design-Driven Innovation for Natural Capital: Mapping Criticisms Among Conservationbodies to Implement Accessible Technological Tools for Conservation **1333**

Pastry as a Medium: Design for Social Innovation of Catering Service in a Chinese Nursing Home **1354**

Augmenting the Double Diamond: Critically Integrating Generative AI in the Creative Process **1371**

Eco-Data Informed Processes. Nature as a Co-Designer to Face Environmental Change **1386**

Hauntological Speculation Device: Designing Lost Futures with Design Students to Explore Socio-Technological Scenarios **1413**

Depictions of Sustainability and Unsustainability: AI-Generated Images as Part of our Semiosphere **1431**

Reassembling Resilience In Breakdown: How Mexico City Recovered Food Security Through Micro-Innovations During the Covid-19 Pandemic **1444**

Design-Led Circularity for Furniture Manufacturing. An Application on Montessori Kindergarten **1462**

Towards A Post-Anthropocentric Creative Framework To Support Designers In Envisioning More-Than-Human Futures Brand Strategy Empowers the Revitalization of Rural Areas and Social Innovation in China **1491**

A Study Of Multisensory Stress-Relieving Product Design for Female Office Workers **1510**

Brand Strategy Empowers the Revitalization of Rural Areas and Social Innovation in China **1528**

Artificial Intelligence as a Catalyst for Individual and Collaborative Creativity in Design Conceptualization **1544**

"Design for Chronicity: The Case of Pharmaceutical Packaging in Medical Treatment for Elderly" **1558**

Enhancing Pro-Social Experiences Through Cross-Cultural Interactions for the Campus of the Future **1577**

Across Borders: A Pilot Phd Programme in Design, Art And Technologies. Open Questions for A Post-Disciplinary Education & Research Model **1597**

Design in the Multidisciplinary Era: Collaborative Approaches to Cultural and Territorial Reactivation **1616**

Hospitals or Homes: Where Will We be Cured in the Future? Design Challenges and Visions in the Rapidly Evolving Home Care Sector **1643**

"Design to Create Value: *Made In...* Paraguay for Transition" **1658**

Design as Resilience: A Model for Global Collaborations **1684**

Space Exploration: Community of Intercultural Identity Through Memory Sharing **1706**

Application Strategies of Artificial Intelligence Technology in Art And Design Education: A Multi-Case Study from the Perspective of Interdisciplinary Thinking Cultivation Feasibility **1721**

Updating Wayfinding Literature and Teaching Methodology **1738**

Explore Boundary Space: Design Strategies for Street Renewal in Beijing's Hutong Neighborhoods Based on the Idea of Symbiosis **1758**

Identity Construction and Spatial Production: The Evolution of Milan's Chinatown **1771**

Archeology in Transit **1789**

Exploring the Concept of Multiespecies Design: Perspectives from Mexico **1818**

Event-Based Education in Design: A Case Study on Fostering Critical Thinking and Social Impact **1846**

Empowering Design: A Framework for Stigma-Free Design and Human Augmentation **1874**

Designing a Participatory Process to Implement Technology-Based Projects in Vulnerable Communities. **1892**

Architecture of Degrowth: A Spectrum **1908**

The Future Evolution of Design-Oriented Practices in the Context of Human and Non-Human Collaboration **1936**

Designing for Durability: How Fashion Brands are Encouraging Longer Garment Life Through Consumer Behaviour Change **1956**

Prototyping a Migrating Virtual Re-Ceptionist Using Physical and Virtual Reality Tools: Implications for Design Competency and Tool Development **1975**

Designing Hybrid Welfare Spaces and Services: Exploring The Intersectionof Physical and Digital Dimensions for Social Inclusion In Urban Contexts and Peripheries **1998**

“Alles Richtig Ist Nicht Richtiges Für Alle” **2011**

Co-Designing with Humans **2030**

Economic Generation Project for Indigenous Women in Northern Cauca **2047**

A Materials Design Practice Between Crafts, Creativity and Technology **2074**

Higher-Order Factors of Creativity: An Analysis of an Attributes Database **2097**

POSTERS **2119**

The Evolution of Graphic Poster Design: A Meta-Analysis Of Media Technology’s Influence On Creative Practice **2120**

Enhancing Child Development Through Interactive Illustration Design In Picture Books: An Interdisciplinary Approach Talavera Of Puebla, Design As An Element Of Cultural Identity Of Puebla, Mexico **2122**

Talavera of Puebla, Design as an element of Cultural Identity of Puebla, Mexico. **2124**

Digital Fashion Education: A Collaborative Approach to Preparing Students for Indutry 4.0 **2126**

Global Collaboration For Sustainability: An Innovative Educational Approach **2128**

Human Mobility And Design **2130**

WORKSHOPS **2132**

Designing for Social Justice and Human Rights: Building Networks for Victims of Violence and Families of the Disappeared **2133**

CMF Strategy Design Using Generative AI **2134**

New Turn In Design Research And Education - A Panel Discussion **2136**

Dear AI, What Do I Want To Say And What Does It Look Like? Tools And Methodologies For Image Making **2137**

Physicalising Symptoms: The Role of Materials in Supporting Intimate Data Collection to Improve Awareness and Communication In Healthcare **2139**

Codex Artificialia: A New Creative Act to Resist the Hype of Smart Commodification and Decolonising Tomorrow **2146**

Design As Community Care: Drafting a New Manifesto for Design Education **2148**

Refugeoly Gam 2149

Co-Creating Collaborative Cultures: How To Teach Collaboration In Design School 2150

Rethinking Design Education: Teaching if We Could be Risky 2152

Designing With The Desert: Crossborder Pedagogies For Sustainable Bioregions 2156

Designing Plural Futures 2163

Green Threads: Sustainable Fashion Jam 2165

Beyond Words: Image, Gesture & Empathy 2166

Application Workshop Cumulus Conference Monterrey 2024 2168

Robotics With Us in our Meaningful Places: Combining Art-Based Methods With AI to Build Empathy Between Human-Robot Interaction 2171

The Country of Origin Effect: Mapping Design Values and Patterns 2176

Systemic Design Interventions: Understanding the Transformation Towards the Circular Plastic Economy Through the Lens of Aquaculture Case 2179

Strange Strangers In Strange Lands: A Collaborative Storytelling Game For Community Biodiversity Activism 2196

SLIDE DECKS 2202

Art and Design Activities as Data 2203

Cultivating Community Collaborations to Foster Societal Change 2204

Gota and Gulshan: Poetic Adornment 2206

Transformation to a Circular Campus 2208

Technology and Māori Narratives in Design Education and Research 2210

Co-Designing Health Communication for Neurodevelopmental Disorders in South Asia 2212

Representing Risk: Radical Collaboration In A Design Classroom 2215

Kinesthetics and Interoception: Future Designs for More Than Five Senses 2218

Decolonizing Design: Equity in Participation 2219

Strategic Foresight for Social Impact: Utilizing Design to Promote Empathy and Intercultural Understanding 2221

The Evolution of Collaboration: Tracking Benefits of Alternative Instruction Methods 2224

We All Need A Home: Co-Creating Sustainable Shelter 2226

Off Road, Try Out & The Choreography of Making 2229

The Future of Craft 2232


PAPERS

NGAUA TE PAE HAMUTI: RISE TO THE CHALLENGE: TETHERING COMMONALITY AND CONTRAST TO CREATE OPPORTUNITIES FOR POSITIVE SOCIAL AND ENVIRONMENTAL CHANGE

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ABSTRACT | In an effort to mitigate the ongoing impacts of hegemony in design, experienced as a result of Modernist storyline this research seeks to reconsider and recalibrate the Universal narrative. Reflecting on the dogged legacy of modernism, this research proposes that design has much to gain by exploring its past as, not one Universal history, but a series of intersecting and diverging narratives. Being place-based, in Aotearoa, New Zealand, this research begins by elucidating untold moments of intersection and divergence between *mātauranga* Māori (Māori knowledge), Pasifika ideology and design's solitary history. Having identified these moments, this work exemplifies the impact of including more diversified understandings of the past, and the knowledge it holds for the future. In these works, design students embrace Indigenous knowledge, specifically Māori and Pasifika worldviews, to guide their methods and mindsets, and showcase the benefits of incorporating these often-overlooked approaches on both global and local scales. Their work challenges linear perceptions of time and space and helps position them in relation to the problem and the solution. This research posits that our histories shape our futures, and that design has much to learn from Indigenous worldviews, and what they offer both design pedagogy and practice by, as reflected in the 2015 Transition Design Provocation, looking to the past to create solutions in the present with future generations in mind. *Ki muri ka mua* - I walk backwards into the future.

KEYWORDS | INDIGENOUS KNOWLEDGE, DESIGN FOR CHANGE, MATAURANGA MĀORI,TRANSITION DESIGN

1. Introduction - Pulling a thread and unravelling the knitting.

Important to this research is its positionality. It is undertaken in Aotearoa, New Zealand, a bi- cultural nation first and foremost. It recognizes The Treaty of Waitangi, (Te Tiriti o Waitangi), as New Zealand's founding document, signed in 1840 between 500 Indigenous Māori chiefs and the British Crown. Guided by that, this research speaks to the principles of equality, equity, collaboration, and self-determination that are also central to our curriculum at Te Kura Hoahoa, The School of Design Innovation (Victoria University of Wellington, Te Herenga Waka) in Aotearoa, New Zealand. Our responsibilities include acknowledging Māori (as New Zealand's Indigenous people) as distinctive and equal partners, and whose beliefs and knowledge systems are not to be blended through cooperation into commonness. To meet these responsibilities and enable changes to our current and future practice as designers the need to firstly acknowledge and include Māori in our design history is necessary. To understand my motivation to undertake this work is the recognition of my own positionality as Tangata Tiriti, and a Pākehā (white, New Zealander). As a design academic and educator, my responsibilities to Te Tiriti o Waitangi explicitly reference protecting Māori interests, caring for future generations with and for Māori and affirming New Zealand's unique identity. The next step which uncovers the connections and divergences within our design history as a part of or distinct from the dominant Universal version, was like pulling a thread and unravelling the knitting.

This work is greatly buoyed by Arturo Escobar assertion of the emergence of,

—"a transnational space, anchored chiefly, but not exclusively in the Global South, that problematizes anew design's embeddedness in global historical relations of power and domination, variously explored in terms of design's relation to histories of colonialism and imperialism, its functioning within modern/colonial matrix of power, the geopolitics of knowledge (Eurocentrism), racism, and patriarchal capitalist colonial modernity" —

(ESCOBAR, A. 2021).

This article promotes the shift towards the transnational space Escobar speaks to and away from the creed of universality, historically devised to unify, and whose history is inherently Eurocentric and linear. Highlighted are numerous unacknowledged intersections between indigeneity and the Euro/American-centric storyline that elucidate the duplicity and shortsightedness its embeddedness to a singular modernity. This research describes and exemplars how, in Aotearoa, Te Ao Māori (the Māori worldview), *mātauranga Māori* (Māori knowledge), and *tikanga Māori* (Māori values and protocols) guide design towards creating inclusive, equitable, and self-determined futures. By understanding and respecting this knowledge as an eco-system, and not as parallel or diverging narratives, the opportunity exists to grow design practice modelling what Buckminster Fuller fittingly described as Spaceship Earth (Fuller, 1969). This research asserts that design curricula and practice should embrace the tensions of this ecosystem, recognizing and respecting both commonality and contrast as critical. The examples offered articulate and demonstrate design that is rooted in the Māori *tikanga* of: (the fluidity and longevity of reciprocity), *whanaungatanga* [authentic connections through collaboration and understanding], *manaakitanga,* (the care offered), and *kaitiakitanga*, (active guardianship) through the recognition of responsibilities to, not for, people and place.

To provide some context, in Aotearoa, we often identify or position ourselves to Te Tiriti o Waitangi in one of three ways; Tangata Whenua, being people of the land (Māori lineage), Tangata Tiriti, people who abide by the Tiriti o Waitangi (non-Māori lineage), and Tangata Moana, (people of Pasifika lineage living in Aotearoa). The Pacific Ocean that surrounds Aotearoa covers one third of the Earth's surface. The island nations of the Pacific are home to around one third of all the world's languages and cultures. Although the number of people in our region is relatively small, they are enormously diverse. Although separated geographically we are also bound together by a common body of water. As a result, we view the Pacific region, as a sea of islands, peoples and places connected forever as part of a reciprocal and sustaining relationship (Hau'ofa, 1994). This relationship brings to the surface an opportunity to challenge the singularity of the Universal; asking how it might acknowledge and accommodate more plural, and inclusive methods and mindsets in its narratives and works. In Aotearoa, our dependence on a Euro-American centric design lens is now being contested, with our design history being rewritten, expanded and retold. This research seeks to rewrite and recalibrate what are currently culturally limited and limiting histories and practices. The aim is to elucidate the relevance of place-based and Indigenous knowledges as a part of design's models and mindsets within current, and for future iterations of social, cultural and environmental innovation and co-designing practices.

Translated into English from Te Reo (the Indigenous language of Māori), the title of this paper, *Ngaua Te Pae Hamuti* means Rise to The Challenge. More colloquially it means Eat the Shit Stick. This perhaps best describes the difficulties we all experience when undertaking design for change. It is difficult and often projected, and we as designers are required to get our hands dirty doing the work needed to address the challenges and changes sought firstly, within ourselves, and then the communities we serve. This study asserts that by re-evaluating our individual and collective reliance on the Universal and learning from what we currently consider old and outmoded knowledge, we can better respect, enable and understand each other - ensuring we are no longer blended through universality into a common-ness.

—"Indigenous knowledge is not old knowledge or knowledge relevant to distant, now outmoded times. Quite distinctly from Western knowledge, Indigenous knowledge has continued to evolve through rebellious, resistant, and resilient practices of its own"—

(O'SULLIVAN, 2018).

Dori Tunstall claims that design itself needs to be redesigned (Tunstall, 2013). Aligning with Tunstall, this article asserts the need to reconsider and recalibrate the Universal narrative, that as designers and devotees of aesthetic beauty we credit to the Modernist doyens. We have continued to rely on this version to seed our aesthetic and social aspirations, but in recent years a growing number in the discipline of design, believe a shift to be well overdue. Exploring the aesthetic and social narratives that the Universal Euro-centric history tells us define modernism and continue to dominate our practice, this research challenges design to retell its history, as histories. It proposes that with a fuller appreciation of the contributions and influences of others, as well as their discrete knowledges, the solutions design offers can be more representative and inclusive of the communities it seeks to serve. Arturo Escobar describes the Universal as "one storyline conceived from the perspective of the Euro-American experience and exported to many world regions over the past few hundred years", (Escobar, 2015). Renata Leitão expands this critique saying, "the leading role of the modern man entails that we live in a planet with only one storyline: the heroic story of the modern man"(Leitaō, 2018). Leitaō also added, "there are numerous cultures in the world whose knowledge could be mobilized in order to remake the relationship between humans and nature and Western conceptions of productivity, consumption, and evolution"(Leitaō, 2018). Building on this criticism, this work proposes that the telling our own histories within an interconnected network would help to better represent our pasts and as a result better enable and elucidate opportunities for designing futures that recognize both the connections and distinctions needed within the solutions we seek. Most importantly, this needs to be as a part of a reciprocal relationship. In response to Tunstall's lament that, "few studies in the design discipline

have focused on the future making process of translating Indigenous values into tangible experiences", (Tunstall, 2013), this article offers an example of how this endeavour is being addressed as a part of design education, social innovation and co-design practice in our School. It may be difficult to appreciate how our specific approach and aspirations can directly relate to a global context or to your (reader) specific context. But in response to this, this article emphasizes the space that Te Ao Māori, *mātauranga* Māori, and *tikanga* Māori already hold, albeit untold, in the design history you know, and throws light, rather than the historic shade usually imposed, on the relevance and capacity that numerous Indigenous knowledges have to contribute to current practices and the more holistic and optimistic outcomes we all seek. It is at this point in the discussion the advocacy Transition Design brings to Indigenous knowledge is acknowledged. This article claims that by reflecting on and sharing how we have begun our journey, in Aotearoa, to embrace and learn our Indigenous wisdoms and knowledges and to recognize the opportunities and connections that these offer us as a bi-cultural nation and multicultural society, it will hopefully become more apparent to others how they could better assist in the mobilization of other Indigenous knowledges, and the aspirations of a pluriverse that Leitão, Tunstall and Escobar also provide to our discipline.

1.1 Kia whakatōmuri te haere whakamua. I walk backwards into the future with my eyes fixed on my past.

This *whakatauakī* (Māori proverb), explains that to begin moving forward, or casting into the future, we need to look backwards. This study illustrates how the history of the Universal looks when viewed from Oceania. This is not to reconstruct all of design's history or to completely debunk it. The aim is to inspire reflection, expansion and adjustment from what is currently a linear trajectory to an intersecting model that is reflective of all of us – as both similar and unique. To initiate this discussion, the familiar and indoctrinated version of design history is challenged by firstly removing the established start line for the Universal. This enables an exploration of design history beyond the early 20th century starting line of Modernism to include other beginnings, and other connections. These include exposing synergies that exist between Indigenous visual-spatial languages and the core tenets of the Universal. Initially comparing the historic trajectory of Māori and Pasifika visual storytelling and their codification of visual codes, some anomalies appear in the history most told. This is then extended to spatial strategies and the synergies between Te Ao Māori, Ta Vā and the educational reforms of Friedrich Froebel (1782–1852) who has been credited with having had a direct "influence within the history of modernism beyond any predictable proportion" (Brosterman, 1997). The conclusion of this first section asserts that the continuation of the duplicities told,

the exclusion of Indigenous knowledge as a part of a design history, and the continued dominance of Euro- centricity are no longer, nor were they ever, justified. The rationalized graphic codes that delineated the order and beauty Modernism and the Universal sought so eagerly, provide a poignant beginning to this claim.

2. E ngaki ana a mua e tōtō mai ana a muri. First clear the weeds, then plan (Elder,2020).

This *whakatauakī* asks that we challenge what we think we know before plant anew. To date modernism and Indigenous knowledge is discussed as two disconnected storylines. Modernism is told in linear and quite separated way from Indigenous knowledge and they have never been investigated as connecting with each other. Highlighting the current roadblock for Indigenous knowledge Santos explains,

—"this knowledge is largely wasted because the theories and concepts developed in the global North and employed by academia (and the commercial world) do not identify such alternatives. When they do, they do not value them as being valid contributions towards constructing a better society"— (Santos, 2016)

To start rectifying the oversight of Indigenous contributions within design history, we begin with the history of ornament. Aesthetic education has long celebrated the work of Vitruvius (c. 90– c.20 BCE) and Leon Battista Alberti (1404–1472). Ornament was highly valued for centuries, culminating in its extravagant use in the late nineteenth century, which led to a backlash against it as excessive. Lumped into this initial criticism were cultural, religious, and historic visual languages. Reacting to the excesses of the Rococo style, mass-production horrors, and the widening economic social divide, theorists like Owen Jones (1809–1874) and John Ruskin (1819– 1900) began scrutinizing ornament. Their ideals in the late nineteenth and early twentieth centuries aimed to democratize society through education based on aesthetic appreciation, making it accessible to all classes and ethnicities. Contradicting the wider assumptions that like the Rococo, cultural visual languages were irrational or excessive, Jones study of ornament immediately pointed to Oceania for examples of rationalized ornament that uniquely related to form and function. This article highlights the importance of Jones' acknowledgment. Jones spoke to Māori and Pasifika ways of seeing, doing, and being that we refer to as Te Ao Māori (the Maori worldview) and Ta-Vā (the Theory of Reality). Understanding these perspectives helps us appreciate what Jones celebrated in his seminal 1856 work, The Grammar of Ornament: A Visual Reference of Form and Colour in Architecture and the Decorative Arts. Te Ao Māori and Ta-Vā emphasize the eternal connection between people and place, involving both tangible and intangible links between humans, nature, and objects. Māori author and anthropologist Amiria Henare explains that "in the Māori world,

people and things have close relations that collapse spatial and temporal boundaries." (Henare, 2015). Similarly, Ta-Vā, a Tongan ideology, describes these relationships as, "All things, in nature, mind and society, stand in eternal relations of exchange" (Mahina,2010). Jones's The Grammar of Ornament depicts a comprehensive historical assemblage of ornamentation across time and the globe. With this anthology Jones highlighted and applauded the aesthetic strategies of Indigenous graphics and flat patterning that was woven, engraved, or drawn into Indigenous artefacts, on bodies and onto tools from the Pacific region. Quizzically, these visual strategies were later sought after within modernism and appear to have been appropriated into the Modernist mindset. Jones recognized the advanced capabilities of Māori in ornament, pattern, abstraction, and innovation. He noted, "There is scarcely a people, in however early a stage of civilization with whom the desire for ornament is such a strong instinct" .This research asserts that these strategies, initially rooted in Indigenous cultures, were later integrated into Modernist aesthetics, albeit predominantly uncredited. At the outset of his writing Jones noted, of Maori culture, "There is scarcely a people, in however early a stage of civilization with who the desire for ornament is such a strong instinct" (Jones, 1856). He went on to claim,



(JONES, 1856).

Figure 1. Image from Owen Jones' 1856 The Grammar of Ornament: A Visual Reference of Form and Colour in Architecture and the Decorative Arts. Depicts the carvings and abstracted designs of Māori. Includes *waka* (canoe) paddles, *patu onewa* (club), and handles from the long staff weapon, *taiaha*.

—"Nothing is more primitive and yet the arrangement shows the most definition and skill. Their eye, accustomed only to look upon Nature's harmonies, readily enters into the perception of the true balance both of form and color. The beautiful New Zealand paddle would rival works of any civilization. (Figure 1) The swelling form of the handle where additional weight is required is most beautifully contrived. True art (design) consists of idealizing (abstracting), and not copying the forms of nature"—

In the production of form, the visualization of narratives, and the expression of both symbolic and pragmatic meanings, ornament has always been a fundamental tool. But as an article of culture, it has also been misunderstood, maligned and misused. It has also been refuted, no more vitriolically than by Adolf Loos (1870–1933) when in 1908 and as a part of his seminal work Ornament and Crime. Despite Jones earlier praise for the reductive and abstractive skill shown by both Māori and Pasifika in their toi (creative practices), and the French reformist Eugene Grasset (1845–1917) who stated, "The return to the primitive sources of simple geometry is a certain guarantee of the soundness of our method" (Grasset, 1905) Loos took offence. Perhaps motivated by who would claim to have bragging rights over the origins of this soundness and not the truth, Loos disagreed and boldly discredited expressions of Indigeneity stating, "The modern man who tattoos himself is either a criminal or a degenerate" and further condemned indigeneity stated it should be considered "as counteractive to the evolution of modern culture" (Loos, A. 1913). This defamation was one of the earliest, most fanatical and this author proposes, most shameful outbursts against Indigenous cultures and knowledges in the history of design or architecture.

It initiated the turning point in which any acknowledgement of expressions of culture, or Indigenous ideologies to inform aesthetics, form or functionality were, rather hypocritically as we can see, eliminated from the curricula or vernacular of design and architecture.

Ruskin and Jones are attributed with a significant contribution in the shift towards a Universal visual language. Building from their work and towards the reductive graphic code design history claims was established in the early part of the twentieth century by (but not exclusively) the Bauhaus Masters, more questions need to be asked. The implication, if Loos and numerous others are to be believed is that this happened in somewhat of a Eurocentric vacuum. Again, let us remove the starting line and consider the educational philosophies of the educational reformist Friedrich Froebel (1782-1852) and compare them to Te Ao Māori and Ta Vā. Froebel's impact on the legacy of modernism is palpable, albeit clouded by the individual claims of the Grandfathers of Modernism. Both Ruskin and Jones were recipients of Froebel's non-conformist teachings. Also not often told as a part of the Eurocentric design history is that Froebel's teachings also influenced the founding ideals and social ideologies of the Bauhaus founder Walter Gropius (1893-1969) and his Bauhaus Masters; Johannes Itten (1888–1967), Paul Klee (1879–1940), Wassily Kandinsky (1866–1944), Lázsló Moholy-Nagy (1888–1967) and Charles- Édouard Jeanneret (1833–1965), known to all as Le Corbusier. In addition, prominent American architects and designers Frank Lloyd Wright (1867–1959), Charles Eames (1907–1978) and Buckminster Fuller (1895–1983) were, like the others also recipients of Froebel's teachings. What has not been considered in the history told or the attribution of these tenets beyond a single source, are the profound synergies between

Froebel's teachings, Te Ao Māori and Ta Vā. All seek distinction *(mana)*, legacy *(whakapapa)*, connection *(whanaungatanga)* and collective understanding *()* through visual and spatial language and perception.

2.1 Poipoia Te Kākano Kia Puāwai. Nurture the seed and it will grow.

(ELDER,2020).

The central learning from this *whakatauakī* is we all need 'care' to fully realize our potential and is also a core belief in the teachings of Froebel. Froebel approached education from both a biological and a spiritual perspective. He believed that a connection with nature and the spiritual world offered a more holistic understanding of world we live in. He balanced science with the environment and promoted physical well-being and emotional connection with the natural world. He had devised curricula and designed tools called The Gifts. In combination these introduced a reductive graphic code based on a sparse grammar of lines and curves, acknowledging relationships within space and building his pedagogy upon holistic, sensory, spatial, and social ideals. Froebel believed that incorporating simple visual and physical elements into education, alongside sensory learning, one could better enable equity and unity within struggling societies. His work, like the Te Ao Māori and Ta-Vā, embraced all things in nature as connected. This offers an early connection between Western thought and Indigenous knowledge systems. Froebel introduced, more correctly, re-introduced, values that emphasized, nurtured, and respected the individual, acknowledging their ongoing or intergenerational connection to a larger collective, whether that is family, community, or the environment. To summarize, the drive by the Reformist, embraced subsequently by the early Modernists, was to initially rationalize, simplify, unify, and empower the individual and the collective through a codified visual language. To most succinctly illustrate the influence, correlations and/or influence of Indigenous visual language on or as a part of the Universal, a visual timeline has been devised in Figure 2. This illustrates resemblances and synergies, those of us in the Pacific regions, seek recognition of. The trajectory illustrates the evolution of reductive, abstracted visual languages from the perspective of Māori who *whakapapa* to (recognize their lineage) and Pasifika peoples, as beginning with the Lapita Peoples of Oceania. It begins the with the visual grammars observed in P.V. Kirch's 1997 work, The Lapita Peoples: Ancestors of the Oceanic World. Identified are the dentate stamping on Lapita pottery from as far back as 3200- 2700 AD. (Figure 2). This illuminates what this research proposes is the first link between traditional Indigenous practices from Oceania and what aesthetic educators ironically refer to as the inception of the Modernist approach, some centuries later. The next intersection came In The Grammar of Ornament, Owen Jones references numerous ancient cultures, taking from them theories and skills of visual representation and abstraction. Not discussed yet, but illustrated in Figure 2 is the incorporation, further application, and

development of these by the Bauhaüsler. The author assumes that the 1919 – 1933 Bauhaus chapter in the history of the Universal is tacit within readers knowledge of design. The timeline, having firstly pointed to the connection, if not the origin, of a reductive and codified visual language, in Oceania, it then clearly shows ongoing correlations between the Lapita, Maori and Pasifika creative practice, onto Jones, into the Bauhaus and beyond as a part of our continued reliance on this approach.



Figure 2. Depicted is a visual lineage of a reductive graphic code claimed by early Modernist's to have been devised and established in the early twentieth century as a Universal Visual Language. A Lapita dentate pottery markings (circa 3200- 2700 AD), B. Māori pre–colonial tukutuku wood and weaving, C. Pacific pre–colonial tapa cloth designs. D. 1850 Froebel workbook – reductive codes, E. 'Savage' Tribes plate from Owen Jones's 1856 Grammar of Ornament, depicting Māori and Pacifika patterns. F. Gunta Stölzl,1928 Bauhaus Weaving Workshop.

3. Te Rerenga Hui-te-Rangiora — follow the footsteps of our ancestors to protect our planet

(ELDER,2020).

By holding fast to the memories of our ancestors, this *whakatauakī* speaks to the of our roles as Kaitiaki, which within the Māori worldview means our role as guardians of both knowledge and the earth; being responsible to it, not for it. This research now goes beyond the discussion of visual language to include the holistic spatial, temporal and social ideologies espoused as a part of early Modernism and their parallel to Te Ao Māori and Ta-Vā. Both Te Ao Māori and Ta-Vā hold the belief that humans, nature and things are connected by both tangible and intangible factors. Froebel also taught this, with Ruskin and Jones expanding the Western appreciation of it. But duplicities start to appear in the dissemination of such knowledge as a part of the Universal. This was particularly evident in the experiences of Itten, and Moholy-Nagy. Despite Gropius, while teaching at Harvard Graduate School of Design, praising Moholy-Nagy's conception of space, saying it "opened design considerations to the problems of the fourth dimension and a modern conception of space" (Bayer, Gropius,Gropius,1938), Moholy's efforts continued to be questioned. His efforts, perpetuated by his widow, Sybil Moholy-Nagy were however resurrected in the mid twentieth century by Buckminster Fuller (Fuller, 1969) and Victor Papanek (Papenek, 1982). Both Fuller and Papanek acknowledged Indigenous ways of knowing and being in their work, with Fuller travelling to New Zealand to further his knowledge of it. But like Itten, and Moholy-Nagy, their efforts went mostly unheeded in their own lifetimes. This work has been picked up in recent years by several of design's leaders, that includes Transition Design and DESIS supported by Design for Social Innovation practices. In concert with both Te Ao Māori and Ta-Vā, Escobar explains, that within the pluriverse no living being exists independently of the Earth and where humans and non-humans are in ever changing entanglements as a part of the Earth's vital forces and processes (Escobar, 2015). The entanglement Escobar speaks to is where, as a part of Te Ao Māori and Ta-Vā, Indigenous knowledge is experienced as an active state of connection, where they nurture and forge positive change. Understanding that Te Ao Māori and Ta-Vā consider space as a relationship that maintains tangible and intangible connections between humans, nature and things that collapse boundaries of time and space is central to the next step in the telling of our design history in Aotearoa. As Tongan academic 'Okusitino Māhina explains,

— "People are thought to walk forward into the past and walk backward into the future, both taking place in the present, where the past and future are constantly mediated in the ever-transforming present".—

(MĀHINA, 'O. 2010).

Froebel, inspired by Jean Jacques Rousseau (1712–1778) and Johann Pestalozzi (1746–1847). All three, similarly to the Māori world, embraced all things in nature as connected, offering an early synergy between Western thinking and Indigenous knowledge systems. Froebel built his pedagogy on holistic, sensory, spatial, and social ideals and explained relationships within space through physical experimentation with perception, connection and divisibility. Jumping forward, Buckminster Fuller would later reference this relationship within his perception of the world as Spaceship Earth. Perhaps a residual implication of Loos' slur, any reference to Indigenous knowledge systems introduced to the Western world by Jones as being relevant to the teaching of relationships between humans and the environment also went unacknowledged. This limitation was also experienced by Itten and Moholy-Nagy within the changes they sought to embed within their holistic and socially orientated pedagogy that considered space and the immaterial. Itten proposed immaterial is an interwoven spatial relationship saying,

—"Walls with windows and doors form the house, but the emptiness in them establishes the essence of the house. The essence of a material is its effect of space, the immaterial. Space is the material of the immaterial."—

(BADURA-TRISKA, 1990)

Moholy- Nagy proposed space as, "shapes which are ordered into certain well defined, if invisible, space relations; shapes which represent the fluctuating play of tension and force". (Bayer, Gropius,Gropius,1938) Fuller proposed "there is no space there are only relationships" (Fuller 1969). Tongan understandings propose space as the in-betweenness, where connection is experienced as an eternal tether.

——"Vā is the space between, the in-betweenness, not empty space, not space that separates but, space that relates, that Vā holds separate entities and things together, the space that is context, giving meaning to things" ——

(WENDT, 1996).

Putting this knowledge of reciprocity into practice we ask students to consider Indigenous knowledge as a perspective from which to frame a critical standpoint on a global issue. Using the ideology of Ta-Vā as the nexus, students articulate their concerns for the spaces inhabited between humans and humans, humans and nature and humans and things. The students used Ta-Vā to discuss how respect, reciprocity, mutuality, and balanced socio-spatial relationships could be engendered into their design investigations. The student examples provided discuss Tā-Vā as offering them ways to investigate and relate to design issues around sustainability, mass-consumption, customization and inter-personal relationships. Their ability to appreciate and utilize the concept of eternal connections between the past, present and future is noteworthy. Students discussed historic experiences and impacts, future aspirations, and noted that the present is

the time when any negotiations towards change need to be undertaken. The first (Figure 3 left to right) argues that to be more considerate of future generations and less consumer driven design has a fundamental responsibility to restructure their thinking and production processes to include responsibility for our past actions and guardianship of next generations. The next argued that virtual relationships contain reduced capacity for empathy and social connection and as a result, human interactions and perceptions of behavior are changing. The student asserted that the design of digital communication technologies comes with a responsibility to better enable the human-to-human relationships it seeks to profit from. They discuss the relationship between humans and computers as fraught with inequities that include a lack diversity, poor accessibility, and minimal safety. The key finding was that a relationship devoid of authentic connectivity, riddled with filters, inaccurate translations, fakeness, dark patterns, inequitable access and dangerous spaces is not a sustainable model to build meaningful and trusted human communication and connection on. To the far right the student argues the need to reconsider what and how we use knowledge. She proposes we honour the past, disrupt the present, and recognize the potent value of taking risks and challenging the status–quo can have on our collective future.



Figure 3. (left to right) Students did typographically designed versions of the abstracts from research essays written to reflect their appreciation of Ta Vā. Student A: Speaks to inter-relational tensions between the planet and consumption. Student B: speaks to the intangible space of virtual communications but the tangible impacts. Student C: Argues for a disruption of Western linear frameworks within design thinking as a circular method not a linear one.

3.1 Kei Te Ahua O Te Kounga O Nga Whakairo O Te Tangata Te Ahua O Te Kounga O Tana Ao: The quality of one's individual thoughts inform the quality of their world (ELDER,2020).

Having outlined from the perspective of Aotearoa, the motivations, cultural context, and historic inaccuracies within the dissemination of the Universal, this article shifts to include examples of student work that, guided by the Te Herenga Waka's design curriculum, acknowledges and incorporates Indigenous knowledge. By expanding students appreciations of time, space and connectivity through Ta-Vā and Te Ao Māori, students have an opportunity to critique the past, and to recognize the relevance of Indigenous knowing and being to current and future behaviors and mindsets. This also encourages students to do this work in the present but situate it within the active space between the past and the future. We explain that this is the only space, in this sequential transition through time, where we can hold conversations, mitigate challenges, and navigate our pathways, using ALL the tools and knowledge available to us in the quest towards positive change, with, not for our communities.

In previous sections I have identified what I believe to be a place for Indigenous knowledge, specifically that of the Pacific region, within both the foundations of design and the future of its practice. This may not be your history, but it is a part of ours and offers design in Aotearoa, New Zealand the agency and confidence to move forward guided by the knowledge, methods and mindsets that Ta-Vā and Te Ao Māori embrace and offer us. To enable a more global approach this work can be considered alongside Transition Design and led by some of its founding words that "design has much to learn from these (Indigenous) approaches to designing and their symbiotic relationship with the natural environment" (Irwin, Krissoff, 2015). Transition Design proposes that in order for designers to act as agents for change, new approaches to design and problem solving must be based upon a deep understanding of both social and natural systems. It asks designers to examine their own value system and the role it plays in the design process. It argues that Transition solutions will be best conceived within a more holistic worldview that can inform new, more collaborative, and responsible interaction. Transition Design acknowledges Indigenous wisdom, specifically that offered by the seventh-generation principle from the Great Law of Iroquois Confederacy. This states that decisions made in the present must result in a sustainable world seven generations into the future. "An important ability of the Transition Designer will be to think about designing in the present and the potential impact of their work to affect the future"(Irwin, 2015).

To best illustrate this, an example from our curriculum is offered. Agents of Change - *Kaiwhakatinana Panonitanga* is a final year project in our undergraduate program. This article now returns full circle to the opening *whakatauakī, Kia whakatōmuri te haere whakamua,* I walk backwards into the future with my eyes fixed on my past.

This course is taught as three strands of knowledge.

- The past: to understand who you are.
- The present: To understand the current context and impact.
- The Future: To frame and propose viable, sustaining and sustainable solutions for future generations.

Importantly *tikanga* Māori are introduced into this work. *Tikang*a are the values and protocols that we engage as a part of the design process, the research we do and the solutions we propose. These tikanga ask that we; show respect, engage authentically, listen, hear, empathize, show compassion and generosity, collaborate, co-design, communicate throughout the design process and most importantly, give the agency or decision0making power to those impacted.

This project specifically engages with external communities and follows the guidance of Te Aho Tū Roa. This is an established social programme working with communities that embrace Māori culture, language and wisdom. Te Aho Tū Roa is the cord that connects and sustains us, joining us to those who have gone before and to those who will come after us. As a social programme, Te Aho Tū Roa seeks to strengthen connection: 'People to People' - including past, current and future generations, and 'People to Place' - embracing every element including the physical, spiritual, and living aspects of our world. Agents of Change engages the *tikanga*,

- Whanaungatanga: the establishment of authentic connections grown and demonstrated over time.
- Kaitiakitanga: guardianship–not ownership or authority.
- Mana: Understanding and respecting other knowledges and worldviews Importantly this must remain intact throughout the entirety of the process, solutions and beyond.
- Nga manakura: empathy and understanding – understanding who/what is impacted by the problem and who/what will be impacted by the solution.
- Manaakitanga: generosity, hospitality and reciprocity– works alongside whanaungatanga and shares stories, kai (food), experiences, knowledge and space with all those involved in the work.
- Rangatiratanga – autonomy and agency. Appreciating that the solution needs to be identified, created, implemented and success measured by, when, where, and how those who will be impacted by the solution, and their next generations, determine.

THE PAST: Pepeha and Positionality. (Figure 4).

Pepeha: Ko mai au? Who am I? Where and what do I *whakapapa* (connect) to. A *pepeha* is the Māori word for introduction. It starts with the student telling their history of connection to the world. What mountain, water mass, tribe, and or area/country they originate from. Only once these connections to place are established do they say their name.

Positionality: The next step in this design process is defining the *tikanga* (values) that will guide the student throughout the work. Asking them to consider what is important to them and how that benefits the work. What role does this afford them? What might they bring to the process? How are they connected to, or disconnected from the problem? Knowing this we then ask if they have the knowledge or experience to address the situation and if not, where will that knowledge come from? The concept of *whakapapa* (genealogy) situates them and is imperative to enabling *nga manakura* (empathy) and establishing the space for *rangatiratanga* (self-determination) where those impacted by the problem and the solution hold agency.

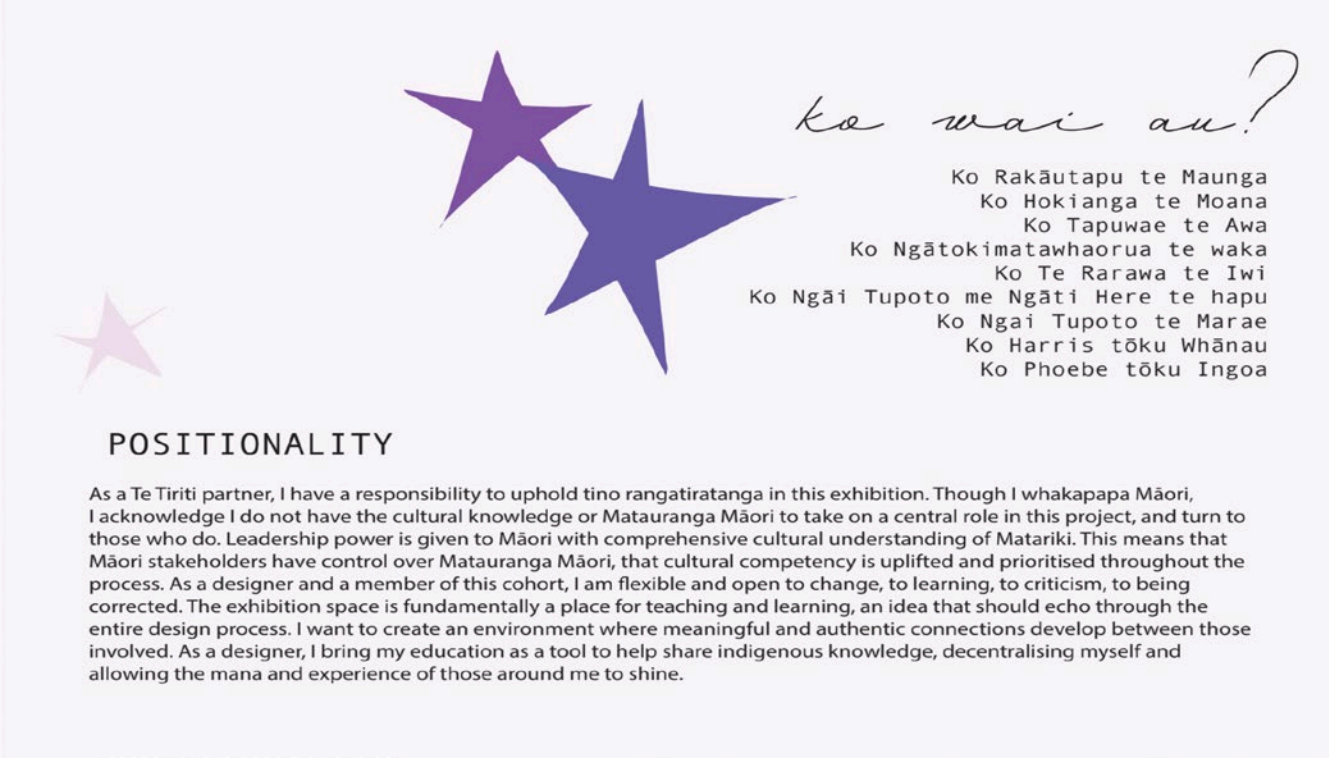


Figure 4. (with student permission) This student work (Agents of Change) depicts the introductory page in which students introduces themselves using a Māori protocol of the Pepeha. As part of this this protocol, one's connections to place and people are described before introducing yourself by name. Students are encouraged to undertake this in Te Reo (Māori language), but also their own first language or English. Positionality is described above.

Methodology: (Figure 5). This part of the project is guided by *manaakitanga* (generosity). It incorporates *mana,* (respectful) face to face activities that acknowledge research as a reciprocal relationship. Engaging *nga manakura* (empathy) these sessions are undertaken with Māori as *wananga* (open discussion sharing different perspectives, opinions and experiences) and with Pasifika peoples as talanoa (dialogue that bring people together to share opposing views). methods bring with them both recognition and *mana* for those with the knowledge sought and often involves a koha as payment (appropriate gifting that is defined by the participant). These sessions also incorporate the sharing of kai (food). This stage seeks to establish whanaungatanga (establishing authentic connections) and requires the student to recognize their own knowing and being and that of others. The project introduces students to the Māori health model, Te Whare Tapa Whā. Created in 1984 by Sir Mason Durie, it is a model devised by Māori for Māori and speaks to the foundations of wellbeing and health as *whenua* (the land) with the four walls of the *whare* (home) building and sustaining spiritual, physical, social and emotional health. Acknowledging that all five components are required throughout the design process and the resultant outcome ensures that the process, participants, forms of participation, how, where, and when to participate (or not), and the appropriate roles and responsibilities of all involved are considered and delivered as a critical measure of the outcome.

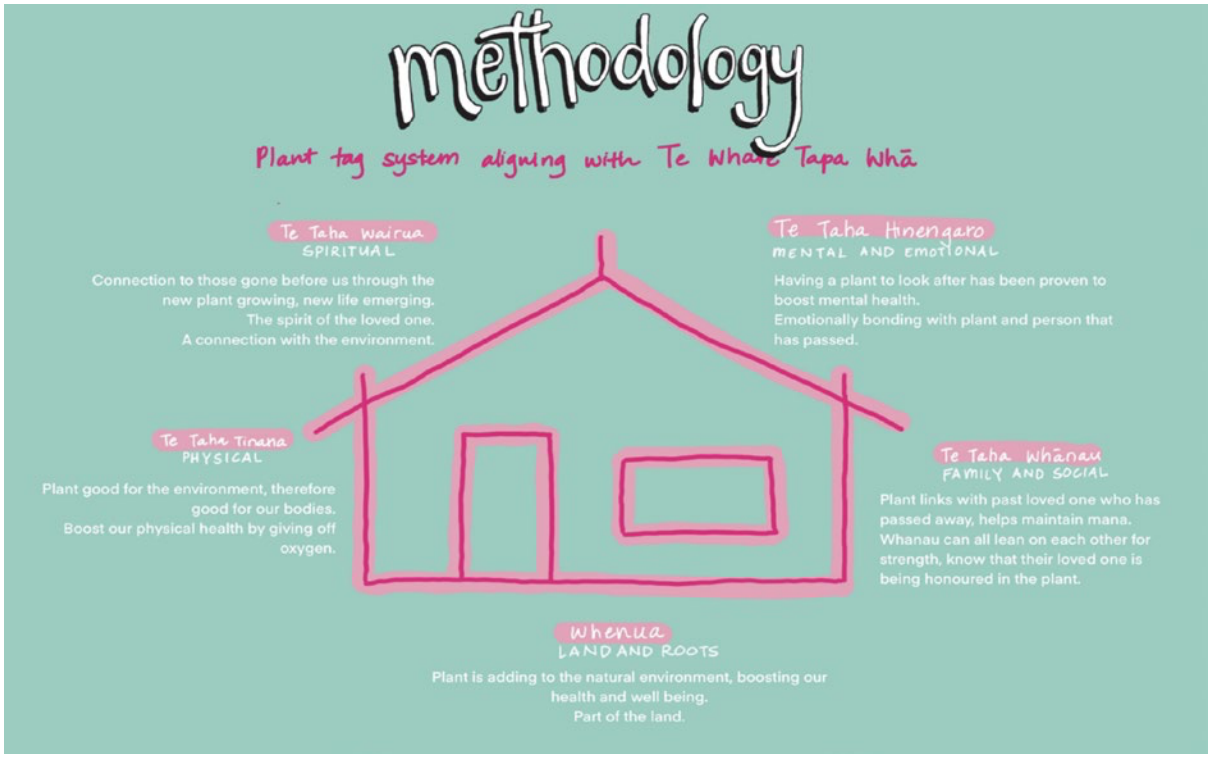


Figure 5. (with student permission) This page in the student project depicts an illustration of the Whare Tapa Wha Health Model. It shows the whare (home) and the interconnected and interdependent structure required to make it stand. It also describes that the stronger the foundations and the connections are, the stronger the whole.

Outcomes: (Figures 6 and 7). Each student, having identified their role and those of their participants and in collaboration with these collectives, formalizes a strategic plan for engagement and learning. Next, and alongside the chosen community, students develop a working prototype that reflects *akoranga* (the knowledge shared between them and the participants), *whanaungatanga* (meaningful engagement) and *rangatiratanga*, an understanding of how the intervention or activation might be enacted or disseminated with or by these communities. With the three threads of knowledge gained from past, present, and future considerations students are enabled to weave or knit together a strong understanding of self and others and how to help enable *kaitiakitanga,* the sustaining and sustainable solutions they and the participants seek as guardians of people, knowledge and their place. The examples provided address food sovereignty for Māori. Engaging with The Museum of New Zealand, Te Papa Tongarewa, the students were asked to create opportunities of visitors to engage with and learn about *Maramataka,* the Māori lunar calendar. The students focused on enabling both sustaining and sustainable solutions. Their goal was to create outputs that both grew and sustained Māori knowledge, were considerate of next generations and that promoted sustainable being.

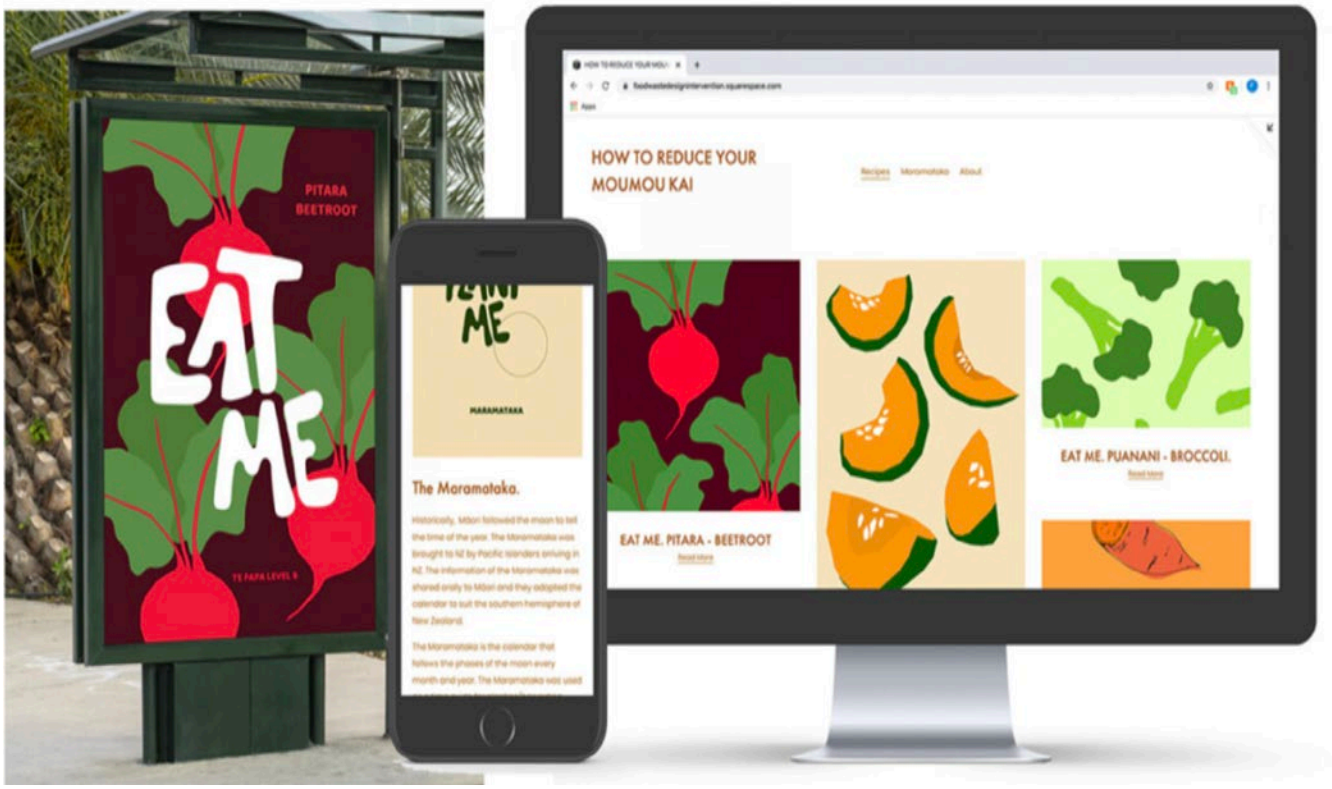


Figure 6. (with student permission) Eat Me, is a project undertaken in Agents of Change: Food sovereignty and sustainability for Māori. A social media campaign and an App were designed to promote healthy and sustainable eating and the use of both fresh food and food scraps.



Figure 7. (with student permission) Maramataka Maumaharatanga: Memory Calendar, Agents of Change: Again, focusing on food sovereignty and sustainability for Māori, this project a card game was designed to enable a resurgence in knowledge for the Māori Lunar calendar and in celebration of Matariki – Māori New Year. It illustrates and prompts discussions around intergenerational knowledge, methods of cultivation, narratives and planting times.

Although this article offered, as a starting point, a very abridged summary of the dominant design history, the overarching aim is to prompt questions about what we understand to be the truths and origins of the design tenets and practices that have driven and continue to drive much of our disciplinary knowledge and development of practice. As a succinctly overview of the Universal design history, John Ruskin gave design New Ways of Seeing, the Bauhaus gave discipline New Ways of Doing, and Richard Buchanan et al, expanded the purpose of design, giving it New Ways of Thinking. Despite the authors doubts as to the accuracy of that, this research suggests that our next step lies in listening to the wisdoms; past, present, and future of Indigenous knowledges that, I propose offer design New Ways of Being. This shift offers design a set of values that can enrich our perceptions, beliefs, mindsets and behaviours. This research points to the integration and appreciation of Indigenous values as being highly beneficial within design practice and asserts that they can enable the much-needed shift from the singular Universal to more inclusive and collective approaches. In doing so we might better accommodate and utilize the commonality and contrast needed to co-exist within reciprocal and respectful

relationships between all of our Spaceship's people and our places.

Acknowledging design in and of Aotearoa, building from our history and acknowledging our place, people and creative strengths, this research positions the Eurocentric version of design as simply one version. I suggest that there is nothing to be lost and everything to be gained by rewriting design's history as an eco-system of histories. In doing so, I propose more culturally diverse, inclusive, empathetic, sympathetic, articulate and sustaining solutions can be found for our futures. The take-away I hope to convey is, that there are numerous scales of collective knowledge, and many more individual perceptions and experiences with, and of our world, that design has yet to acknowledge, listen to, see, or engage with, let alone use its privilege to enable.

The last *whakatauakī* offered is, Ko te mauri, he mea hunaki te maona, powerful aspects of life are often hidden in plain sight. (Elder,2020).

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3D PRINTING OF ENERGY-EFFICIENCY WINDOWS.

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ABSTRACT | Simulations indicate that adding a second or even third layer of glazing with low-E coating compared to traditional windows will reduce heat transfer through the façade. However, incorporating additional glazing layers remains an impractical technology for the Mexican population, especially in vulnerable sectors. The cost of a double-glazed window can escalate up to 10 times that of a typical single-glazed window. Furthermore, only 2% of the national housing stock currently features double-glazed windows. Given that 70% of the country's housing stock is naturally ventilated, it is essential to consider insect screens in window design to maintain household health. These screens can reduce heat transfer by up to 7% when placed on the internal face and up to 14% when positioned externally. Consequently, this research aims to propose innovative solutions, including designs produced through 3D printing and non-conventional, economically viable materials—potentially sourced from recycled materials—to make energy-efficient windows accessible across all sectors.

KEYWORDS | SUSTAINABILITY, CLIMATE CHANGE, SOCIAL INNOVATION.

1. Introduction

The United Nations (UN) provided the right to adequate housing on its declaration of human rights (UN, 2014). Concurrently, the World Health Organization (WHO) set the right and parameters for healthy housing, highlighting a strong relationship between environmental conditions and well-being (WHO, 2018). Yet, this is not the case in at least 30% of the Mexican homes (INEGI, 2017).

Prolonged exposure to high temperatures poses severe health risks, including cardiovascular diseases and even mortality (Bonfigli et al., 2017). The events of the 2003 heatwave in Paris, which resulted in approximately 700,000 deaths, predominantly among the elderly, highlight the lethal consequences of extreme heat events exacerbated by climate change. As the planet continues to warm, the necessity for housing that provides both thermal comfort for today's climate, and resilience against rising temperatures becomes increasingly urgent. A critical factor in the thermal dynamics of buildings is heat transfer through the different elements of the building skin. Undesirable openings, such as cracks, can compromise thermal insulation, exacerbating energy poverty and undermining the health and well-being of residents. This issue is particularly severe in northeastern Mexico, where widespread poverty coincides with extremely high temperatures.

This region heavily relies on energy-intensive air conditioning systems. Contrary to popular belief, even vulnerable populations, such as low-income groups, use these types of technologies. Additionally, air conditioning systems with inverter technology tend to be more expensive, leading those with lower incomes to purchase cheaper systems, even though this results in higher energy consumption in the long run. Addressing these challenges requires practical solutions that enhance energy efficiency while ensuring affordability and accessibility. Extensive research has explored adding insulation to walls and examining the applicability and effectiveness of the NOM-020 standard related to heat transfer (Romero-Pérez, RodríguezMuñoz, Alpuche-Cruz, & Martín-

Domínguez, 2017; Zepeda-Gil & Montiel-Castro, 2023). However, to date, there has been little attention on providing low-cost solutions for windows, being the element of the façade that contributes most to heat transfer. In fact, the NOM-020 standard does not require double glazing in Mexican homes. This paper examines the role of glazing, particularly in mitigating thermal transmittance through windows, through 3D printing and HDPE (high density polyethylene), we highlight the transformative potential of simple, costeffective interventions.

As climate change accelerates and the threat of prolonged heat exposure increases, the urgency of fortifying vulnerable areas of buildings, such as windows, cannot be overstated. This paper calls for scalable solutions that empower university students and educators worldwide to engage in community-driven initiatives. By fostering awareness and advocating for accessible improvements in housing infrastructure, we aim to contribute to a future where every individual can reside in environments that safeguard health, dignity, and resilience in the face of a warming world and advocating for accessible improvements in housing infrastructure, we aim to contribute to a future where every individual can reside in environments that safeguard health, dignity, and resilience in the face of a warming world.

1.1 State of the art

Filament-based three-dimensional printing technology, also known as Fused Deposition Modeling (FDM), has been employed in a myriad of applications, ranging from the construction of small accessories or adaptations for existing commercial parts to the fabrication of car bodies or even yachts. The primary challenges of this technology in most fields can be enumerated as follows:

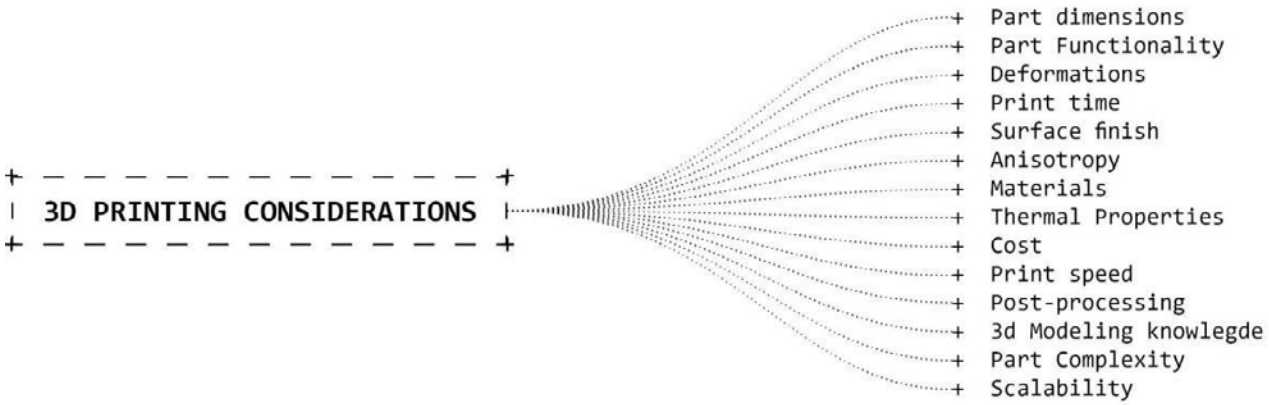


Figure 1 - 3D printing considerations

The following section describes the parameters to anticipate some challenges, as well as the opportunity area represented by the research and development proposal.

1. **Part Dimensions:** Commonly constrained by the dimensions of the printing platform of the equipment used, which can vary between Delta and Cartesian printer configurations.

2. **Part Functionality:** This involves determining whether the part will experience mechanical stress along any of its axes (x, y, z) or if it is produced for didactic or entertainment purposes, where exceptional resistance is not required. The mechanical properties of 3D printed parts can vary based on the material used, layer orientation, print speed, layer height, and other factors.

3. **Deformations:** Larger parts (exceeding 20 cubic centimeters) typically experience greater deformation during cooling, caused by internal stresses.

4. **Print Time:** While current speeds range from 300 to 600 mm/s, increasing the print speed can lead to greater deformation in the resulting part.

5. **Surface Finish:** Directly related to layer height, the surface finish can range from rough or stratified to relatively smooth if the layer separation is less than 30% of the nozzle diameter.

6. **Anisotropy:** Closely related to the orientation of the part within the printing platform.

7. **Materials:** Continuously evolving, current materials include composites like glass or carbon fiber mixed with PLA, ABS, or ASA. However, compared to the wide range of industrial plastics, the available options remain limited.

8. **Thermal Properties:** Affected by the manufacturing process itself, as low-temperature thermoplastics are used, limiting their application in high-temperature environments.

9. **Cost:** While the accessibility of 3D printing has become more affordable over the years, specialized materials and large part dimensions can increase costs.

10. **Print Speed:** As mentioned earlier, this directly affects surface finish and can impact productivity in serial production since it is not designed for repetitive industrial use.

11. **Post-processing:** Necessary for parts where the surface finish needs to mimic molded parts. Otherwise, it is recommended to avoid post-processing to reduce production time and costs.

12. **3D Modeling Knowledge:** While open-source repositories can provide solutions, specialized designs require a deeper understanding of specialized software."

13. **Part Complexity:** This can necessitate the use of support structures during the build process and extend print time.

14. **Scalability:** A characteristic closely related to the possibility of large-scale

production. When designing window profiles using 3D printing, we face the challenge of managing the variable properties of the parts, which are directly influenced by the printing parameters. A clear example is the relationship between layer separation and surface finish. Increasing this separation accelerates the process, but at the cost of a lower quality surface finish. Similarly, the orientation of the part can affect its mechanical strength due to the need to use fewer supports.

These challenges will be presented in the following proposal and will be considered when making decisions regarding the research line and production of the pieces to be created.

2. Methodology

2.1 Design process

This study proposes a comprehensive review of existing literature on FDM printing for profiles as a first step. The scarcity of research in this area underscores the need for our work, which aims to pioneer the use of rapid prototyping in the construction accessories industry. Companies like *Liniar*® have already demonstrated the potential of 3D printing for agile product development. By enabling low-cost, in-house prototyping, 3D printing offers immediate feedback on dimensions and finishes, accelerating the design process.

3D printing has been widely used to validate theoretical designs by comparing them to physical prototypes. Various simulation tools are employed to create virtual environments and test designs under different conditions. This study will utilize simulation software to explore the relationship between profile characteristics and thermal performance. By employing this approach, we aim to gain a deeper understanding of how design choices impact the overall performance of the system. The Mexican standard NMX-R-060-SCFI-2013(hereafter referred to as NMX-060). will be used as a benchmark in the design, development, and evaluation of the proposed materials to be obtained as part of the research process, as it provides us with the basic aspects that windows and architectural products for exterior facades must comply with. Although not mandatory, this list of guidelines allows us to understand the control points and properties that must be considered in the design of enclosures. The following are listed:

a. **Resistance to wind load.** Property of a window or enclosure indicating its ability to withstand a specific wind intensity without significant deformation or destruction.

b. **Water tightness.** It is defined as the ability of a window or enclosure to resist water penetration. Water penetration is the continuous or repeated wetting of the inner face of the frame or of parts not designed to be wet when water drains towards the outer face.

c. **Air permeability.** Defines the ability of a window to resist air infiltration through its joints and cracks when subjected to a differential pressure caused by wind.

d. **Acoustic insulation** (of a window). Measures the sound level difference (in dB) transmitted through a window or enclosure separating two spaces or the exterior and interior.

e. **Thermal insulation.** Overall heat transfer coefficient (K): This is the amount of heat that a construction system allows to pass through per square meter when there is a temperature difference of 1 K.

f. **Weather resistance,** g) Functional resistance and integrality of the enclosures, h) Other specifications of the enclosure hardware system, i) Glazing. Use requirements, j) Installation on site.

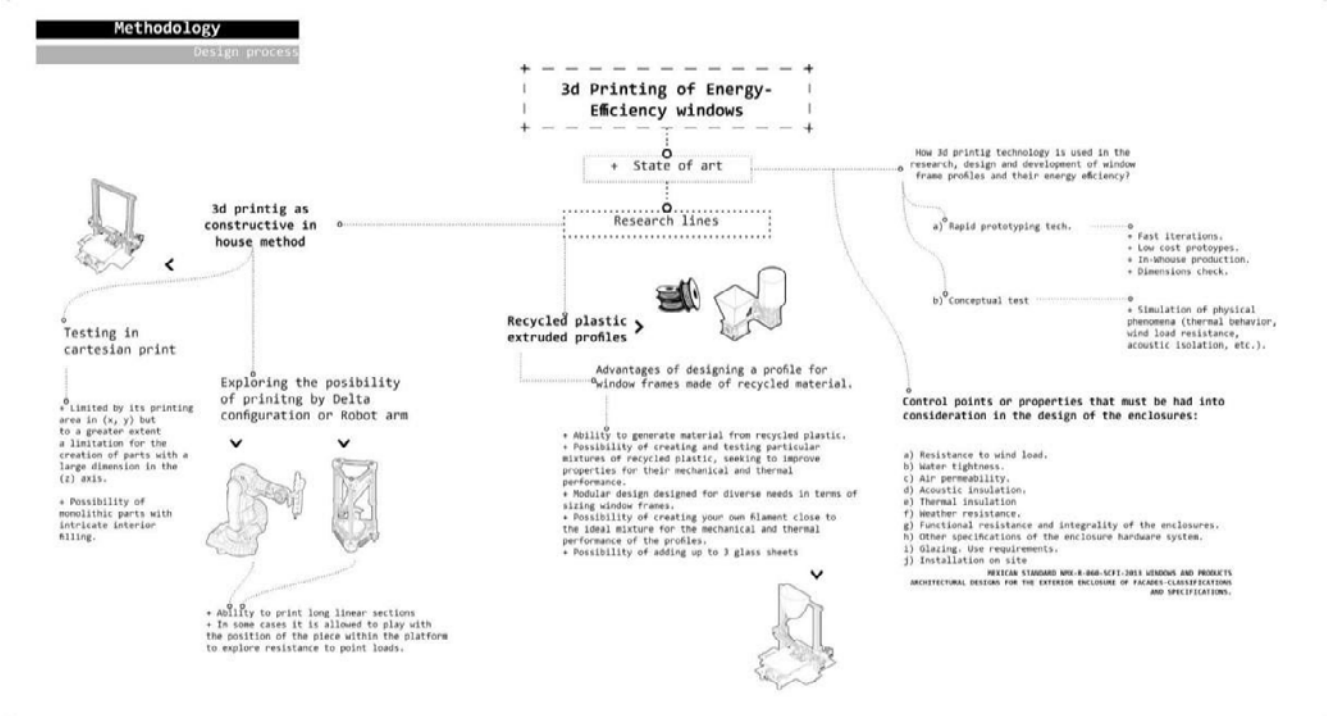


Figure 2 - Figure 2. Methodology | Design process.

2.2 Materials

A crucial aspect in the design of any industrially or semi-industrially manufactured product is the material to be used for its materialization. For the following research, polymers are proposed as the primary material for the development of test prototypes. Due to their physicochemical properties, they are an excellent option to meet the expected performance of window profiles and frames. Polymers have been widely used in various industries, from food packaging to tool coatings and automotive parts. Just as there has been a significant evolution in the design

and development of polymers, this material has also been adapted for use in additive manufacturing processes such as FDM.

For use in the FDM process, polymers can be presented as small granular spheres, which are introduced into a hopper where they are melted and then extruded through nozzles with diameters ranging from 0.4mm to 1mm commercially. Another presentation in which we can find polymers prepared for FDM, and which is the most commercial presentation we will find on the market, is in the form of filament (thread/cable), which is standardized to a diameter of 1.75mm so that it can be fed to the extrusion nozzle.

Similarly, it can be mentioned that the most commonly used material in the commercial sector is polylactic acid (PLA). This material has the great advantage that in its composition, since it is a thermoplastic monomer derived from renewable organic sources such as corn starch or sugarcane. The use of biomass resources differentiates the production of PLA from most plastics, which are produced using fossil fuels through the distillation and polymerization of petroleum.

ASA (Acrylic Styrene Acrylonitrile) is a technical material that is considered a successor to ABS. Compared to ABS, ASA is more UV resistant, warps less, and doesn't smell as much. ASA is a tough and resilient material that is, thanks to its UV and temperature resistance (up to 93 °C), suitable for outdoor use and for making technical parts. The main disadvantage of ASA is significant warping caused by temperature differences between the model and its surroundings. Another disadvantage is that ASA releases potentially dangerous fumes during printing - this means you should keep your printer in a well-ventilated area. ASA can be easily sanded both wet and dry.

We could continue enumerating and demonstrating the various materials used in the FDM process, their properties, their printing behavior, their final surface quality, etc.; however, a relevant aspect of the present study is the possibility of using recyclable plastic waste (e.g., HDPE - High-Density Polyethylene), subjecting it to a washing, drying, and grinding process to be used as raw material in the construction of window profiles. A significant contribution of this work is believed to lie in the obtaining of a proprietary recycled plastic mixture, which would be designed to provide improved thermal efficiency in the frames, while also complying with the parameters established in the aforementioned NOMs.

2.3 Standard NMX-R-060-SCFI-2013

The standard classifies windows according to their properties based on the list below. It ranks the elements from 0, V1-V5, and exceptional. The different charts of accepted ranges can be seen in Annex 1.

a. **Wind load resistance.** The test includes a minimum load that the item should resist, and the window frontal deflection.

b. **Water tightness.** This should meet the requirements of Table 3 from Annex 1.

c. **Air permeability.** This should meet the requirements of Table 4 from Annex 1.

d. **weather resistance** This is divided into subsections based on the material. As we are selecting materials with properties similar to PVC, our goal will be to fulfil the requirements specific to this material.

i) For temperatures > 25 °C, it should be able to resist a total solar annual over a horizontal surface of ≥ 5 GJ/m2.

ii) Impact resistance in PVC-U main profiles is measured by a mass drop test at -10 °C.

e. **Thermal insulation.** Although the standard does not measure this, it is possible to recreate the conditions of the materials and simulate the thermal behaviour of the window, as presented in by Van Den Bossche et. Al., (Van Den Bossche, Buffel, & Janssens, 2015)

3.0 Expected results, and future work.

This paper aims to present the methodology, materials, and testing methods for designing a low cost, easily accessible window frame, that also allow for a U-Value of 2 W/m2K or lesser, equal to a double glazing window in the market.

3.1 Prototypes

3.1.1 Prototype 1: 3D Printed Model

The objective of prototyping is not only to identify the best materials for creating strong windows, but also that meet the NMX-060 standards in terms of strength, durability and overall sustainability. Hence, we will determine a series of polymers, composites, and other from recycled sources, providing that the window must be able to reduce heat transfer, must be UV resistant, and mechanically strong, while being a much cheaper option than those in the market.

Another aspect that will be considered is Design optimization. 3D Printing allows for creating complex geometries and infills that are not possible to produce with traditional extrusion methods. Through grasshopper, we aim to explore distinct infill patterns for the window profiles so eventually we can produce a model that is both light and strong. The iterations will also be based on optimizing parameters such as print speed and temperature settings. As mentioned in the methodology, all our prototypes will be tested according to the NMX-060.

To address sustainability, we will conduct a comprehensive lifecycle assessment (LCA) utilizing SIMAPRO software. This analysis will facilitate a comparative evaluation not only in terms of costbenefit but also in environmental impact. We anticipate a substantial reduction in CO2 emissions compared to traditional window manufacturing methods, as our

process will predominantly utilize recycled materials. The LCA includes the entire production cycle, from material extraction to endof-life disposal, ensuring a thorough assessment of the environmental footprint.

3.1.2 Extruded

The main advantage of considering extruded profiles with recycled materials, is that basically any HDPE (high density polyethylene) can be transformed into high quality and highly resistant pellets. This has significant environmental benefits, reducing waste and the need for using raw materials.

3.1.3 Prototypes using robotic Arms

Robotic arms offer a more advanced approach to 3D Printing. They are more flexible and precise, particularly when dealing with printing at larger scales. In this aspect, we aim to explore materials that are suited for arm-based 3D printing such as recycled HDPE (high density polyethylene) produced inhouse.

The primary advantage of this technique is its capacity to fabricate larger profiles in a single production run, thereby eliminating the need to join multiple pieces and potentially compromising the structural integrity of the final element. In light of this capability, our objective is to investigate novel infill geometries that are not feasible with conventional 3D printing methods. This exploration aims to enhance both the mechanical properties and design flexibility of the produced components.

4.0 Conclusions and limitations

This paper presents the methodology that will be undertaken to create a low cost highly insulated window. Our methodology focuses on various aspects from exploring different materials, aggregates and composites, prototyping and design, parametrization, testing under the NMX-060, economic feasibility and cost benefit analysis, and finally a life cycle assessment. Our primary focus is to use conventional and non-conventional 3d Printing and to incorporate recycled materials. Our main objective is to foster circular economy, create windows with lower carbon footprints, and overall to enhance the living conditions of vulnerable sectors in Mexico.

While we present a detailed methodology, we acknowledge that at present, no empirical data nor physical prototypes have been created to test our proposed approaches. We are also aware of potential limitations with our approach such as the quality of recycled materials, unexpected problems when dealing with robotic arms, the potential problems of scalability to massproduce our successful prototypes given availability of recycled materials and 3d Printing times, and the possibility that the properties of the considered materials may not be able to mimic those in the market. These limitations will be addressed by testing various polymers, composites and recycled materials, aiming to identify the best options. Testing and performance evaluations are key aspects of finding the best mix to achieve the goals of this research. Although data and prototypes are yet to be developed, these will be rigorously tested and validated to ensure their feasibility.

This work aims to fill a gap in research, and a inherent need from the most vulnerable sectors through novel technologies like 3D Printing, promoting a more sustainable construction industry and innovative design solutions.

ANNEX

Annex 1 – Classification ranges according to the NMX-060

CLASE DE VIENTO	P_1 (Pa)	P_2 a) (Pa)	P_3 (Pa)
0	Ventana no ensayada		
V1	X ≤ 400	X ≤ 200	X ≤ 600
V2	401 < X ≤ 800	201 < X ≤ 400	601 < X ≤ 1200
V3	801 < X ≤ 1200	401 < X ≤ 600	1201 < X ≤ 1800
V4	1201 < X ≤ 1600	601 < X ≤ 800	1801 < X ≤ 2400
V5	1601 < X ≤ 2000	801 < X ≤ 1000	2401 < X ≤ 3000
Excepcional b)	2001 < X	1001 < X	3001 < X
a) Estas presiones son repetidas 50 veces.			
b) Una muestra de ensayo ensayada con una carga de viento superior a la Clase 5 se clasifica Exxxx, donde xxxx es la presión de ensayo actual P1 (ej., 2350, etc.) X = Resultado de carga en cada etapa de ensayo.			

Table 1 - Classification Ranges. Wind load resistance according to the minimum load they must withstand

Flecha Frontal Relativa Máxima Admisible	Clasificación
L/200	A
L/300	B
8 mm	C

Table 2 - Classification ranges. Wind load resistance according to the maximum allowable relative frontal deflection

CLASE DE PERMEABILIDAD AL AIRE	P (Pa)	Q (m^3 / h / m^2)
SIN CLASIFICAR	100	> 50
Clase 1		27 < Q ≤ 50
Clase 2		9 < Q ≤ 27
Clase 3		3 < Q ≤ 9
Clase 4		Q ≤ 3

Table 4 - Classification ranges. Air permeability.

PRESIÓN DE ENSAYO (Pa)	CLASIFICACIÓN	
	METODO A	METODO B
-	0	0
0	E1 A	E1 B
50	E2 A	E2 B
100	E3 A	E3 B
150	E4 A	E4 B
200	E5 A	E5 B
250	E6 A	E6 B
300	E7 A	E7 B
450	E8 A	-
600	E9 A	-
>600	EE_{xxx}	-
NOTA 4:		
El método A es apropiado para productos que estén totalmente expuestos.		
El método B es apropiado para productos que estén parcialmente protegidos.		

Table 3 - Classification ranges. Water tightness.

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ANALYSES OF SUSTAINABLE DEVELOPMENT IN CITY VISUAL IMAGE DESIGN: A STUDY BASED ON CITESPACE KNOWLEDGE MAPPING METHOD.

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ABSTRACT | The city visual image, acting as a vital conduit for disseminating urban culture and nurturing city brands, is crucial for enhancing a city's competitive edge and also plays a significant role in driving social transformation and fostering inclusive development. This study applies the CiteSpace knowledge mapping approach to provide an extensive review and strategic foresight into the academic discourse on city visual image design. Employing bibliometric methods of collaboration network analysis, co-citation, and co-occurrence analysis, we have identified key areas in urban visual image design, including artificial intelligence, social media, visual perception, and brand development. The research indicates three directions for future studies: (1) Deepening systematic studies of city visual image to promote intercultural and intergroup dialogue, reflecting the diversity of cultural expressions and values, thereby enhancing social inclusivity and appeal; (2) Enhancing stakeholder engagement in the discourse and decision-making processes of city visual image design to foster a stronger sense of social belonging and responsibility; (3) Exploring the integration of artificial intelligence and leveraging digital technologies to expand public engagement and steer society towards greater openness and innovation. This research extends the boundaries of city visual image design, infusing the discipline with renewed vigor. It delivers essential practical insights to urban planners, designers, and policymakers, ensuring that city visual images are pivotal in driving social transformation and fostering an environment of inclusivity and participatory development.

KEYWORDS | CITY VISUAL IMAGE DESIGN, BIBLIOMETRIC ANALYSIS, KNOWLEDGE MAPPING, CITESPACE

1. Introduction

As integral players in the process of globalization, cities have emerged as potent catalysts for innovation and development. They have transformed into pivotal hubs for the dissemination and exchange of culture (Guimarães, Ribeiro, & Machado, 2021), the integration and innovation of technology (X. Chen, 2019), and the cultivation of social sustainability (Dias et al., 2024). The city's visual image, a cornerstone of cultural soft power (Dong, Liang, Liu, & Wang, 2022), is instrumental in crafting a unique city brand (Hsun & Jie, 2022) and deepening its cultural narrative . It accentuates cultural diversity and inclusiveness, energizing community engagement (Kallus, 2016). Such engagement is crucial for enhancing a sense of identity and belonging among residents, which is essential for fostering social transformation and inclusive development (Belabas & George, 2023; Paganoni, 2012). Therefore, the visual image of city is key to enhancing urban attractiveness and competitiveness (Sevin, 2014) and serves as a crucial engine driving future urban change and development.

Despite the considerable advancements in the study of the ontology, media, and audience aspects of city visual image research, there is a discernible gap in the availability of review studies. As the academic literature expands, the necessity for bibliometric analysis and visualization techniques has become more pronounced. Bibliometrics, esteemed for its methodological rigor, serves as a powerful tool for exploring the vast expanse of scientific data. It not only enables in-depth analysis and scrutiny of extensive datasets but also furnishes crucial insights for mapping the progression and identifying nascent trends across various scholarly disciplines (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021). Currently, bibliometric inquiries into city image design have extended across diverse dimensions, encompassing pivotal themes such as the image of city tourism destinations (Guo, 2023), urban landscapes (Yang & Lu, 2022), the evolution of smart cities (Zhou, Zhang, Liu, Zhang, & Zhao, 2020), and the crafting of creative cities (Ren, Zhong, & Sun, 2023). As the corpus of research knowledge grows and the quest for a profound examination of city visual images intensifies, the reliance on conventional

qualitative and quantitative research methodologies has become inadequate to fulfill the evolving demands of the field. Consequently, the integration of bibliometric and visualization analysis tools stands out as an essential component, vital for nurturing the synthesis and innovation of knowledge within this domain.

This paper undertakes a systematic analysis of the academic discourse in the field of city visual image design, covering the period from 2013 to 2024. Through an exhaustive search within the Web of Science (WoS) Core Collection database, the research meticulously selects and synthesizes seminal literature to curate an extensive and nuanced dataset.

Utilizing the visualization capabilities of CiteSpace, the study aims to address three pivotal inquiries:

- What is the current state of scholarly research on city visual images;
- What constitutes the knowledge framework of city visual image, and how has it evolved;
- What are the prospective research directions for both theoretical scholars and practitioners in the field of city visual image.

This study aims to achieve the following objectives:

- To provide a macro perspective on the academic landscape by deeply analyzing the contributions of different countries, institutions, and key scholars in the field of city visual image design;
- To elucidate the foundational knowledge and the structural framework of city visual image design by scrutinizing co-cited references and co-cited journals. This process entails identifying pivotal literature and authoritative journals, thereby providing a deeper understanding of the evolution and dissemination of knowledge within this scholarly domain;
- To identify and explore research hotspots and emerging themes in city visual image studies through keyword co-occurrence and clustering analysis using cooccurrence network analysis. Additionally, by integrating keyword timelines and keyword bursts, this study aims to forecast future development trends, offering prospective guidance for research in this field.

Through bibliometric and visualization analysis, this study systematically reviews the current research status and knowledge structure in the field of city visual image design. It identifies key research hotspots and frontier areas, providing a scientific basis for decision-making and directional guidance for researchers. Furthermore, this endeavor aims to support innovation and development in cities within a global context. It facilitates social transformation, promotes inclusive growth, and enhances community engagement, thereby contributing to the broader goals of sustainable urban development.

2. Research Methods and Procedures

The overall research framework of this study is depicted in Figure 1, which primarily consists of three stages: data collection, data cleaning, and data analysis.

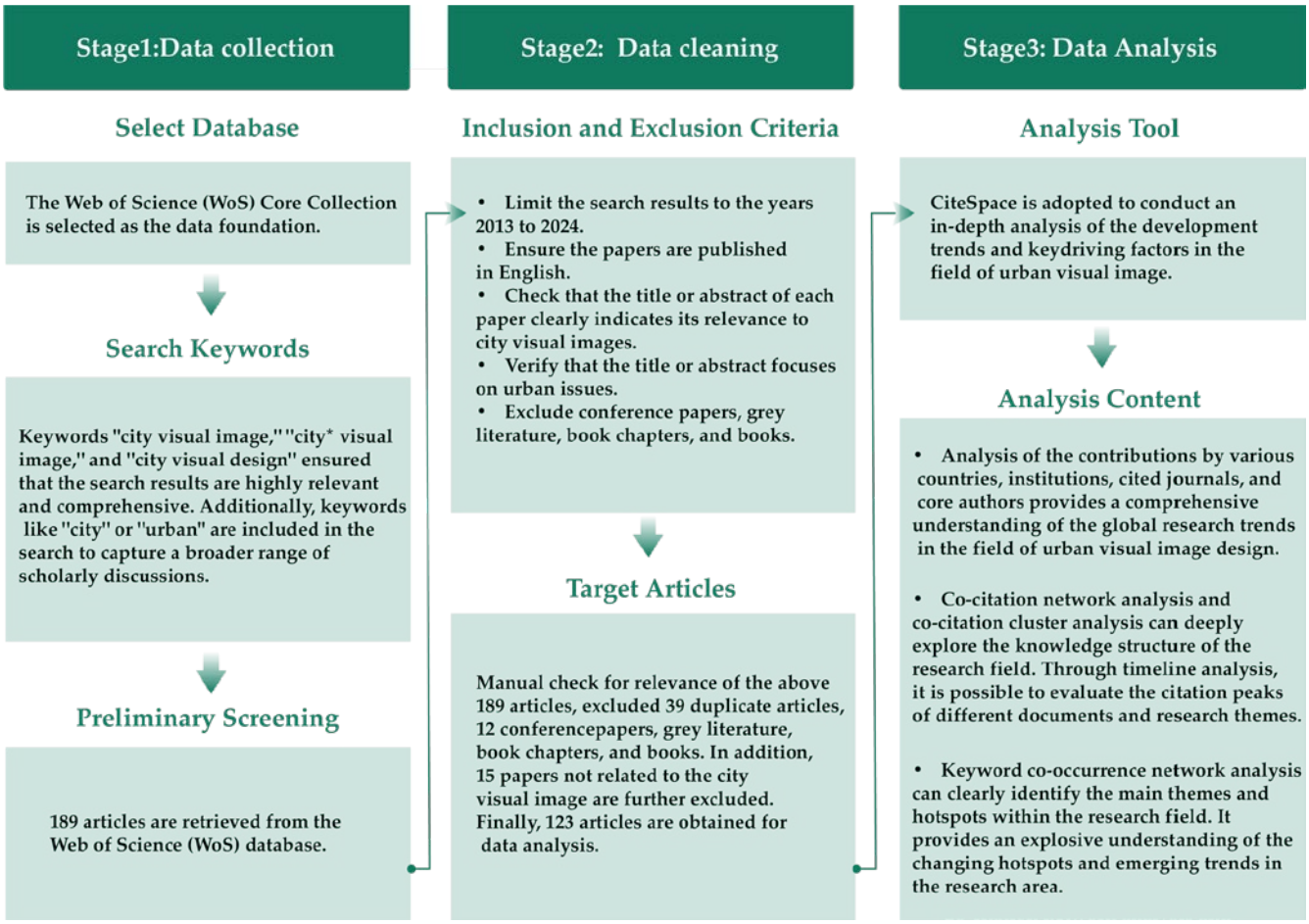


Figure 1. Research Framework.

2.1 Data Collection

In this study, the Web of Science (WoS) Core Collection was selected as the data foundation, with the CiteSpace tool employed to assist in the keyword search strategy, ensuring both depth and breadth in the research. WoS, as an authoritative platform for bibliometric analysis, provides extensive bibliographic and citation resources and includes high-quality scholarly articles that have undergone rigorous peer review, thus ensuring the reliability and authority of the research. The citation analysis capabilities of WoS further enhance the ability to identify key trends and themes within the discipline. Given the multidimensional nature of city visual images, this study adopted a precise keyword

search strategy. The core keywords 'city visual image,' 'city* visual image,' and 'city visual design' were carefully selected to ensure high relevance and comprehensiveness of the search results. To broaden the research perspective, terms such as 'city' or 'urban' were also included in the search to capture a wider range of academic discussions. The research period, spanning from 2013 to 2024, was intentionally selected to facilitate a focused examination of the most recent scholarly contributions to the city visual image discipline. This timeframe enables an in-depth analysis of the field's knowledge advancements and offers a sharp perspective on the dynamic trends shaping the academic vanguard. Utilizing a strategic combination of keywords in the Web of Science (WoS) database, we have curated a collection of literature that is both extensive and pertinent. This compilation forms a solid basis for a detailed analysis of the progression of city visual images within the academic community. As a result, the study is poised to engage with this complex and rich topic in a manner that is both exhaustive and insightful.

2.2 Data Cleaning

This study established inclusion and exclusion criteria to ensure that the analysis was based solely on the most pertinent literature. Throughout this process, non-target documents, including conference papers, gray literature, book chapters, books, and duplicate articles, were meticulously excluded. By employing the CiteSpace software, documents were systematically organized by title, author, and publication year, effectively identifying and eliminating duplicates. To guarantee the study's quality and reliability, the research was focused exclusively on peerreviewed journal publications, thereby excluding other types of publications. This strategic decision ensured that the literature under review was of high quality and had undergone rigorous peer review, thereby more accurately reflecting the research topic. In the subsequent screening phase, three independent reviewers evaluated the titles, abstracts, and keywords, which were pivotal in the decision-making process. Any discrepancies among the reviewers were resolved through collaborative discussion, thereby mitigating the influence of personal bias on the study's results. During the abstract screening stage, studies that were not pertinent to city visual images were meticulously excluded to ensure the high relevance of the literature to the research topic. Ultimately, 123 articles were selected as samples for further analysis based on their relevance to the research theme.

The inclusion and exclusion criteria were as follows:

- The time range was confined to the period from 2013 to 2024;
- Papers had to be published in English;
- The title or abstract of the paper must explicitly indicate its relevance to city visual images;

- The title or abstract must primarily address city issues;
- Excluded were conference papers, gray literature, book chapters, and books.

Through this rigorous screening process, the study ensured that the analyzed literature met the required standards for both quality and relevance, laying a solid foundation for an in-depth exploration of city visual images.

2.3 Data Analysis

The CiteSpace tool was employed to conduct a profound analysis of the development trends and pivotal drivers within the realm of city visual image studies (C. Chen, 2004). It simplifies complex scientific literature into digestible visual representations and offers a suite of visualization tools, including collaboration, co-citation, and co-occurrence networks. By generating knowledge maps, CiteSpace facilitates an in-depth examination, synthesis, and summarization of the leading trends and knowledge linkages in the field, providing critical insights for future scholarly endeavors (C. Chen, 2006, 2017).

Initially, an exhaustive examination of the distribution of contributions from countries, institutions, and key authors offers a holistic view of the global research landscape in city visual image design (Martínez-López, Merigó, Valenzuela-Fernández, & Nicolás, 2018). This analysis not only pinpoints principal contributors and gauges the research's collective quality and impact (Bahroun, Anane, Ahmed, & Zacca, 2023) but also lays the groundwork for future international collaboration, knowledge dissemination, and resource amalgamation.

Subsequently, the application of co-citation analysis for references and journals explores the research field's knowledge base and structure. Co-citation analysis of references surfaces the seminal literature, uncovering the academic community's foundational texts with considerable sway (Shiau, Dwivedi, & Yang, 2017). Extended co-citation analysis of journals unveils the thematic spread and research emphases of various journals, charting the evolution of knowledge and offering a comprehensive grasp of the field's knowledge architecture.

Ultimately, keyword co-occurrence and clustering techniques distinctly delineate the research field's focal points and areas of intense interest (Zhu & Zhang, 2020). Moreover, keyword timeline analysis assesses the citation peaks of diverse literature and thematic areas, revealing the temporal influence of research outcomes and identifying seminal works that have significantly propelled the field's development at particular junctures (Li, Ma, & Qu, 2017). Additionally, the surge in certain keywords often signals the advent of new research frontiers or directions. A scrutiny of these terms' distribution sheds light on emerging trends, shifts in research priorities, and the dynamics of current research hotspots, thereby aiding in the prognostication of the field's prospective directions (Guo, 2023).

3. RESULTS AND ANALYSIS

3.1 Collaboration Network Analysis

The publication output in the field of city visual image design, as indexed in the Web of Science (WoS) database, has experienced significant and sustained growth from 2013 to 2024, reaching its zenith in 2023, as illustrated in Figure 2.

Further examination of the collaboration networks among nations in city visual image research, illustrated in Figure 3, reveals that China, the United States, Japan, the United Kingdom, Malaysia, Russia, and South Korea are the principal contributors to this field. China is particularly prominent, occupying a central position in the international research network and engaging in extensive collaborations with the United States, South Korea, Russia, and other nations. Table 1 presents a quantitative overview, with China at the forefront, publishing 55 papers, followed by the United States with 19 and Japan with 6. The betweenness centrality metric, which quantifies a country's capacity to facilitate connections within the network, is highest for China (0.54), underscoring its pivotal role in global research collaboration. The United Kingdom also demonstrates considerable influence, with a betweenness centrality value of 0.24, indicating its impact in the field.

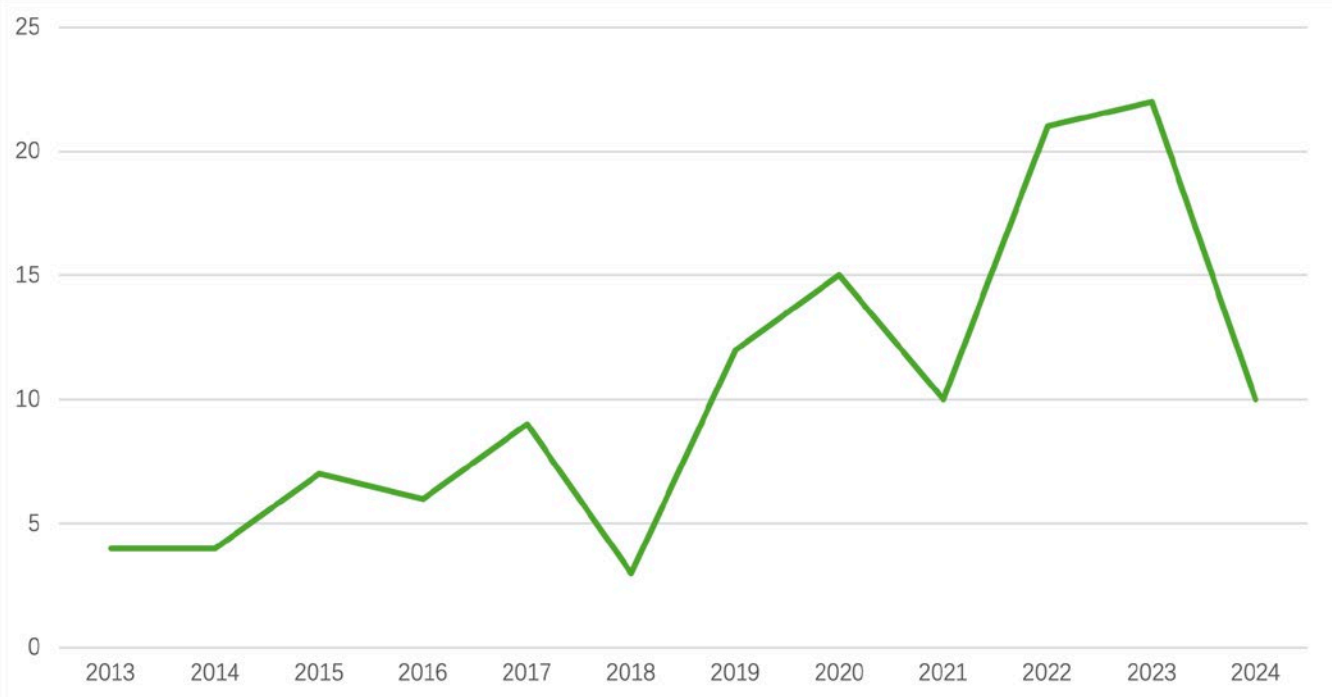


Figure 2. Annual Publication in City Visual Image Research on WoS from 2013-2024.

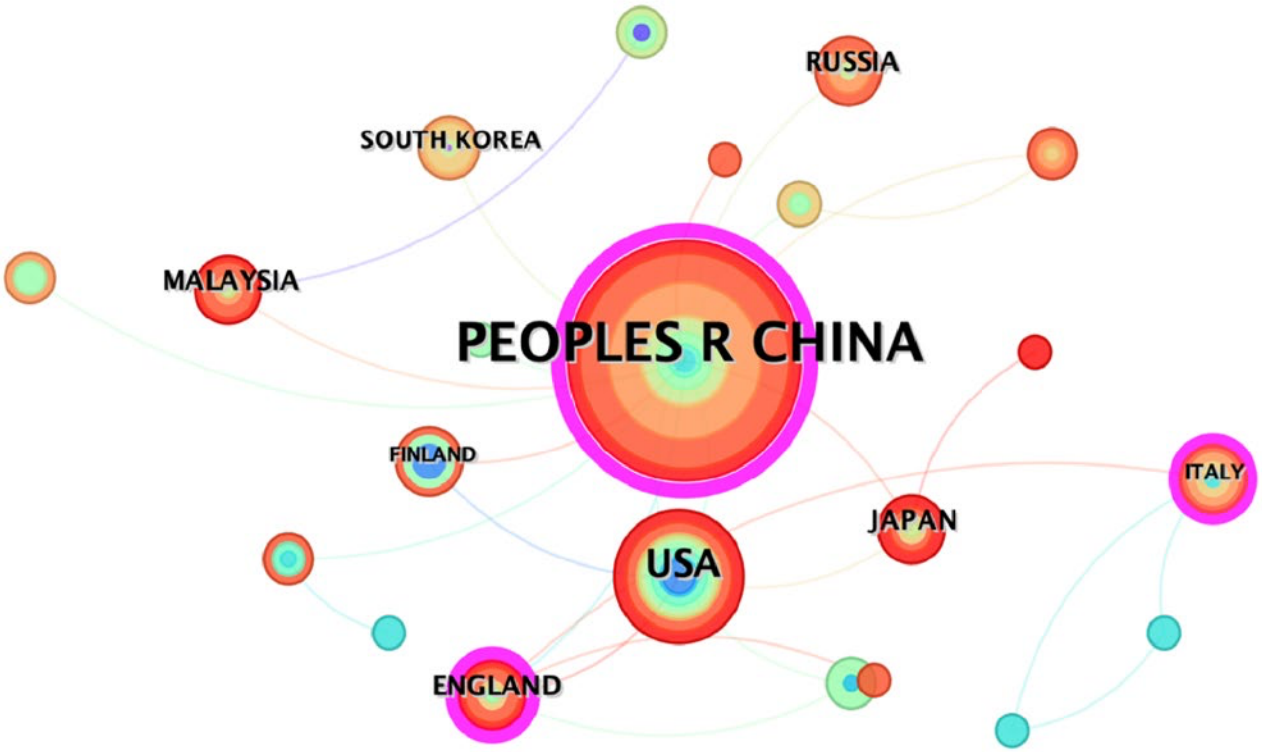


Figure 3. The Network of Countries for City Visual Image Research.

Table 1. Leading Countries in City Visual Image Research.

Country	Frequency	Country	Centrality
PEOPLE 'S REPUBLIC OF CHINA	55	PEOPLE 'S REPUBLIC OF CHINA	0.54
USA	19	ENGLAND	0.24
JAPAN	6	ITALY	0.12
ENGLAND	6	USA	0.06
MALAYSIA	6	JAPAN	0.06
RUSSIA	6	MALAYSIA	0.06
SOUTH KOREA	5	SWITZERLAND	0.06

The institutional collaboration network in city visual image research, as illustrated in Figure 4, highlights the significant collaborative roles of institutions such as the Hong Kong University of Science and Technology, Massachusetts Institute of Technology (MIT), Peking University, and City University of Hong Kong. The figure vividly represents the close-knit cooperative ties among these institutions, especially the pronounced interactions between the Hong Kong University of Science and Technology and its peers, through the network's connecting lines.

Table 2 quantifies the publication output, centrality, and burstiness of leading institutions in this research domain. Institutions like MIT, the University of Helsinki, and Delft University of Technology showcase their active engagement through substantial publication volumes.

Centrality, an indicator of an institution's prominence within the collaboration network, peaks at 0.04 for the Hong Kong University of Science and Technology, with MIT closely trailing at 0.03, emphasizing their influential roles in promoting inter-institutional partnerships. Burstiness, which signifies a notable surge in publication activity over a defined period, is most pronounced for Delft University of Technology, with a value of 1.45. This metric suggests a swift escalation in the institution's interest and commitment to the field of city visual image research.

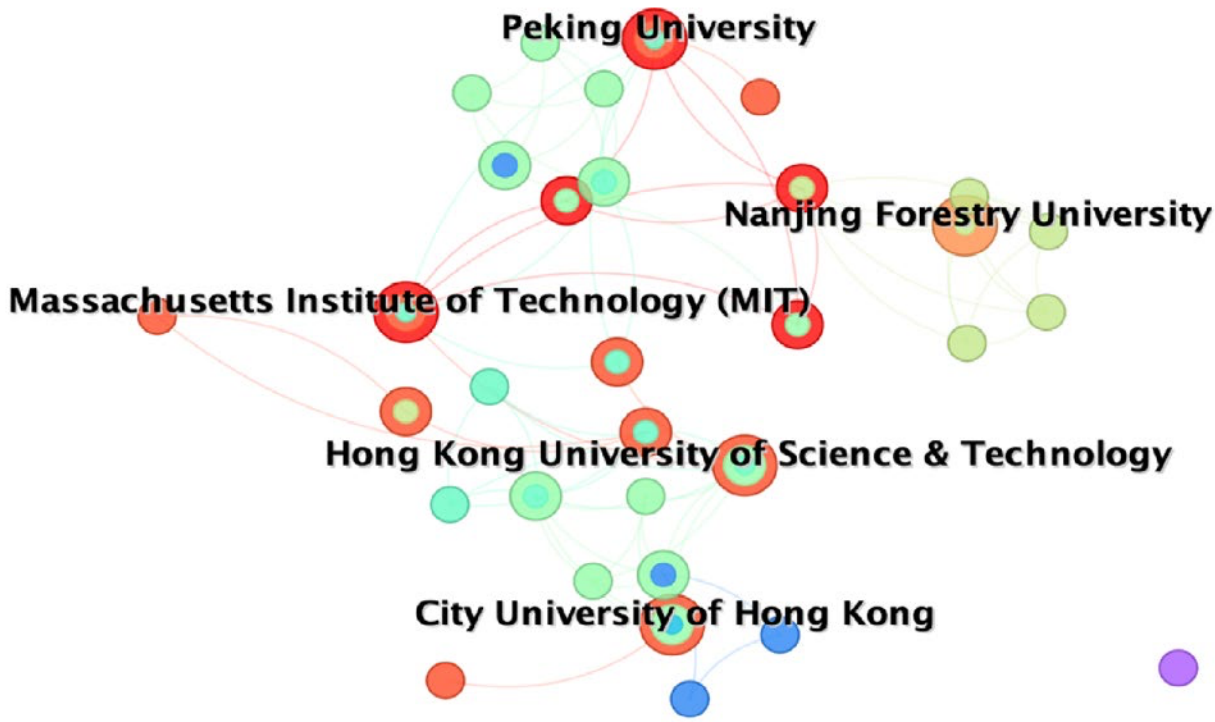


Figure 4. The Network of Institutions for City Visual Image Research.

Table 2. Contributing Institutions by Frequency, Centrality, and Burst.

Institutions	Frequency
Massachusetts Institute of Technology (MIT)	3
University of Helsinki	3
Delft University of Technology	3
City University of Hong Kong	3
Hong Kong University of Science & Technology	3
Peking University	3
Tsinghua University	3
Nanjing Forestry University	3
Institutions	**Centrality**
Hong Kong University of Science & Technology	0.04
Massachusetts Institute of Technology (MIT)	0.03
Chinese University of Hong Kong	0.02
Nanjing Normal University	0.02
Chinese Academy of Sciences	0.01
Peking University	0.01
ETH Zurich	0.01
Jiangxi Normal University	0.01
Institutions	**Burst**
Delft University of Technology	1.45
Nanjing University	1.29
Xi'an Jiaotong-Liverpool University	1.14
National Cheng Kung University	1.14
Tongji University	1.03
Chinese University of Hong Kong	1.03
Nanjing Forestry University	1.01

Table 3 enumerates seven distinguished authors in the field of city visual image research: Ammar Al-sharaa, Azizam Aziz, Hangyu Gao, Yu Liu, Suhardi Maulan, Binh Nghiem-phu, and Minna Valjakka. The majority of these scholars initiated their research endeavors in 2023, accentuating their engagement in this burgeoning area. Notably, Yu Liu has been active in related research since 2018, marking an early and sustained contribution to the field.

The author collaboration network depicted in Figure 5 positions Yu Liu as a central figure, having established fruitful collaborations with scholars such as Min Chen, Michael Batty, Fabio Duarte, and Gary Hack. The network's interconnections not only delineate the collaborative efforts among these researchers but also highlight Yu Liu's critical role in mediating academic discourse and disseminating knowledge. This pattern of interdisciplinary and interinstitutional collaboration serves as a powerful catalyst for innovation and the advancement of city visual image research.

Table 3. Contributing Authors by Number of Publications.

Authors	Publications	Year Begin
Al-sharaa, Ammar	2	2023
Aziz, Azlizam	2	2023
Gao, Hangyu	2	2023
Liu, Yu	2	2018
Maulan, Suhardi	2	2023
Nghiem-phu, Binh	2	2015
Valjakka, Minna	2	2015

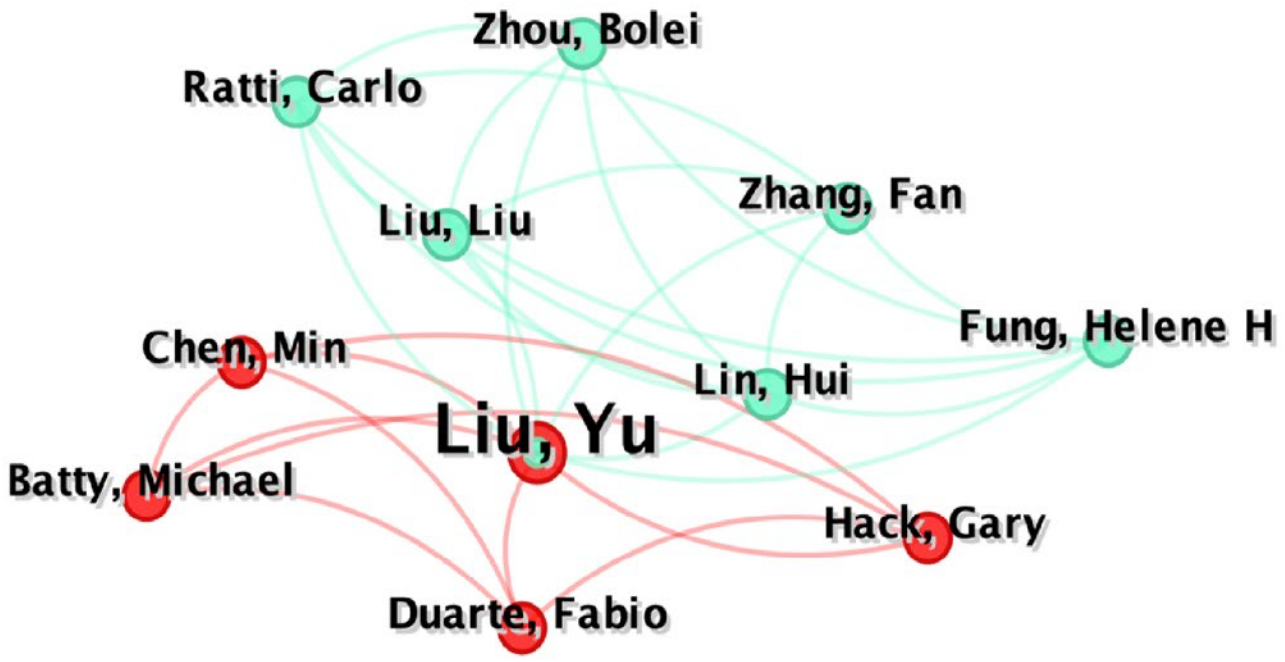


Figure 5. The Network of Contributing Authors.

3.2 Co-Citation Analysis

The co-citation network diagram in Figure 6 visually represents the academic prominence of papers by the size of their nodes, with larger nodes indicating higher citation frequencies (Xie, 2015). The connectivity between nodes illustrates the density of co-citation relationships. Tang JX (2019) and Zhou H (2019) are particularly conspicuous for their substantial node sizes, underscoring their influential status within the academic sphere. The central positioning of the Tang JX (2019) node, with its numerous connections to various research themes, signifies its pivotal role and broad academic influence. The pronounced linkage to Bijecki F (2021) suggests a frequent co-citation of these works, reinforcing their significance in city visual image design research.

Table 4 enumerates 25 papers with notable increases in citation rates, denoting their emergence as focal topics of research within specific timeframes. The citation surge for Tang JX (2019) and Zhou H (2019) between 2023 and 2024 is particularly striking, indicating a marked academic impact during this period. Additionally, the papers by Ma XY (2021) and Bijecki F (2021) have exhibited robust citation growth since their publication, establishing themselves as new research focal points. The robust co-citation ties among these works indicate a close thematic interrelation, reflecting their collective contribution to the discourse on city visual image design.

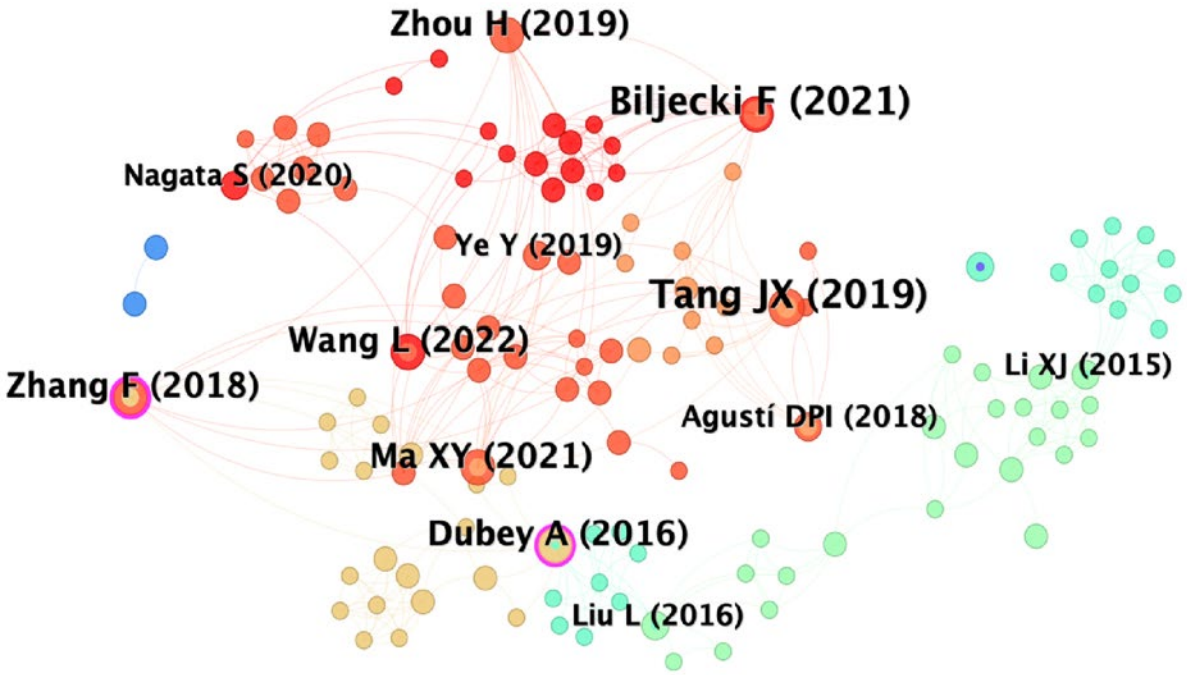


Figure 6. The Network of Cited Reference.

Table 4. Top 25 References with the Strongest Citation Bursts.

References	Year	Strength	Begin	End
Tang JX, 2019, LANDSCAPE URBAN PLAN, V191, P	2019	2.21	2022	2024
Zhou H, 2019, SUSTAIN CITIES SOC, V50, P	2019	2.13	2023	2024
Ma XY, 2021, CITIES, V110, P	2021	1.77	2022	2024
Wang L, 2022, ISPRS J PHOTOGRAMM, V190, P215	2022	1.77	2023	2024
Biljecki F, 2021, LANDSCAPE URBAN PLAN, V215, P	2021	1.76	2022	2024
Dubey A, 2016, LECT NOTES COMPUT SC, V9905, P196	2016	1.75	2021	2021
Liu L, 2016, GEOJOURNAL, V81, P817	2016	1.65	2018	2019
Li XJ, 2015, URBAN FOR URBAN GREE, V14, P675	2015	1.65	2018	2019
Ye Y, 2019, LANDSCAPE URBAN PLAN, V191, P	2019	1.59	2023	2024
Agustí DPI, 2018, ANN TOURISM RES, V73, P103	2018	1.32	2022	2024
Krizhevsky A, 2017, COMMUN ACM, V60, P84	2017	1.28	2020	2020
Wang MQ, 2015, CHINA INFORM, V29, P176	2015	1.25	2015	2015
Marinelli M, 2015, CHINA INFORM, V29, P154	2015	1.25	2015	2015
Parke E, 2015, CHINA INFORM, V29, P226	2015	1.25	2015	2015

Visser Robin, 2010, CITIES SURROUND COUN, V, P	2010	1.25	2015	2015
Bain Lesley, 2012, LIVING STREETS: STRATEGIES FOR CRAFTING PUBLICSPACE, V, P	2012	1.22	2017	2017
Naik N, 2014, IEEE COMPUT SOCCONF, V, PP793	2014	1.22	2018	2018
Long J, 2015, PROC CVPR IEEE, V, PP3431	2015	1.22	2019	2019
Hu YJ, 2015, COMPUT ENVIRON URBAN, V54, P240	2015	1.22	2019	2019
Xu G, 2017, ENVIRON MODELL SOFTW, V91, P127	2017	1.22	2019	2019
Hunter WC, 2016, TOURISM MANAGE, V54, P221	2016	1.22	2021	2021
Zhang K, 2019, TOURISM MANAGE, V75, P595	2019	1.22	2021	2021
Yin L, 2016, APPL GEOGR, V76, P147	2016	1.22	2021	2021
Gascó-Hernandez M, 2018, COMMUN ACM, V61, P50	2018	1.22	2022	2022
Harvey C, 2017, ENVIRON PLAN B-URBAN, V44, P668	2017	1.22	2022	2022

The Cited Journals Network depicted in Figure 7 distinctly highlights journals that wield considerable academic influence in the field of city visual image design. The high-citation journal analysis in Table 5 underscores the prominence of *Landscape and Urban Planning, Cities*, and *Sustainability-Basel*, each amassing over 25 citations, indicating their esteemed status within the academic community.

Table 6 provides an in-depth analysis of the citation intensity among these journals, with *Sustainability-Basel* emerging as a journal of significant influence, boasting a high citation intensity of 2.45. This figure attests to its prominent role in shaping scholarly discussions within the academic community. Regarding centrality, Cities plays a key role, serving as a bridge across diverse research themes with a centrality score of 0.22. This value emphasizes its integral position within the academic network. *Computational Environment and Urban Systems*, with a centrality of 0.17, is recognized for its meaningful contributions to urban environment research. *Annals of Tourism Research,* holding a centrality of 0.16, affirms its substantial influence in the domain of tourism research.

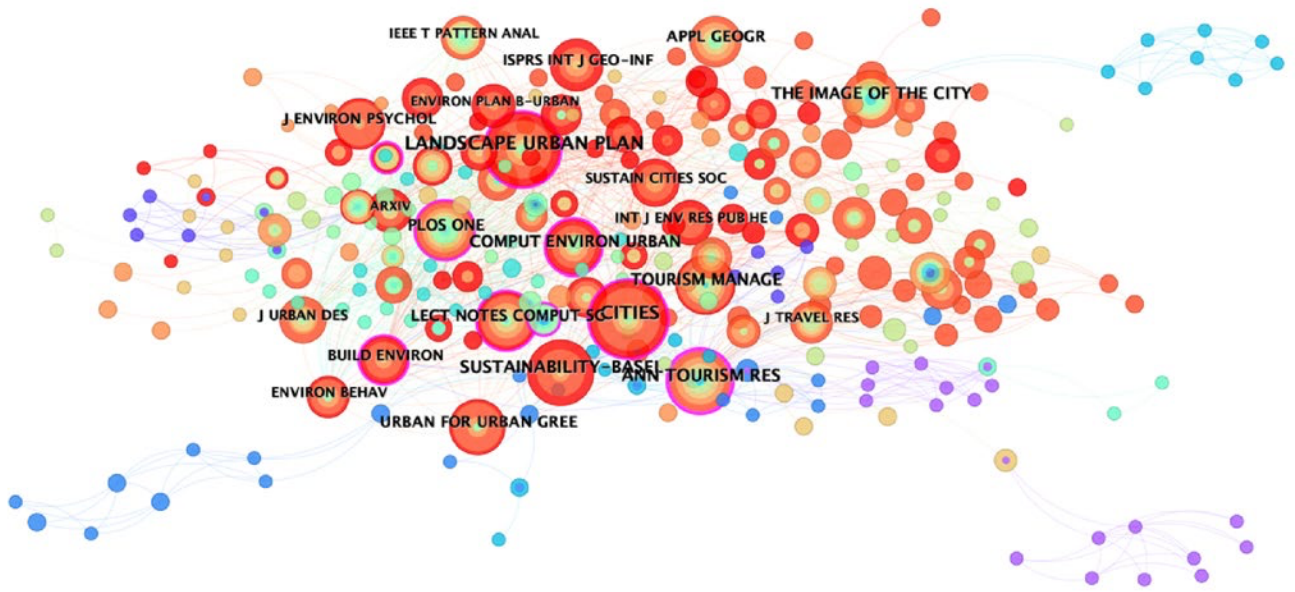


Figure 7. Cited Journals Network.

Table 5. Journals with More than 10 Citations.

Source	Frequency	Year	Centrality
Landscape and Urban Planning	28	2014	0.05
Cities	27	2013	0.22
Sustainability-Basel	25	2018	0.01
Computers, Environment and Urban Systems	19	2015	0.17
Urban Forestry & Urban Greening	17	2016	0.02
Tourism Management	15	2008	0.13
ISPRS International Journal of Geo-Information	15	2020	0.06
PLOS ONE	14	2013	0.04
Sustainable Cities and Society	14	2018	0.01
Annals of Tourism Research	12	2010	0.16
International Journal of Environmental Research and Public Health	12	2019	0.00
Building and Environment	12	2018	0.03
arXiv	12	2016	0.13
Environment and Planning B: Urban Analytics and City Science	11	2017	0.04

Table 6. Top Cited Journals by Citation Bursts and Centrality.

Journals	Strength
Sustainability	2.45
Tourism Management	2.26
Forests	2.22
Lecture Notes in Computer Science	2.16
International Journal of Environmental Research and Public Health	2.12
Land-Basel	2.04
Journals	**Centrality**
Cities	0.22
Computers, Environment and Urban Systems	0.17
Annals of Tourism Research	0.16
Tourism Management	0.13
arXiv	0.13
Communications of the ACM	0.13
Visual Studies	0.12
Ethnography	0.10

3.3 Co-Occurrence Analysis

The co-occurrence network is dissected across three dimensions—Term, Keyword, and Category—with the analysis of keywords being of paramount importance. This section concentrates on keyword co-occurrences, clustering, timeline analysis, and burst detection to uncover the research focal points and developmental trajectories within the field. The keyword co-occurrence analysis, as depicted in Figure 8, illustrates each keyword as a node, sized according to its prevalence in the literature, and the node connections represent the frequency with which keywords appear together in documents. This visualization highlights the pivotal keywords that dominate academic discourse in the field. For example, the keyword 'city' stands out with a large node size, underscoring its centrality to discussions on city visual image research. Additionally, keywords like 'destination image,' 'built environment,' and 'deep learning,' which exhibit high co-occurrence rates, indicate the

interdisciplinary nature of city visual image research and its intersections with urban tourism, urban design, and machine learning, respectively.

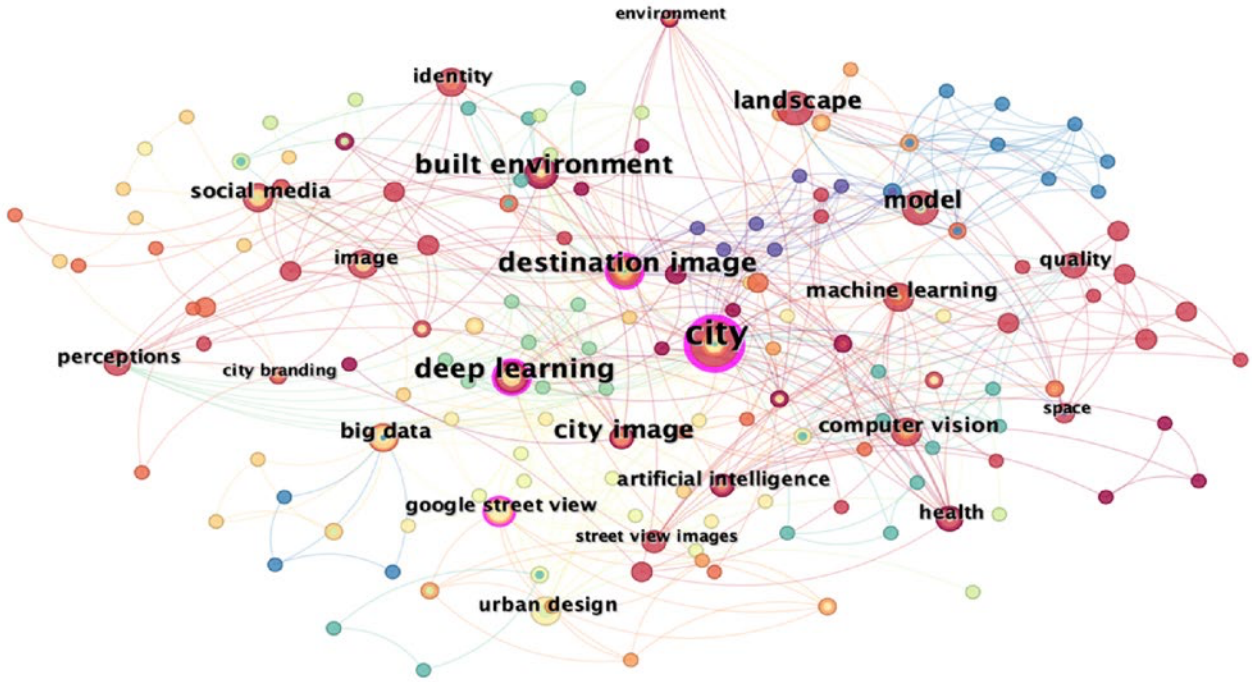


Figure 8. The Network of Keywords Co-occurrence.

Figure 9, employing a multidimensional approach to keyword clustering distribution, precisely identifies seven primary clusters, each addressing distinct research foci and represented by different colored regions. An S-value exceeding 0.5 signifies a robust clustering evaluation, and the high value of 0.8665 substantiates the effectiveness of the clustering. The 'City Image' cluster investigates the conceptualization, dissemination, and assessment of city images, with a particular emphasis on the role of social media in research. The 'Deep Learning' cluster examines the integration of deep learning in the analysis of city visual imagery, encompassing themes such as urban health, streetscape image processing, and environmental impact. The 'Google Street View' cluster is dedicated to the utilization of Google Street View and GIS tools for the examination of urban built environments and spatial configurations. The 'Urban Design' cluster delves into the perception of visual imagery in urban design, consumer behavior, and the establishment of symbolic capital. The 'Artificial Intelligence' cluster discusses the application of AI technologies, especially computer vision, in analyzing urban density and structural elements. The 'Perception Approach' cluster concentrates on the methodologies used to study the public's perception of city visual images, including

visual preferences, quality assessments, and user-generated content. As the most extensive cluster, the 'Destination Image' cluster underscores the development of city destination images, urban branding, and the integration of big data in destination image research.

The interconnections within the figure reveal the relationships between clusters, reflecting the interdisciplinary nature and mutual reinforcement of research themes. For instance, the strong association between the city image and destination image clusters underscores their interdependence in academic inquiry. These clustering analyses offer valuable insights into current research hotspots and trends, such as the escalating significance of deep learning and AI in city visual image studies, and the ongoing emphasis on urban design and perception methodologies.

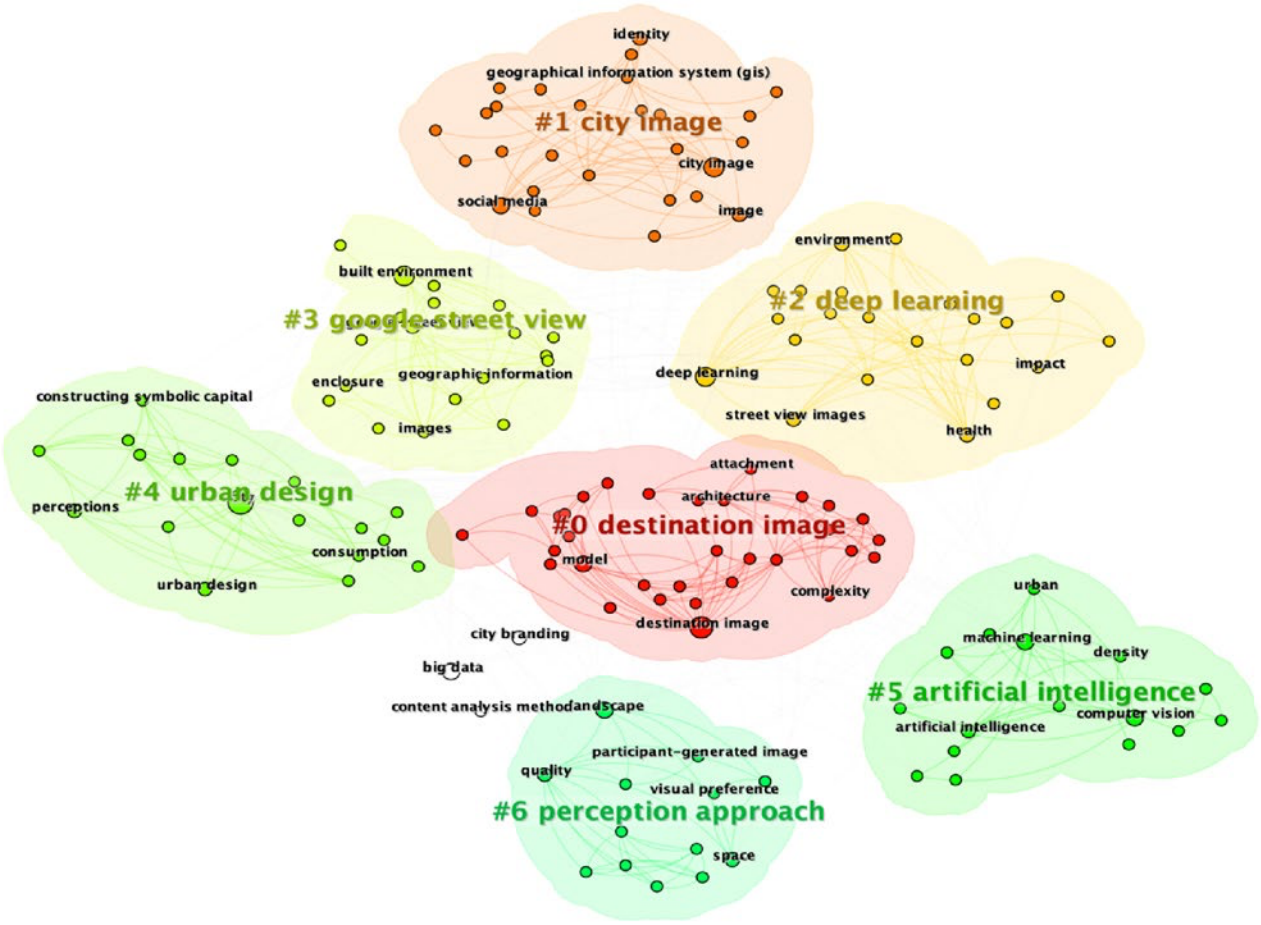


Figure 9. Clusters of Keywords.

Figure 10 presents a keyword timeline that visually maps the progression of key terms in city visual image research, tracing the field's development over the past decade and highlighting the varying activity and influence of keyword clusters across time.

The ‘Destination Image’ cluster has maintained a consistent presence in the research landscape since 2013, initially emphasizing content analysis, model development, and the intricacies of architectural design. More recently, the focus has shifted towards understanding the nexus between complexity and destination image perception. Interest in ‘City Image’ has been on an upward trajectory since 2015, with a surge in associated keywords such as ‘social media,’ underscoring the significance of promotional strategies in shaping city visual imagery. Research in the ‘Deep Learning’ domain has expanded since 2015, with an increase in keywords like ‘urban environment,’ indicating the growing application of deep learning techniques in the analysis of city visual images. The ‘Google Street View’ and ‘built environment’ clusters have seen a significant uptick in research post-2015, mirroring the effective incorporation of geographic information systems and streetscape imagery in the study of city visual images. The ‘Urban Design’ cluster has shown a steady increase since 2013, with keywords such as ‘perception’ and ‘consumption behavior’ underscoring the pivotal role of visual images in urban design processes. Investigations into ‘Artificial Intelligence’ and ‘computer vision’ have witnessed a marked increase since 2015, reflecting the escalating relevance of these technologies in the analytical framework of city visual image research. Finally, the ‘Perception Approach’ cluster has gradually gained momentum since 2015, with keywords like ‘visual preference’ and ‘space’ indicating a deepening exploration of the methodologies employed to perceive city visual images.

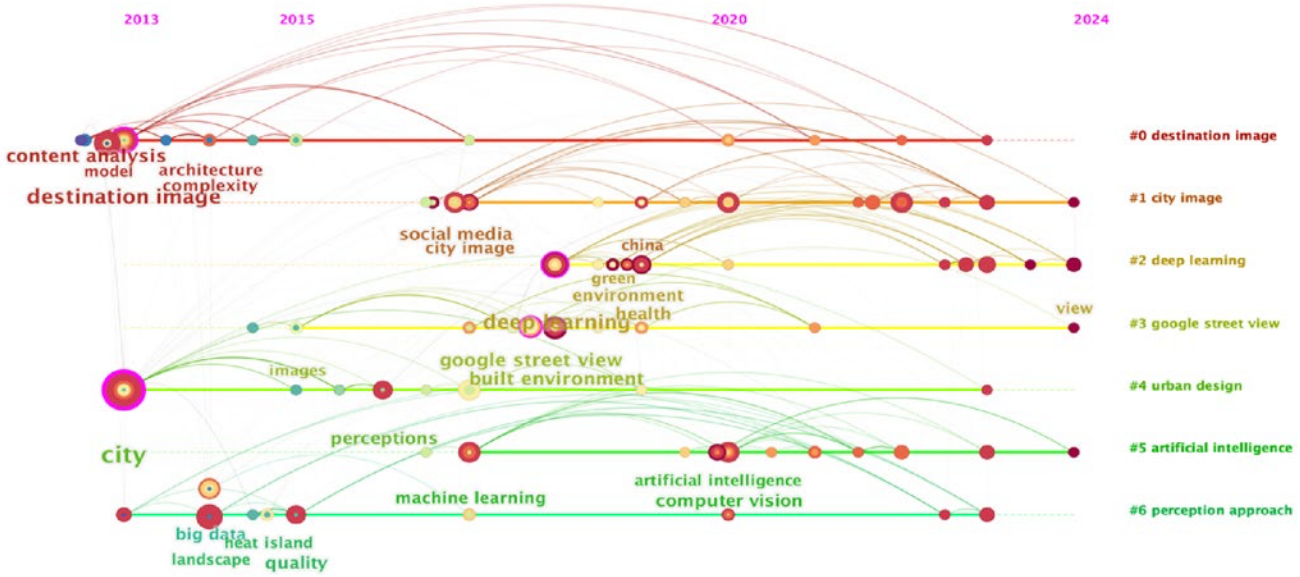


Figure 10. The Timeline of Keywords from 2013 to 2024.

Keyword bursts in the field of city visual image research are indicative of evolving research trends and focal points over time. Table 7 offers a comprehensive snapshot of these bursts, detailing the keyword, burst strength, start year, and end year, thereby mapping the dynamic trajectory of the research.

In the early years from 2013 to 2014, a significant surge in the keyword 'Content analysis' indicated an initial concentration on methodologies for content analysis within the discipline. Moving forward, between 2015 and 2017, there was a discernible rise in interest in 'Brand image' and 'Images,' while 'Urban design' peaked from 2017 to 2019, signifying a shift in research emphasis. The period from 2018 to 2024 saw 'Deep learning' and 'Google Street View' emerge as prominent areas of study, suggesting a growing focus on technological applications in the analysis of city visual images. Additionally, 'Big data' and 'Social media' garnered considerable attention in 2019 and 2020, underscoring the increasing relevance of data-driven approaches in the field. Since 2022, advancements in 'Artificial intelligence' and 'Computer vision' have begun to draw the interest of researchers, indicating a pivot towards more sophisticated technological integration and innovation in city visual image research.

Table 7. Top 25 keywords with Strongest Citation Bursts.

Keywords	Year	Strength	Begin	End
Content Analysis	2013	1.23	2013	2014
Brand Image	2015	1.01	2015	2017
Images	2015	0.93	2015	2018
Urban Design	2017	2.00	2017	2019
Deep Learning	2018	1.78	2018	2020
Google Street View	2018	1.70	2018	2021
Built Environment	2018	1.07	2018	2019
Big Data	2014	1.22	2019	2020
Color	2019	1.04	2019	2020
Geographic Information	2019	0.93	2019	2021
Attachment	2020	1.10	2020	2021
Image	2020	1.05	2020	2020
social media	2017	0.97	2020	2020

computer vision	2020	0.86	2020	2024
density	2021	1.06	2021	2022
identity	2022	1.28	2022	2024
network	2022	1.17	2022	2022
urban	2022	1.17	2022	2022
machine learning	2017	0.90	2022	2024
landscape	2014	1.90	2023	2024
street view images	2023	1.29	2023	2024
model	2013	1.19	2023	2024
quality	2015	1.02	2023	2024
perceptions	2016	1.02	2023	2024
urban studies	2023	0.86	2023	2024

4. Discussion, Conclusions and Research Agenda

4.1 Discussion and Conclusions

The primary objective of this study is to systematically dissect the structural evolution and trend directions in the field of city visual image design from 2013 to 2024. This analysis aims to deepen the academic community's understanding of existing research and to provide insights into potential paths and future development directions for city visual image studies. The optimization of city visual images not only significantly enhances a city's attractiveness and competitiveness (Sevin, 2014)) but also effectively promotes societal transformation and inclusive growth ((Belabas & George, 2023; Paganoni, 2012). Despite numerous researchers having explored city visual images from various perspectives and methods, the field as a systematic area of study is still in its developmental stages. This paper employs bibliometric analysis using CiteSpace software to thoroughly review the research dynamics in city visual image design, with the intention of offering new insights and methodological support for academic research and practical applications in this domain.

RQ1 of this study aims to explore the current academic status of city visual image design research. By examining the quantity

of scholarly publications, international collaboration networks, institutional cooperation networks, and collaborations among scholars, we have provided an in-depth response to this question. The study's findings indicate a significant increase in the number of academic papers indexed in the Web of Science (WoS) database from 2013 to 2024, peaking in 2023 as illustrated in Figure 2. Furthermore, as shown in Figure 3, researchers from various countries including China, the United States, Japan, the United Kingdom, Malaysia, Russia, and South Korea have begun in-depth explorations of city visual image. This trend of cross-cultural engagement suggests that city visual image has become a widely recognized research focus globally, with its importance increasingly highlighted. Within the timeframe of this study, China has exerted the greatest influence in the field of city visual image research, establishing solid cooperative relationships with countries such as the United States, South Korea, and Russia, as shown in Table 1. Further analysis of inter-institutional collaboration networks (refer to Figure 4 and Table 2) reveals the significant roles of institutions like the Hong Kong University of Science and Technology, the Massachusetts Institute of Technology (MIT), Peking University, and the City University of Hong Kong in this field. Table 3 lists the outstanding scholars in the field, outlining the influential collaboration networks they have built. As the field of city visual image design expands globally, enhancing international cooperation and academic exchange is crucial for further development in this area. Concurrently, it is anticipated that scholars will focus more on city visual image research in cross-cultural countries, aiming to promote knowledge sharing and academic innovation worldwide.

RQ2 is dedicated to uncovering the literature and journals that hold significant influence within the field of city visual image design. Tang JX (2019) and Zhou H (2019) are key documents in this domain, with their high citation frequency and strong linkage relationships in Figure 6 and Table 4, highlighting their central position in academic research. Journals such as Landscape and Urban Planning, Cities, and Sustainability-Basel have a notable impact in this area, as shown in Figure 7 and Table 5, particularly excelling in citation intensity and centrality as per Table 6. The analysis of co-cited literature and journals reveals the interdisciplinary nature of city visual image research, spanning various academic fields including sociology, design studies, and management science. Within these widely cited documents, researchers have employed big data and deep learning technologies for empirical studies on urban forms, which not only deepen our understanding of city visual images but also provide new perspectives on their evolution through model simulation and prediction. This is essential for accurately grasping the perception of city visual images. The study of city visual images is a field where multiple disciplines intersect, and future research should focus on deepening the theoretical foundations, innovating research methods and technology applications, and constructing

a comprehensive knowledge system to better understand the construction process of city visual images and their profound impact on urban development.

RQ3 investigates the key themes and keywords in city visual image research, probing into future research prospects. The co-occurrence analysis of keywords, as seen in Figure 8, indicates emerging interdisciplinary integration with fields such as urban tourism, environmental studies, and machine learning. Cluster analysis, depicted in Figure 9, reveals seven major research themes, emphasizing the growing significance of deep learning and artificial intelligence, while sustaining ongoing interest in urban design and perceptual methodologies. Timeline analysis, tracked in Figure 10, monitors the evolution of keywords in city visual image research over the past decade, highlighting shifts in the activity and influence of keyword clusters at various points in time. Burst analysis, detailed in Table 7, shows that the “content analysis” methodology garnered considerable attention between 2013 and 2014. Subsequently, from 2018 to 2024, “deep learning” and “Google Street View” emerged as prominent research areas, indicating an increasing focus on the application of technology in city visual image analysis. Furthermore, “big data” and “social media” received significant attention in 2019 and 2020, underscoring the growing relevance of data-driven approaches in the field. Since 2022, advancements in “artificial intelligence” and “computer vision” have begun to attract the attention of researchers, signaling a shift towards deeper technological integration across the industry. Looking ahead, research will continue to focus on the integration of city visual image with cutting-edge technologies such as artificial intelligence, further deepening the understanding of perceptual theories, urban branding, and cultural interactive communication. Through comparative case studies of multiple instances, the harmonious coexistence of urban spaces and technology will be fostered, laying a solid foundation for constructing smarter and more inclusive future cities.

4.2 FUTURE RESEARCH AGENDA

Based on the analysis, we have observed that the field of city visual image research is continually expanding. This has provided us with a clearer understanding of the importance of city visual images. Consequently, we propose three key themes that hold potential and value for further research.

This first set of agenda is dedicated to an in-depth investigation of city visual image systematic research, employing distinctive branding strategies to bolster urban competitiveness. Through an intensive study of keyword cluster 0, we have garnered theoretical support for the development of city brands with personalized characteristics. In the crafting of city brands, highlighting the uniqueness of the city is a crucial step. The distinctive features of a city are not only the foundation of city brand development but also embody the city’s unique charm, core values, cultural diversity, and historical depth. Researchers can perform case studies on

various city types, such as historical cities, tech-oriented new cities, and cities renowned for their natural scenery, to uncover their historical narratives, cultural identities, natural landscapes, and social frameworks, thereby creating city visual images and brands that inspire a sense of identity and belonging. Future research on city visual image can closely integrate urban characteristics with personalized branding to facilitate dialogue and understanding among different cultures and social groups, establishing a foundation for a more harmonious and inclusive social environment. This approach not only enhances residents' identification with their local culture but also serves as a key strategy for the sustainable development of the city visual image.

The second set of agenda focuses on enhancing stakeholder engagement in the design of city visual images. Within keyword clusters 1 and 4, we have identified that social media and consumer behavior play a pivotal role in driving stakeholder participation in the dissemination of city visual images. Social media has not only transformed the modes of city image communication but also propelled urban consumer behavior towards diversification and personalization. On one hand, user-generated content on social media has become a central conduit for the propagation of city images. The public's perception of cities is significantly influenced by the sharing and recommendations on social media platforms. On the other hand, the personification and emotional expression of city image communication content, through storytelling that resonates with the public, can effectively enhance a city's appeal and approachability. In future research on city visual images, scholars can focus on exploring effective cross-cultural communication strategies to stimulate active involvement of city residents and visitors in the construction of city images. Such participation not only fosters innovation in city visual image design, making it more vivid and diverse, but also improves the quality of urban planning decisions and their broad acceptance by the public.

The third set of agenda is committed to actively exploring artificial intelligence and utilizing digital technology methods to enhance the interactivity and user experience of city visual image. We are actively exploring the integration of artificial intelligence (AI) and digital technologies to improve the interactivity and user experience of city visual images. Our focus on keyword clusters 2, 3, and 5 highlights the potential of AI and digital technology in enhancing the perception of city visual images. By utilizing AI, we can conduct detailed analyses of vast amounts of urban data, covering various aspects such as resident behavior, traffic flow, and environmental conditions. This provides urban planners with a solid data foundation, enabling them to develop more precise and efficient strategies for city visual images. Furthermore, the advancement of new media technologies allows us to offer customized visual experience services based on individual user needs, creating unique and immersive visual effects. For example, through innovative tourism route design and augmented reality

(AR) navigation technology, we not only expand the boundaries of traditional visual experiences but also pioneer new interactive modes by blending the virtual and the real. Looking ahead, the integrated application of artificial intelligence and new media technologies will propel society towards a more open and innovative direction.

Limitations

This study has yielded affirmative outcomes in its in-depth examination of sustainable development within city visual image design. However, it is not without its limitations. Deliberately narrowing the research scope, while beneficial for concentrating on pivotal issues, may have inadvertently excluded certain perspectives essential for a holistic grasp of city visual image design. Moreover, the study's reliance on English-language publications could have inadvertently marginalized studies in other languages that might offer valuable contributions to the global academic discourse. The exclusive use of the Web of Science (WoS) as the primary database might also have constrained the inclusion of diverse research viewpoints available in other databases.

To address these limitations, subsequent research endeavors should consider the following strategies to enhance the study's comprehensiveness and profundity:

- Broaden the research scope to encompass additional databases such as Scopus and Google Scholar, thereby amplifying the diversity and representativeness of the research sample;
- Undertake cross-linguistic studies to ensure a global and inclusive research outcome, encompassing insights from various cultural perspectives;
- Embrace sophisticated technologies like artificial intelligence and machine learning to investigate their potential to influence research methodologies and practices in city visual image design, uncovering innovative avenues and analytical tools.

By implementing these measures, future research will be positioned to explore the sustainable development of city visual image design more exhaustively, offering more profound insights and guidance for urban planning and design. This will, in turn, stimulate innovation and advancement in the realm of city image construction.

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“THE EUROPEAN FUSILLI PROJECT IN THE CITY OF TURIN: THE SYSTEMIC DESIGN OF CIRCULAR AGRI-FOOD PROPOSALS INVOLVING LOCAL ACTORS OF MIRAFIORI SUD DISTRICT”.

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ABSTRACT | The topic of enhancing food waste and preventing wastefulness in all phases of the food value chain is nowadays increasingly prevalent to respond to some complex contemporary challenges. When the food issue is treated outside the industrial context, covering the urban scenarios, it also involves the dimension of neighborhoods and micro-communities. In this background, transdisciplinary Systemic Design projects originate which aim to plan and implement Circular Economy for Food activities in the catering, agricultural, and domestic sectors, aimed at inclusively involving the diversified communities of local citizens. The objective of this contribution is to illustrate the results that the European H2020 FUSILLI project is bringing within the city of Turin (Piedmont, Italy), in particular in the peripheral neighborhood of Mirafiori Sud, where different migratory flows have stratified over the years. Specifically, through the Systemic Design methodology, a circular restaurant and a circular kiosk were developed through co-creation processes within a Sustainable FoodLivingLab, based on the valorization of the less noble parts of food. In particular, the aim is to increase levels of food awareness in terms of recovery and valorization of food, still characterized by sensorial and nutritional properties, respecting the gastronomic cultures of the different ethnic groups of the neighborhood and triggering virtuous behavioral change. The project was supported by the collaboration of the University of Gastronomic Sciences of Pollenzo, the Fonda azione Comunità di Mirafiori, Orti Generali, the University of Turin and, obviously, the City of Turin, and required the trans-disciplinary collaboration of designers, gastronomes and local administrators.

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KEYWORDS | SYSTEMIC DESIGN, CIRCULAR ECONOMY FOR FOOD, FOOD LIVING LAB, FOOD WASTE, H2020 EUROPEAN PROJECT

1. Introduction
1.1 Food Waste in the Catering and Household Sectors

Our economy exceeds the planet's limits (Rockström et al., 2009) and social limits (Raworth, 2017), adopting unrestrained predatory behavior without limits on a planet that, instead, is limited. It is a parasitic symbiosis that damages our common house (Pope Francis, 2015). However, the greatest crises often mark decisive transitions between epochs, destabilizing the categories of thought with which human beings interpret life. The erosion of natural capital accelerated in recent decades mainly due to food production, has already partly compromised the stability of cultural capital (Bourdieu, 1980). At a time when social inequality is widening more and more, dividing those who have access to quality food and those who do not, acting and designing for change, in collaboration with others, can restore hope in the community, moving away from linear, high-impact models of production and consumption. Environmental and social degradation are the main consequences of these models, in which food waste, in its broadest sense, plays a significant role, resulting in a loss of the nutritional, social, and educational value of food (Kowalewska et al., 2018; Niaki et al., 2017), as well as of the resources used in its production. There are two broad definitions of food waste: the first distinguishes between loss and waste throughout the food supply chain, while the second focuses on the difference between loss and waste of edible and inedible food.

According to the FAO (Food and Agriculture Organization), food waste refers to food suitable for human consumption that is discarded, lost or wasted along the entire food chain, from operators in the sector to final consumers (FAO, 2019). Food is discarded even when it is still edible and safe for human consumption. This definition includes waste in both domestic and industrial settings (restaurants, hospital and school canteens, supermarkets, farms, etc.) and is broader than the definition of the Environmental Protection Agency of the United States (EPA, 1997), considering advances in food logistics and

increased environmental awareness. Concretely, food waste includes discarded, overproduced, unsold, and leftover food (CalRecycle, 2009). Furthermore, according to the Waste & Resources Action Programme (WRAP, 2009), food waste can be divided into three categories: avoidable, possibly avoidable, and unavoidable. The first two categories include 'edible waste', i.e. food that is discarded while still being eatable, or food that some people eat and others do not (e.g. bread crusts, apple peels, etc.). The third category, on the other hand, concerns 'inedible food waste', which includes waste from food preparation (such as bones, eggshells, etc.). This last concept, however, may vary considerably depending on the gastronomic culture of the territory analyzed. In fact, the "maximum efficiency" of an agro-food product cannot be achieved if the raw material is considered inedible. In this sense, the boundaries of defining what is considered inedible should be re-evaluated.
In the catering sector, between 4% and 10% of the food purchased is wasted in kitchens before reaching the consumer (LeanPath, 2008). Another significant portion is served but not consumed. The main causes of this wastage include the size of the portions prepared and served, the quality standards required by specific restaurant chains, the need to maintain large stocks in order to constantly offer a wide choice of offerings (Kantor, 1997), the difficulty in planning food purchases, and the lack of widespread practices in which unconsumed food is taken home by customers (Barilla, 2012). The behavior and culture of kitchen staff also significantly influence the generation of food waste. In the United States, for example, plate waste accounts for the largest fraction of food losses. On average, customers left over 17% of their meals, and 55% of these potential leftovers are not taken home (Buzby, 2011). In particular restaurant scenarios, centralized management may make waste prevention more difficult, due to the lack of flexibility at the local level that prevents the creative valorisation of food and leftovers. However, household food waste is also a major critical issue, as much food that is still edible ends up directly in municipal solid waste (Gaiani, 2013). For example, in Italy, it is estimated that each citizen wastes about 566g of food weekly (Waste Watcher Report, 2024). In this scenario, the main cause of waste is not only the perishability of food, but also an increasingly robust relationship between the food sector and hyper-consumerism, which includes growing overproduction, excessive food shopping (with an increase in the selection of products on promotion or close to expiry), limited knowledge of how to preserve food, the tendency to prepare and serve excessive quantities of food, and frenetic lifestyles that are less and less inclined to autonomy in preparing daily meals.

1.2 The Circular Economy Lever for Food

Food consumption and management habits can change considerably according to historical and geographical contexts. Globally, developing countries show significantly lower levels of household food waste than developed countries. For example, in the

United States, the amount of food wasted at the household level is ten times higher than in Southeast Asian countries, highlighting significant differences in consumption habits and food management policies between different regions of the world (FAO, 2011). In this regard, in the context of the Circular Economy applied to food, there is a growing interest in the anthropological theme of "agricultural bricolage" (Lévi-Strauss, 1962). This concept refers to the ability of traditional societies to operate on material and immaterial knowledge by creatively recombining it, to enhance it to the maximum and avoid the generation of waste. Historically, this mode of operation was typical of women, who with few resources were able to feed an extended family, composed of people from different generations with different nutritional needs. Thanks to this mentality, traditional dishes were born that today represent the history of Italian gastronomy, such as the more international meatballs, invented in Roman times (between 25 and 35 B.C.) as a good practice to utilize leftover cooked meat. Today, these processes can be described as a true "short cycle" typical of "biological metabolism" in the kitchen, using the conceptualisations of the Circular Economy found in the "Butterfly Diagram" developed by the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015) to describe the essence of the new economic paradigm.

Reference is made to the 'cascade cycle' when the food chain does not end with human consumption, but supports the needs of animals or agriculture, in line with the most recent European directives on the "Food Waste Hierarchy" (European Commission, 2018). So, the circular economy applied to food is not a new concept, but it is rooted in the domestic economy and reminds us that underlying this constant action-research, besides economic scarcity, there is exploratory thinking and a deep dialogue with ecosystems.

In conclusion, the Circular Economy for food identifies itself as a sustainable practice aimed at addressing urgent contemporary issues, such as the inefficient use of resources and their consequent waste, the impacts of human actions in terms of climate change and soil and ocean pollution (Esposito et al., 2020; Jurgilevich et al., 2016). However, when analyzing in depth many case studies that claim to adopt circular economy practices, risks emerge related to an approach that could encourage manipulative design for waste, which paradoxically could accelerate planned obsolescence (Fassio & Tecco, 2019). The complexity of the food system therefore requires the adoption of a long-term holistic perspective, typical of Systemic Design and Gastronomic Sciences, based on a new knowledge paradigm that can trigger a virtuous change in current design and action models. With this awareness, the H2020 FUSILLI project was developed at European level.

[1] The priorities of the European Food 2030 policy are the development of sustainable and healthy diets and that of smart and sustainable food systems, the pursuit of circularity and waste reduction, and finally, innovation and community empowerment)

1.3 The European project H2020 FUSILLI in the city of Turin

FUSILLI is a project funded in 2021 by the European Horizon 2020 programme, which aims to transform the urban food system through the implementation of Innovative Living Labs (FUSILLI Project, n.d.). In detail, the acronym FUSILLI literally means 'Fostering the Urban Food System Transformation through Innovative Living Labs Implementation'. In fact, the project intends to trigger an integrated holistic transition towards sustainable, healthy and inclusive food systems in urban, peri-urban and rural areas, through innovative and replicable urban policies, leading to the implementation of improvement actions at all stages of the food value chain, consistent with the priorities of the European FOOD 030 Policy[1] (European Commission, 2021). In order to achieve this objective, a real network has been developed between 12 different European cities[2], which, through the development and implementation of Living Labs of various natures and identities, are launching concrete actions in the diverse European scenarios. Specifically, a Living Lab is a place, but more than that, it is a real-life context characterized by a deep-rooted social dimension, supported by the involvement of several stakeholders through inclusive and participative methods. Collaboration between citizens and stakeholders is defined as fundamental in order to give rise to experimentation processes aimed at achieving innovative objectives. In the case of the FUSILLI project, the aim is to start a sustainable transition of the urban food system by involving the multifaceted dimension of food. Living Labs are characterized by extreme dynamism, as they necessarily adapt to the urban environment within which they develop. Moreover, they are strongly based on the legitimate inclusion of different groups of citizens, sometimes suffering from a state of even acute vulnerability. Generally, where possible, in such contexts, the domination of a few actors is avoided and the broad participation of local communities is favored, encouraging a participatory continuity in the project paths undertaken. Indeed, it is not uncommon for a cohesive and thriving community to develop around a Living Lab, characterized by the sharing of common values, through which co-design and innovation processes can be facilitated (Bason at al., 2017). In the last decade, more and more Living Labs have been dedicated to the topic of sustainable food systems, with a particular focus on urban food production (Dell'Era & Landoni, 2014; Blay-Palmer et al, 2016; Balzan et al., 2020). In this, in Europe, the FUSILLI project has been a substantial encouragement (Wilde, 2022). The discipline of Design is well suited to act in such open contexts that welcome innovative transdisciplinary approaches.

[2] The cities involved in the project are Athens (Greece), Castelo Branco (Portugal), Differdange (Luxembourg), Kharkiv

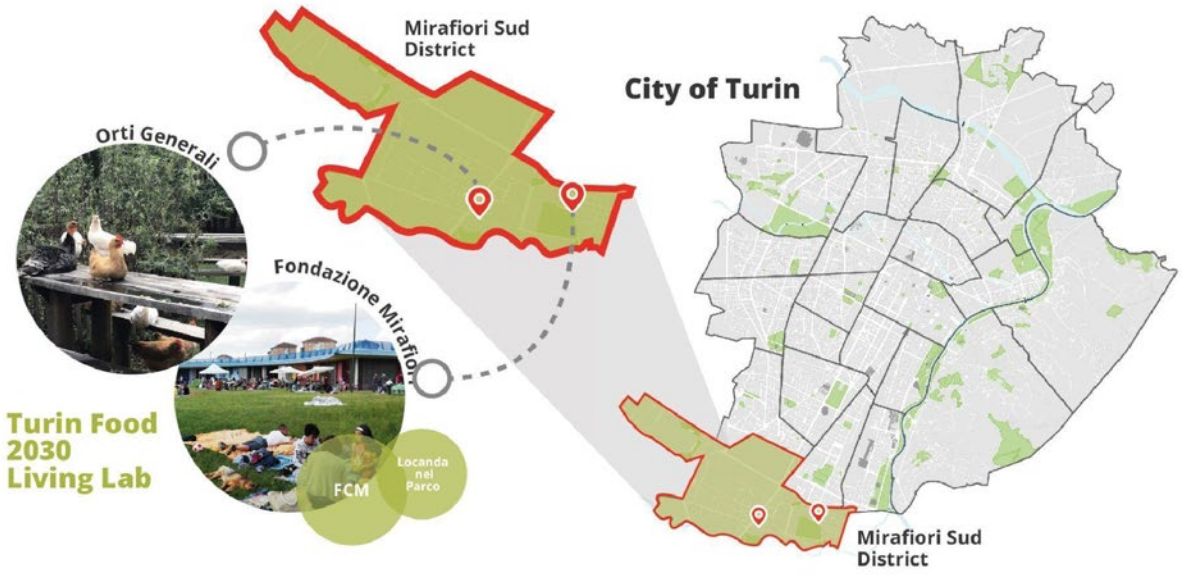


Figure 1. The suburban district of Mirafiori SUD (Turin, Piedmont, Italy) involved in the European Project H2020 FUSILLI

Among the cities involved in the project, which will still be ongoing until the end of 2024, the City of Turin (Piedmont, Italy) stands out for its achievements. Many partners are involved in it, including the Municipality of Turin, the University of Gastronomic Sciences of Pollenzo (UNISG, Cuneo, Piedmont, Italy), the University of Turin (UNITO), the Mirafiori Community Foundation (FCM) (Mirafiori Foundation, n.d.) - within which the Locanda nel Parco social restaurant is also located - and, finally, the suggestive urban agriculture community, Orti Generali (Orti Generali, n.d). The latter are located in Mirafiori SUD, a suburban district of Turin, primarily involved in the FUSILLI project (Figure 1) and they represent the roots of Turin's first Food Living Lab.

Mirafiori Sud was originally a historical center, but it underwent rapid expansion between 1960 and 1970 to accommodate mainly migratory flows from southern Italy, attracted by the jobs available in the FIAT factories, a major Italian automobile company. Thus, the district embraced the critical issues typical of fast-growing neighborhoods: housing challenges, distance from essential services, and a concentration of complex social and economic problems. However, towards the end of the 1990s, a long process of redevelopment began, which involved significant project interventions to improve the area and support the communities. Among these, the various European projects activated stand out, such as the H2020 ProGireg Project, which designed, tested,

(Ukraine), Kolding (Denmark), Nilufer (Turkey), Oslo (Norway), Rijeka (Croatia), Rome (Italy), Turin (Italy), San Sebastián (Spain), Tampere (Finland).

[3] The Food Council is a set of governance tools that create and support the network of parties involved in all urban and peri-urban food-related issues, defining the spheres of action, the objectives and processes necessary to elaborate, implement, and measure the policies of a territory.

and implemented different nature-based solutions to activate an urban regeneration of post-industrial areas in Europe and China, based also and above all on the design of new behavioral models (Nohra, 2019).

All of the partners in the FUSILLI project are working together on many goals, including:

- the definition of a system of sustainable food policies, which will generate a real Food Council[3] for the city of Turin, as already exists in other cities around the world, Toronto (Ontario, Canada), Milan (Italy), etc. (Calori & Magarini, 2015);
- the design of educational and awareness-raising activities on the food topic;
- the pursuit of projects related to the Food Atlas of Metropolitan Turin (Atlante del Cibo, nd; Calori et al, 2017);
- the development of concrete actions on the Food Hub concept, thus on the recovery, management and redistribution of food surpluses to the most vulnerable segments of the Turin population.

Specifically, the University of Gastronomic Sciences of Pollenzo, in collaboration with the above-mentioned partners, is acting concretely within the Circular Economy for Food dimension. It has worked on the design of a circular restaurant and a circular bar, an integral part of the Food Living Lab (at the Locanda nel Parco social restaurant and at the Orti Generali kiosk, respectively). These concepts may be able to reduce and prevent the generation of food waste, creating community co-evolution processes and preserving the natural and cultural capital.

2. Methodology

2.1 Approach and Design Phases

In order to design the circular restaurant and circular bar, belonging to a broader Circular Business Model project applied to the Food Living Lab in Mirafiori Sud, the typical methodology of systemic design was adopted (according to the Italian view of the Politecnico di Torino). By definition, systemic design is a design approach, adapted to the design of products, services, processes, strategies, experiences, and in particular, production chains and complex systems, aimed at connecting economies, people, territories and resources, with a view to environmental, social and economic sustainability (Celaschi et al., 2016, Jones, 2014; Bistagnino, 2011). Moreover, it can be defined as a suitable tool to define and implement circular economy projects in different scenarios, such as agrifood, urban or industrial waste, social, etc. However, before being defined as such, it is a tool for decoding complexity to design flexible, virtuous and sustainable strategies and action plans. Adopting the Systemic Design approach not only attempts to reduce the ecological footprint and social repercussions of a project. In fact, it also lends itself to finding creative and coherent methods to enhance local culture, strengthening the identity of communities and territories (Barbero et al, 2022; Parente

& Sedini, 2019). The development of systemic business models thus makes it possible to generate sustainable economic flows, avoiding situations of imbalance, in terms of impacts and benefits, among the actors involved.

Following this methodology (Figure 2), the first step was the realization of a holistic diagnosis (Tamborrini & Stabellini, 2018) of Locanda nel Parco and Orti Generali, i.e. a capillary survey of the case studies that would respectively host the future circular

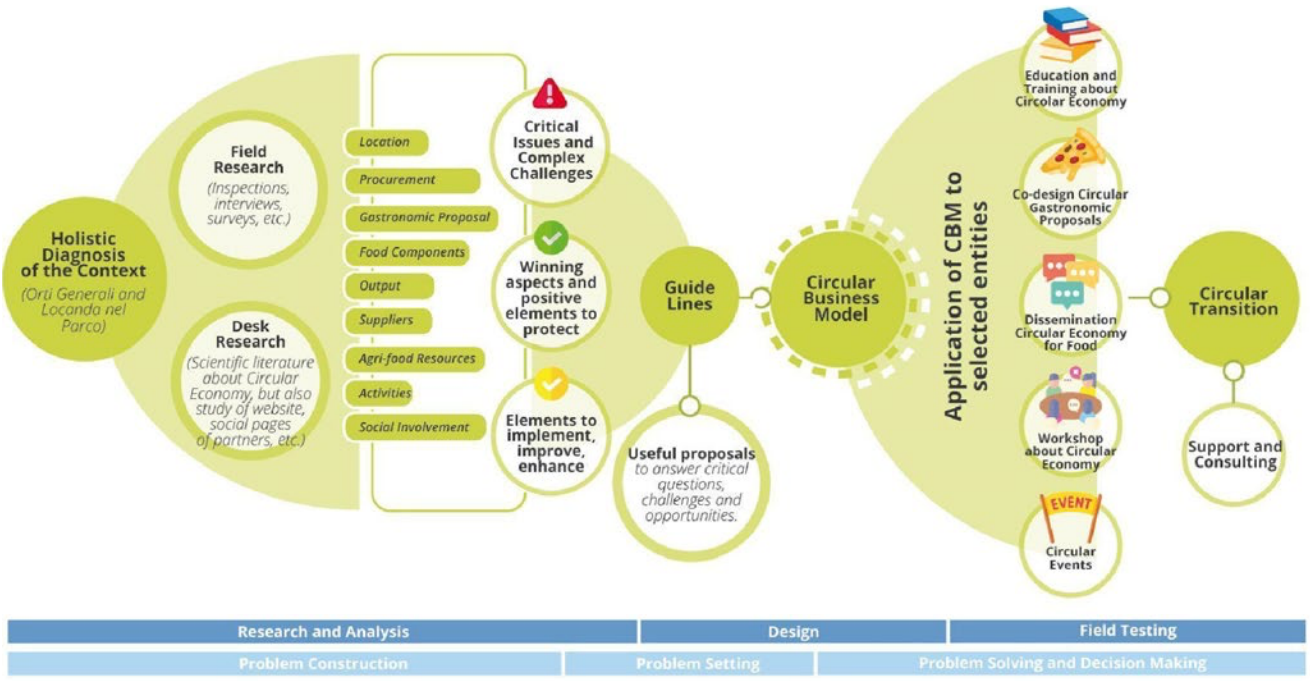


Figure 2. The systemic methodology adopted within the design path undertaken in the H2020 FUSILLI European Project by the University of Gastronomic Sciences of Pollenzo

restaurant and circular bar. This step was carried out starting from the analysis of the territorial context of the urban district of Mirafiori Sud, in which, as already mentioned, different migratory flows have stratified over the years, bringing to the Piedmontese city, the most diversified cultures from the regions of Southern Italy and those from the Middle-East. Through an initial field research, several visits were carried out through which it was possible to interview the actors active in these places, very often represented by citizens belonging to the local community.

Subsequently, the analysis was extended to the food dimension of these locations. The type of food supply, the gastronomic offer, the typology and materials of the components used for the consumption of food, the partnerships with suppliers and their location, as well as that of the resources used, the output produced in terms of waste and by-products in the food processing and consumption phases, and finally, the activities of social involvement of the most marginalized segments of the population, such as families with insufficient income

to lead a decent life, people with motor or cognitive disabilities, people who have come out of crime, etc., through collaboration with non-profit organizations and associations, were all investigated. through cooperation with non-profit organizations and associations.
Considering the purpose of the project, this field research phase was supported by a desk research phase, in which the scientific literature relating to the Circular Economy for Food was analysed, in which other national and international circular food case studies were traced and explored in depth (from which to take inspiration). The product of the holistic diagnosis finally allowed the design of a systemic graphic map for each place analyzed which linked suppliers, food resources, the type of output produced, and the consequent management and disposal (Figure 3). This first methodological phase allowed a simpler identification of the critical aspects to work on, the most complex challenges to address, as well as, the dormant assets and, equally, the winning sides to protect, emphasize, or implement. Therefore, some useful guidelines for the design process were drawn up.

In order to respond to the critical elements, as well as to the need to implement the intrinsic opportunities of such contexts, approximately 100 students from the Gastronomic Design Course (Bachelor's Degree in Gastronomic Sciences and Cultures, UNISG, Pollenzo, Italy) were involved, who developed a panel of circular proposals applicable within the scenario of the future Turin Living Lab 2030. They acted within four specific themes:

- the development of partially or totally circular menus (circular and symbiotic gastronomic proposals such as genuine local products, or alternative formats such as circular picnics and aperitifs);
- the definition of systems for the valorisation of food and inorganic outputs currently not re-inserted into the system;
- the design of laboratories, events, cooking courses and workshops related to the Circular Economy for Food theme;
- the experimentation of tools for the widespread dissemination of circularity.

The best proposals were presented to the managers of Orti Generali and Locanda nel Parco to adapt them appropriately to their needs and begin the first design steps towards a sustainable circular transition of the food system they support. In this process, the transdisciplinary approach of Systemic Design was fundamental. In fact, a close collaboration between eco-designers, gastronomes, food geographers and, more generally, catering professionals was activated. In particular, the support of the Pollenzo FoodLab (UNISG, n.d), an experimentation and training laboratory for innovation in the kitchen, run by chefs and gastronomes specialized in circular agrifood processes, was essential.

In general, the role of the gastronome is to spread the culture and good practices of food sustainability and sovereignty, to develop and share new perspectives on the agri-food

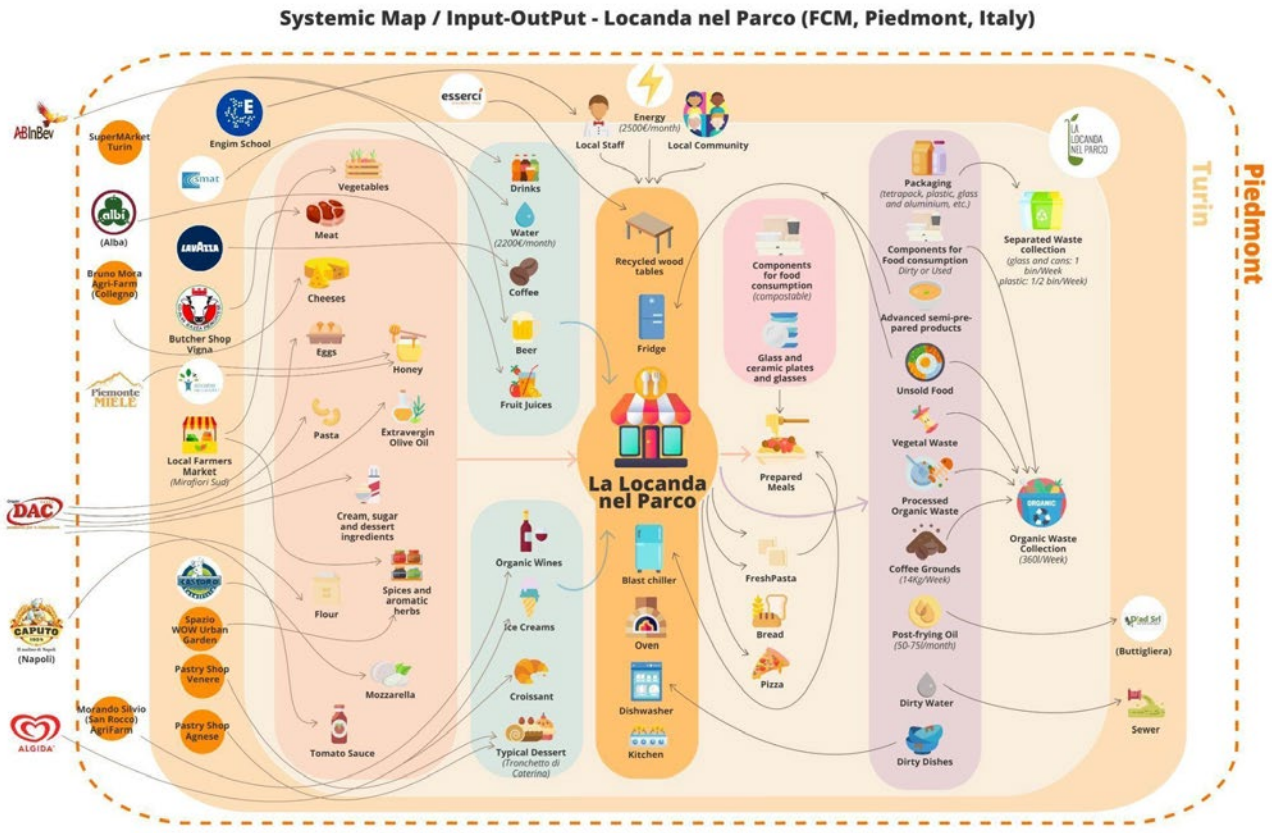


Figure 3. An example of a Systemic Map designed for the Holistic Diagnosis of the Locanda nel Parco Social Restaurant. In particular, graphical representation of the input and output analysis.

system with a holistic view of food production, processing and consumption, and finally, to design possible future food scenarios. In this framework, systemic designers guided and supported co-creation processes, but above all, worked as mediators of different backgrounds, minimizing conceptual and communicative obstacles and working out compromises between different visions. In this sense, they facilitated dialogue between different disciplines and professions in order to achieve high project standards. This specific role of creative connector is extremely favorable to co-design processes with different communities and teams (Celaschi, 2008, Savina & Peruccio, 2020).

3. Discussion and Results

3.1 The Circular Valorisation of the Less Noble Parts of Food

On the basis of the methodology described in the previous section, through the collaboration of the actors introduced, symbiotic circular menus were designed that could be included in the circular restaurant and circular kiosk's agri-food offer.The holistic analysis undertaken has thus allowed the coherent and virtuous planning of the agri-food proposals. These menus were developed following the cycles of the Circular Economy (Ellen MacArthur Foundation, 2012)

and the fundamental principles of Systemic Design, based primarily on the valorisation of outputs, the creation of relationships between the parties, local action, with a strong focus to the protection of the environment and communities (Barbero & Tamborrini, 2015). However, the key principle that guided the development of the menus is not only an integral part of the systemic approach, but is also a key rule of ecology, according to which all waste matter can become a form of nourishment for other systems (Commoner, 1971).

Each circular agri-food proposal has been designed, experimented and preliminarily tested within the Pollenzo FoodLab, under the guidance of cooks, chefs and researchers.



Figure 4. Local citizens involved in the circular gastronomic events organized in the Mirafiori Sud district (Turin, Italy)

The citizens of Mirafiori Sud, already actively involved in Orti Generali and Locanda nel Parco, took part in the co-creation process, which was able to enhance ancient knowledge and traditions of cultures and peoples even far from the Piedmontese territory (Figure 4). In this, the value of the elderly emerged, i.e. citizens of senile age (from 65 years onwards) who in most cases preserve food and agricultural rituals and traditions, to be handed down to younger generations. Citizens from Southern Italy, although grafted into Piedmont for social and work related reasons, have in fact often shown themselves to be very close to the riches of rural settings, often forgotten in more developed urban areas.

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Among the activities designed and implemented in the Food Living Lab it is possible to mention the Circular Cooking Course, (from which the Participated Circular Aperitif format originated) and the Symbiotic Circular Pizza. In both cases, the direction was to valorise the less noble parts of the agri-food products used and that of the by-products of the food transformation processes.

Generally, food waste is that food, or those parts of food, which in the common perception are not useful for human consumption or which, more simply, were not valorised before they became inedible (e.g. food defined as not suitable for consumption , spoiled, expired, advanced, manipulated food, etc.). Changing terminology, however, the perception of food waste changes. In fact, talking about "less noble parts of food", rather than food waste, has made it possible to refer to those parts/ elements of agri-food products that are usually discarded, which however are still perfectly useful for human consumption and, on the contrary, still have good organoleptic/sensorial properties, so much so that they can be fully exploited in the kitchen, following appropriate gastronomic transformations. These are edible components of food, such as fruit peels and leaves, greens, basal/apical parts, seeds and, again, food processing by-products, such as the cooking water of a product. In circular menus, the potential of all the parts of an ingredient are studied and analyzed (Whole Ingredient concept), so that they can be enhanced in the different agri-food courses and in some cases, increase the nutritional intake of a meal.

The target of the circular actions undertaken is primarily the citizens of the Mirafiori district of the city of Turin. However, it extends to all urban citizens, as well as to all urban gastronomic scenarios, as one of the objectives of the project is precisely to increase food awareness at a territorial level. In order to reach such a wide audience, for each of the gastronomic experiences, and specifically, for each menu designed, simplified systemic maps were created (Figure 5 - Figure 8), which, through the use of visual communication, represented a useful tool for communicating the effective circularity of food proposals to an average user, therefore to a mixed audience, characterised by different cultural levels, as well as different disciplinary languages. In some cases, these easy-to-use maps were printed on the placemats inserted inside the aperitif boxes or for the administering of the Circular Pizza during the dissemination events of the project and the official launch of the proposals. This graphic-visual tool generally allows for an easier metabolization of concepts aimed at changing the user's behavioral habits.

3.2 The Circular Cooking Course and the Participatory Circular Aperitif

Within the evocative natural spaces of Orti Generali, which host 178 urban gardens, a synergistic vegetable garden and an didactic farm with animals such as chickens, bees, hares and Irish cows, a participatory, zero-waste circular aperitif format open to all local citizens has been designed every year, since 2022, in the summer season.
This format included a preliminary circular cooking course, through which to collectively cook the agri-food proposals, under the expert guidance of the pollentine chefs. Around 20 chefs from the Turin restaurant sector were involved annually, mostly belonging to Turin's neighborhood houses, and around 100 citizens, reaching a broader social dimension. The objective of the event was to spread the principles of the Circular Economy for Food in the restaurant sector and among local citizens, so that the urban food transition could take place both in restaurant and domestic environments, involving the dimension of daily life. The course led cooks and chefs to experiment with the preparation of vegetable and circular proposals based on the integral use of seasonal and local vegetables (such as tomatoes and courgettes, wild vegetables and legumes), creating a concrete menu of sustainable circular proposals, in mutual symbiotic connection, through the complete valorization of the less noble parts of the ingredients and preparation waste. The citizens who attended the circular agri-food training actively contributed to the cooking course, while the other citizens were the users of a broader dissemination process, which concluded with the tasting of the circular aperitif (Figure 5).

Considering the multiple geographical identities of the local community involved, the menus were designed by revisiting international gastronomic elements. In the systemic map representing the circular menu of the participatory aperitif designed in 2023 (Figure 6), it is possible to see how, starting from the integral valorisation of three ingredients (beetroot, radish, red onion), some typical recipes of Argentina, Greece, America, but in particular the Middle East (as well as those of other regions of Italy) have been revisited. These recipes belonging to different geographical contexts (such as chimichurri sauce, tzatziki sauce, hummus, ketchup) have been re-designed following the concept of mutualistic symbiosis (Bronstein, 2001). In the preparation of each of them the process output of further gastronomic preparations is present. The format of this circular aperitif demonstrates how the concept of Circular Cuisine, already partially anticipated by the Italian chef Massimo Bottura (Italia Circolare, 2020), does not undertake to exclusively valorise what is commonly treated as waste, but also the resources and the communities of a specific territory.

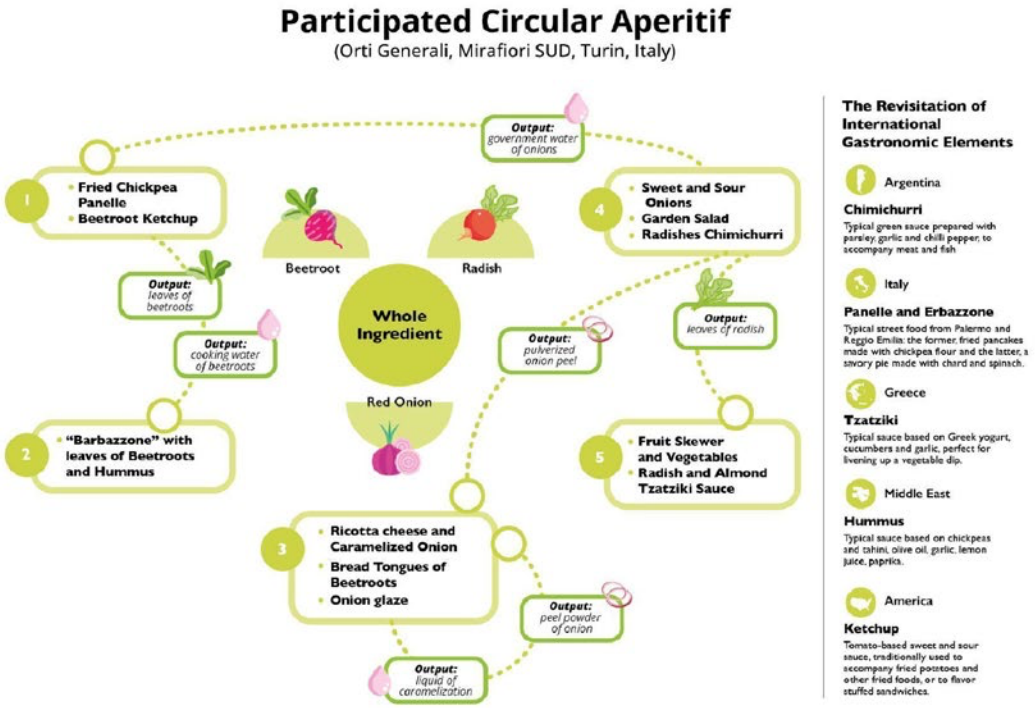


Figure 5. The Systemic Map of the gastronomic proposals of the Participated Circular Aperitif (Orti Generali, 2022)



Figure 6. The Participated Circular Aperitif, with the Preliminary Circular Cooking Course (Orti Generali

3.3 The Symbiotic Circular Pizza

Following the same methodological process, the Symbiotic Circular Pizza was designed at the Locanda nel Parco social restaurant (Figure 7). This is not a static recipe, but an iconic Italian product, which, following the 3Cs of the Circular Economy for Food (synthesized as Capital, Cyclicality, and Coevolution) (Fassio et al., 2020), enhances the ingredients in their wholeness, avoiding the generation of waste, enhancing the natural and cultural biodiversity typical of the territory and involving the local community with a nutritious and healthy product.
Its recipe, extremely versatile depending on the annual periods and geographical areas, proposes the use of vegetables that are a seasonal expression of the Piedmontese territory and that of typical local products, coming from sustainable production processes. The broader ambition was to circularly revisit some great classics of Italian cuisine. In the circular restaurant project, the Circular Pizza changes seasonally. Furthermore, it was designed in a symbiotic relationship with a circular starter. In the following image (Figure 8) it is possible to analyze, as in the same way as the circular aperitif, also in the case of this food combo, the elements of products and preparations that are not enhanced within the pizza, with appropriate transformations, represent the main ingredients of the appetizer and vice versa.



Figure 7. The Circular Combo (Circular Aperitif and Circular Pizza) of the Locanda nel Parco social restaurant (FCM, 2023)

Although these projects are located in a micro-local dimension (in this case purely urban), the strategic choice of some agri-food products, such as pizza, known internationally, has made it possible to make the new agri-food proposals vehicles of circular innovation and information

in different international contexts, not just Italian ones, overcoming every cultural and geographical barrier[4]. In this sense, the objective of contributing to the sustainability of the food sector has been achieved in a much broader way. In fact, these are Italian food rituals that lend themselves well to adoption by other territories and cultures, albeit with appropriate variations. The prevention of food waste and the valorisation of the less noble parts of food are in fact activities and values that can be communicated and learned in any kitchen in the world, where the Circular Economy is often already intrinsically present.

It is important to point out that the development of circular menus is not enough for the design and subsequent construction of a circular restaurant and a circular kiosk. In order to complete these concepts, further fundamental points have been adopted, such as:

- the use of energy-saving technologies, such as ovens made of refractory materials to maintain temperature and reduce consumption;
- the use of renewable energy, through the installation of solar panels;
- self-production, where possible, of vegetables, fruits, herbs and other food products, in compliance with current Italian food safety regulations;
- the use of agro-ecological cultivation practices, without the use of chemical herbicides, within urban agriculture activities;
- the facilitation of on-site separate waste collection by all the actors involved,
- the supply of drinkable water in pitcher, to avoid the over-production of plastic waste;
- the production of common goods useful to the community starting from food waste that cannot be exploited in the kitchen, such as the artisanal production of soaps starting from the used oil resulting from the frying process;
- the supply of doggy bags to avoid wasting leftover food, encouraging the domestic consumption of what is not consumed in the catering sector.

The development of the aforementioned activities, connected to the designed circular gastronomic experiences, adapt well to the concept of Food Living Lab, already widely rooted in the Mirafiori Sud district of the City of Turin. The local community welcomed the initiatives undertaken, demonstrating a growing interest which allowed the rapid

[4] In 2023, the Circular Pizza concept was presented at the Karlín Forum in Prague, Czech Republic,during the international catering event organized by Fany, major food retailer, and at the World Pizza Championship 2023 (Parma Exhibition Centre, Italy).

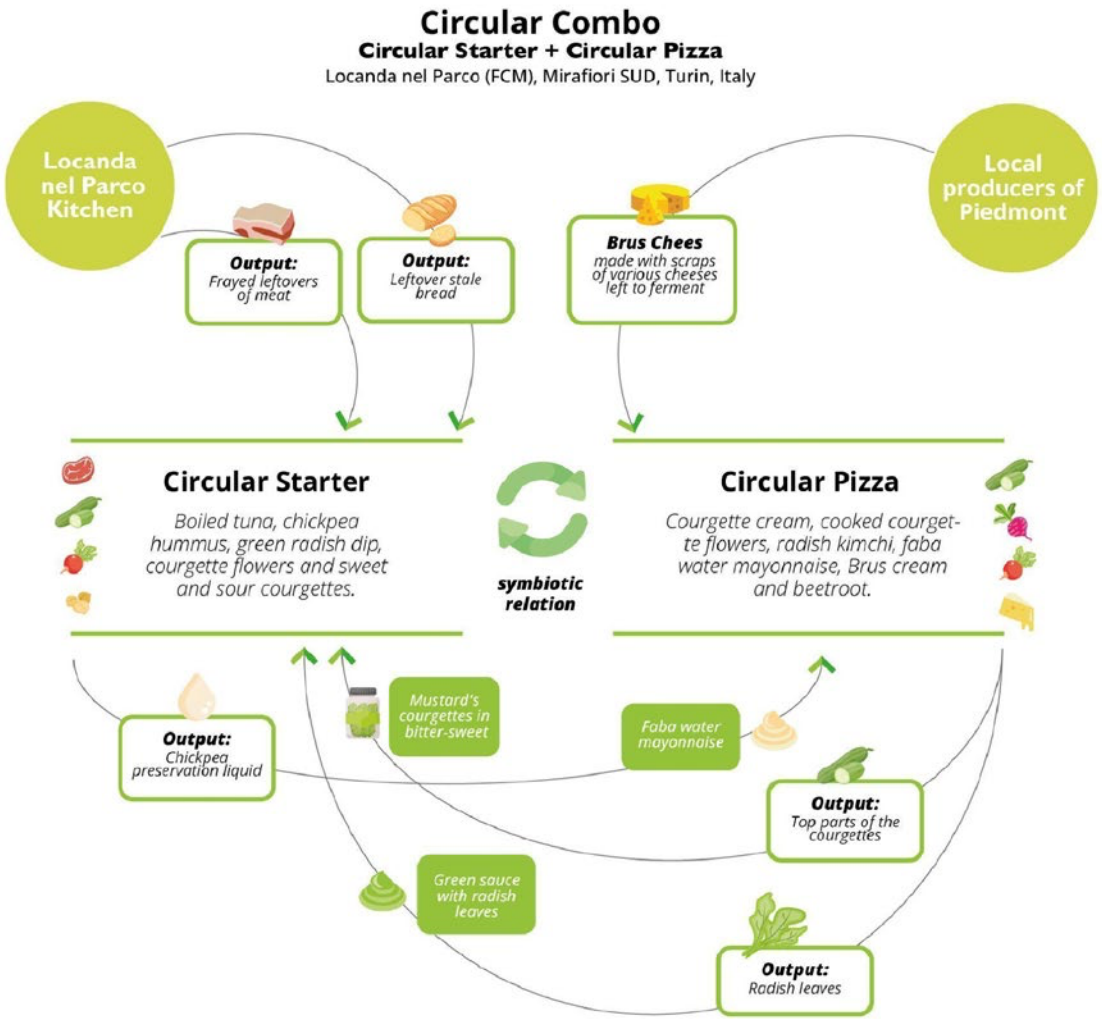


Figure 8. The Systemic Map of the Circular Combo (Circular Aperitif and Circular Pizza) designed for the Locanda nel Parco social restaurant (FCM, 2023)

metabolization of the circular experiments and effective autonomy in the reproduction of the developed model.

Furthermore, the project demonstrated how design is an effective tool in supporting "wicked interactions" (Buchanan, 1992; Granovetter, 1973), and in creating local informal networks, contributing to territorial social capital. In this sense, design manifests itself as a discipline extremely suitable for the coordination of multidisciplinary groups and the management of 'community-centered' projects (Manzini and Meroni, 2014), i.e. initiatives in which local communities (stakeholders and citizens) actively participate in the design path, leading to the achievement of a holistic result and a collective virtuous behavioral change (Wendel, 2013). In many cases, such as the one presented in this article, such projects can become versatile models that can be replicated in different territories.

4. Conclusion

Through the circular agri-food experiments launched through the European H2020 FUSILLI project within the city of Turin, it was possible to act on several elements of the urban food system. Although the starting point was, for obvious reasons, a supply of seasonal local resources, favoring sustainable production processes, the main focus was directed more concretely on the food handling and transformation phases, in particular to prevent the generation of waste in the pre-consumption phase. Working with food catering, in fact, allows us to act in the phase preceding the meeting with the final consumer. Working with food catering makes it possible to take action in the phase before meeting the end consumer. In addition, applying circularity in the kitchen for the elaboration of gastronomic catering proposals makes it possible to indirectly contribute to increasing the food awareness of the public reached, initiating processes of ecological literacy (Sterling, 2012), which facilitate the arrival of the Circular Economy also in the domestic sphere, triggering a change in people's daily habits. In this sense, food, and more specifically, design for gastronomic sciences, becomes a vehicle for sustainable virtuous principles.

Although local citizens were defined as the primary target of the project, the activities carried out also significantly involved several catering professionals. In turn, they will be able to replicate the good practices learned within their food business, also adopting a sustainable change in the systemic design of menus, with a broader vision of the different food formats, which, on the contrary, often embody formulas that involve massive consumption at low cost, to the detriment of the quality and sustainability of the products and working conditions. In this sense, the ecological transition path initiated wants and must also consider the social dimension of the designed system.

Currently, the FUSILLI project is still ongoing at European and Italian level and it will end in December 2024. The real challenge will be to preserve the results achieved at the Food Living Lab in Mirafiori Sud, progressively expanding them and maintaining the active participation of the community and stakeholders involved. The limits of the project are in fact in some cases to be found in the lack of continuity, which is predominantly the most critical element, not only in associationism, but also in forms of citizen self-organization. European projects make it possible to direct substantial funding towards the exploration of specific topics and the development of joint activities related to them, which can lead to tangible impacts on territories and communities in different European nations. This allows the realization of individual local programmes characterized by concreteness, capable of generating employment over time, also thanks to the structuring of expected periodic results, verified by international managers. Nevertheless, it is not uncommon

that there are inconsistencies between the peculiarities of each territory and the standard requirements dictated by specific KPIs (key performance indicators), the same for all cities in their diversity, Political involvement supports and nurtures the life of such projects, and vice versa, such projects help political administrators in the development of targeted innovative activities. One of the most decisive strengths has been the structuring of a heterogeneous local partnership of which the research organizations are part, which has made it possible to combine different competences and approaches to achieve extensive results in terms of food awareness and new sustainable good practices.

The downside, however, is the risk that the activities undertaken will be suspended at the end of the funding period, not allowing the final achievement of results or their maintenance over time. This means that in the event that the project has not generated structured activities on the ground capable of self-management and self-financing, the impact on communities risks fading over time, unless the arrival of new funding allows for investment in the continuation of the results achieved.

As regards the fruits of the FUSILLI project in the city of Turin, the greatest legacy is undoubtedly the development of an Interdepartmental Group of Food Policies (GIPA), capable of making departments and local authorities discuss the topic of food, with a shared effort and with different points of view. This discussion will establish a real Food Council, which can develop healthy and sustainable food policies for all citizens and the environment, educating on more virtuous food consumption and production behaviors, in line with the Sustainable Development Goals of Agenda 2030. To conclude, in 2024, through the activities developed in Turin, the University of Gastronomic Sciences of Pollenzo won the prestigious CEFoodCycle AWARD (Lamoro, 2024) which recognized the most innovative circular economy initiatives in the food sector, and identifying some circular pioneers on the European scenario.

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AN ANALYSIS OF INCLUSIVE DESIGN INTEGRATION AND INTERSECTIONALITY IN DESIGN EDUCATION CURRICULA.

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ABSTRACT | This paper investigates the integration of inclusive design principles and intersectionality within design education by analyzing curricula from top-ranking international design programs. The study employs an interpretative approach to examine 23 undergraduate and postgraduate courses from the top 10 universities in the QS World University Rankings (2023). A research protocol features a comprehensive analysis grid focusing on five main clusters: 1) General Information, 2) Inclusive Approach, which evaluates how each course addresses inclusive design both explicitly and implicitly, 3) Mapping of Course Aims and Approaches, 4) Levels of Design, and 5) Integration of 13 individual identities in diversity. Data were collected from university websites and databases, with fifteen literature-derived terms used to guide the search within course descriptions. The findings reveal current practices incorporating inclusive design principles across leading design programs. The research underscores the necessity of embedding inclusive design principles into design education, advocating for both practical applications and a holistic approach to address complex societal challenges. The paper concludes with potential future research, emphasizing the value of the analytical protocol developed. In fact, this protocol could serve as an example for similar studies or as a tool for educators to assess and enhance their courses. By providing an initial overview of this educational area, the paper aims to stimulate reflection, foster meaningful engagement, and guide the evolution of design education to integrate inclusive design principles better.

KEYWORDS | INCLUSIVE DESIGN, DESIGN EDUCATION, INTERSECTIONALITY, DESIGN CURRICULUM ANALYSIS

1. Introduction

The landscape of inclusive design is evolving, driven by two key factors: an increasing recognition that "good intentions cannot be enough" (Del Gaudio et al., 2020; D'Ignazio & Klein, 2020) and a shift from physical exclusion to more complex forms (Donahue & Gheerawo, 2021). Inclusive design, traditionally focused on integrating disabled and elderly groups into mainstream society, has expanded its scope beyond traditional accessibility concerns (Clarkson & Coleman, 2015; Lillegård et al., 2021; Szlavi & Guedes, 2023). There is a growing imperative to address diverse issues such as race, gender, social status, and sexual orientation, acknowledging intersectionality, as introduced by Kimberlé Crenshaw (1989). Intersectionality and the matrix of domination (Collins, 1990) shed light on how privilege and oppression intersect. Despite the momentum of intersectionality, a gap exists in design education, necessitating comprehensive studies on how students approach and address intersectional biases (Berry et al., 2022). This paper aims to analyze the educational landscape of design and answer the research question: **How are inclusive design principles and intersectionality addressed in different design curricula?**

Drawing inspiration from Das et al.'s (2023) methodology for ethics, equity, and justice audits of design pedagogy, this paper analyzes the course programs of top-ranking international design universities and colleges. A literature review informs a protocol for analyzing existing design education programs. The research protocol includes an analysis grid to map the courses and compare the results. Initially, the results are analyzed quantitatively, followed by a qualitative examination to highlight the primary considerations that emerged from the inquiry. The research, restricted to the top 10 universities in the 2023 QS World University Rankings by subject: Art and Design, examines programs and course descriptions of 23 undergraduate and postgraduate courses. Second-hand data from university websites and databases were analyzed, with fifteen terms derived from the literature as search criteria within course descriptions. The

analysis provides insights into the current state of design education programs and their incorporation of inclusive design principles. Overall, this research highlights the importance of integrating inclusive design principles into design education, emphasizing practical applications and holistic perspectives to address complex societal challenges effectively. The paper concludes with discussions and reflections on potential future avenues for similar studies, aiming to contribute to ongoing discourse and advancements in design education. The primary goal of this paper is not to provide exhaustive research but to lay the foundation for further investigation and to share tools for analyzing and reflecting on design courses.

This brief research is part of a PhD research focused on prioritizing inclusive design within design education, particularly in the methodological learning approach aimed at redefining design briefs (problem-framing). Research on problem-framing, which influences decisionmaking, can be significantly biased, resulting in superficial efforts to promote inclusive actions (Holmes, 2020). This study is based on the principle that addressing awareness, power dynamics, and biases at the beginning of the design process is crucial to prevent these biases from affecting the proposed solutions (Costanza-Chock, 2020).

2. Theoretical background

This section offers general reflections on the future of design education by identifying fundamental changes underway to address the urgent needs of global development. It explores the dimensions of these changes and how scholars are intervening to implement them. Additionally, it analyzes the literature on inclusive design, attempts to define the term, and outlines how current research approaches this subject.

2.1 Exploring the Changing of Design Education

The field of design education is undergoing substantial changes, necessitating the development of new courses, curricula, and teaching methods (Mercer & Terresa, 2019). Two interrelated factors primarily drive this transformation. Firstly, ongoing global and local challenges of unprecedented scope and intricacy highlight the limitations of traditional, discipline-specific design education in preparing students for emerging contexts (Pontis & Van der Waarde, 2020). Consequently, there is a pressing need to reconsider the future direction of design education (Jones et al., 2022). Designers today face increasingly complex and impactful challenges, necessitating reevaluating educational methodologies to effectively address contemporary issues (Pei & Colombo, 2023). Simultaneously, there is a growing recognition of design's role in influencing societal structures. This shift in perspective

demands a critical reassessment of current practices and calls for an expanded definition of innovation that encompasses socially inclusive outcomes (Noel et al., 2023; Monteiro, 2019). Monteiro (2019) claims, "The world is not broken but works exactly as it was designed to work, and we are the ones who designed it", underscoring the importance of transformative processes within the design discipline. In its various manifestations, design is increasingly viewed as a catalyst for social change, capable of empowering marginalized communities and promoting innovative behavioral patterns (Avelino, 2021; Meyer & Norman, 2020). This comprehensive reform requires interventions at various scales, driven by the increasing emphasis on diversity, inclusion, and equity. Researchers are reevaluating macro and micro scales to foster genuine change within the education system.

Three dimensions are identified here:

1. **Rethinking the pedagogical model**
   At the macro level, there is a need to rethink the entire pedagogical model. One prominent theme in this discourse is transdisciplinarity. As design education expands to incorporate critical, inclusive, and systemic tools, its potential as a discipline and a mode of teaching and learning becomes more evident (Jones et al., 2022). This shift acknowledges that traditional disciplinary boundaries are less beneficial for higher education graduates compared to more active and constructivist learning opportunities. In this dimension, while strong and widely theorized ideas remain relevant, there is a challenge to the traditional "banking mode" of education, where educators are viewed as experts depositing knowledge into students. According to hooks (1994), the primary goal of education is to cultivate critical thinking skills in both teachers and students. This approach, known as critical pedagogy, involves educators posing thought-provoking questions, fostering collective critical awareness, formulating action plans, and helping students become more autonomous. Fundamental principles of this pedagogy necessitate that all participants are capable of thinking, questioning, and acting on issues that matter to them (Tang et al., 2020). Furthermore, recognizing the incomplete nature of individual knowledge, collaboration and active listening among participants is crucial. New and more disruptive ideas are also emerging, built on similar foundations. For instance, the Matriarchal Design Futures framework rejects capitalistic and hierarchical structures, instead focusing on caregiving and nurturing for all identities. It emphasizes values of collectivism, cooperation, inclusivity, and human rights, challenging the priorities set by white supremacy and capitalism (Place, 2022). This approach avoids using metrics to measure success and seeks to highlight and discuss issues rather than provide definitive answers. The goal is to spark public conversation and collaborative imagination.

2. **Rethinking Design Curricula**

The effects of dominant design education curricula are now recognized in both practice and educational research (Jones et al., 2022). From the broader reconsideration of pedagogical models, a need arises to revise the educational offerings of design universities. Rethinking design curricula opens new research frontiers that follow the trend of inclusion more comprehensively and systemically (Noel, 2022). A significant example is the focus on decolonizing design curricula, a topic debated for decades, with much work still needed to represent a plurality of design practices, cultures, and approaches. Design education has historically played a role in global projects aimed at universalizing design principles, both in subject matter (e.g., modernism and internationalism) and curriculum (e.g., the dominance of the Western "Bauhaus model") (Kambunga et al., 2023). Escobar (2019) highlights that concepts like universalism, impersonality, and standardization are often considered virtues in modern society. However, this emphasis on universalist methodologies in design pedagogy can lead to homogenization, reducing diversity, perpetuating social inequalities, and favoring a dominant narrative (Noel et al., 2023). Dominant narratives are deeply embedded in mainstream design forms, potentially leading designers to employ discriminatory practices (Prendeville & Koria, 2022). Noel (2023) argues for questioning the global uniformity of curricula and recognizing what is lost when the richness of specific and local design cultures is marginalized (Berry et al., 2022; Noel, 2022). With its Bauhausian and Ulmian roots, the education system risks uniformity that erases cultural specificity, which could otherwise enrich student design education (Noel, 2022). Moving away from modernist and Eurocentric approaches to design history involves adopting a global perspective that includes design practices from Latin America, Africa, and Asia— adding "non-Western" design objects to an existing Eurocentric curriculum and rethinking historical narratives to center previously marginalized or erased design practices (Charlotte Smith et al., 2020; Jae & Kevin, 2023). The pluriversal approach in design education, as advocated by Mignolo (2020) and Noel et al. (2023), values a range of locally rooted perspectives, acknowledging that design shapes different ways of existence despite contextual contradictions and conflicts (Bianchin & Heylighen, 2018). Pluriversal thinking encourages diverse viewpoints, addresses power imbalances, and avoids extractive practices (Rodriguez Schon & Celi, 2023). It promotes teaching design from local contexts and actively involves those most affected by the design process. This shift challenges the conventional transactional view of design, emphasizing relationality instead.

3. **Reforming Courses Structures and Methods**

At the micro level, researchers are challenging the structure of design courses and proposing new solutions for teaching methods and application contexts. Emerging work is rethinking when, where, and how design education occurs, shifting the focus from what and how to why and from things and processes to intentions such as improving, facilitating, provoking, and conserving (Davis & Dubberly, 2023). This systemic thinking implies that interventions in university organizations must be holistic. Just as a company must ensure that its internal operations and external results align with its values, universities must address change comprehensively. For example, using recycled materials is mere greenwashing without a genuine commitment to energy-saving production and sustainable product end-of-life strategies (Davis & Dubberly, 2023). Thinking about systemic change is necessary but can be problematic since it is often only a trivial exercise of speculation (Jones et al., 2022), and, critically, it avoids questioning how a change to design education takes place (Noel, 2020). Furthermore, there is the potential to trigger broader transformations through local course interventions. Starting at the departmental level and gradually expanding to the international level can foster meaningful reflections and actions. Scaling efforts from local to global can spread insights and practices, initiating broader discussions and collaborations.

2.2 Inclusive design as a mindset

Inclusive design has become a focal point within design education since design schools have become where social impact, engagement and innovation can be developed, analyzed, and sustained. Design schools now play a critical role in equipping educators with the necessary tools to promote diversity, inclusion, and equity (Noel, 2022). Inclusive design is becoming more than a method to apply and persuade; it is a mindset that should change from the beginning of the approach to the project.

Traditionally, inclusive design focused on disabled and elderly individuals, known globally as “Design for All” in Europe and “Universal Design” in the US, originating in the 1950s (Clarkson & Coleman, 2015). However, two critical conditions are transforming inclusive design: the realisation that good intentions are insufficient (Del Gaudio et al., 2020; D’Ignazio & Klein, 2020) and a shift from physical exclusion to more complex forms (Donahue & Gheerawo, 2021).

These two critical conditions are briefly summarized as follows:

· Designers play a crucial role in shaping our world, as their decisions can have global consequences (Norman, 2023). It is easy to cause harm with good intentions (Costanza-Chock, 2020; D’Ignazio & Klein, 2020). Prejudices, norms, and stereotypes are embedded in many artefacts, and design has the potential to strengthen

them (Prochner & Marchand, 2018). There is a growing awareness in the design process that recognizes the responsibility of design and how unconscious biases can influence and impact decisions (Costanza-Chock, 2020; Wachter-Boettcher, 2018). Unconscious biases are learned, natural, instinctive, unintentional preconceptions so deeply rooted that they quickly affect a person's behavior (Canlı, 2018; Lillegård et al., 2021). "Exclusion happens when we solve problems using our biases" (Holmes, 2020). Designers must recognize their biases and be open to questioning their perspectives to avoid tokenistic attempts at inclusivity and shifting to community-driven approaches instead of the traditional power dynamic (Place, 2022).

· The literature highlights the need to expand the definition of exclusion, moving beyond traditional accessibility concerns (Lillegård et al., 2021; Szlavi & Guedes, 2023). While issues like ageing have received attention, there is a growing imperative to address other critical issues and steer research towards a more holistic direction (Donahue & Gheerawo, 2021). Inclusive design should consider characteristics like race, gender, social status, sexual orientation, and others, embracing the theory acknowledging intersectionality. This concept was introduced by Kimberlé Crenshaw (1989), a Black feminist legal scholar, in 1989. Crenshaw (1989) has highlighted how race and gender intersect, particularly the experiences of racism and sexism endured by black women. The concept of intersectionality was developed within a legal framework to show how a "single axis framework" often failed to protect Black women workers (Crenshaw, cited in Costanza-Chock, 2018). The predominance of what Crenshaw calls "single-axis analysis", in which race, class, or gender is considered an independent construct, continually undermines the intentions of well-meaning designers who hope to challenge bias through the objects, systems, or environments they design. Intersectionality reveals that forms of oppression are interconnected. Another concept related to Intersectionality is the representation of the "matrix of domination" (Collins, 1990). Intersectionality and the "matrix of domination" help us understand how privilege and oppression are interconnected. A privileged view will also likely inform beliefs, assumptions, and norms that shape many design decisions made throughout design projects. If designers become more aware of and sensitive to how privilege and oppression (including their own) function in the contexts they are designing, they can make decisions to challenge status quo inequities and patterns of oppression produced (Goodwill et al., 2021).

This increased awareness has prompted scholars to strive for equity and justice in their practice. New frameworks actively pursuing this goal are emerging from the literature,

such as Design Justice (Costanza-Chock, 2020), Liberatory Design (Anaissie et al., 2021), and Design for Belonging (Anaissie et al., 2022).

Design Justice, developed in 2018, aims to ensure the equitable distribution of design benefits and limitations, meaningful participation in design decisions, and recognition of communitybased design traditions (Costanza-Chock, 2018). Liberatory Design, first introduced in 2016 and reviewed in 2021, encourages self-awareness and reshapes power dynamics in design processes for collective liberation (Anaissie et al., 2021). Design for Belonging supports designers in fostering community belonging and reducing othering through diversity-driven design choices (Anaissie et al., 2022). In this research, "inclusive design" encompasses these emerging frameworks, particularly the principles of design justice influenced by intersectionality theory. The concept of intersectionality has initiated a slow but ongoing shift in the social sciences, legal studies, and various research and practice fields (Crenshaw, 1989; CostanzaChock, 2018; Gianfrate et al., 2024). This shift, linking intersectionality with accessibility and empowerment, fosters a more integrated understanding of discrimination, social exclusion, and stigma. It is also beginning to influence the design industry by promoting comprehensive approaches that enhance collective efficacy, recognize marginalized individuals and their autonomy, and build community solidarity and tacit knowledge (Gianfrate et al., 2024).

Despite the growing acknowledgement of intersectionality, design education still faces challenges. There is a need for further research on how students engage with intersectional biases (Berry et al., 2022) and for practical guidelines to help educators teach these concepts effectively beyond theoretical discussions (Costanza-Chock, 2020).

A research question emerged from these reflections: How are inclusive design principles and intersectionality addressed across various design curricula? This question aims first to analyze the current state of the art and then explore potential ways to address gaps.

3. Research Methodology

The literature review facilitated the identification of key parameters necessary to assess the presence of inclusive design within design universities.

To effectively operate within societal contexts, designers must be trained to incorporate ethics, equity, and justice into their practice. With this premise, an analysis of design curricula was conducted, drawing inspiration from the work of Das et al. (2023), who developed a methodology based on the Design Justice framework for auditing ethics, equity, and justice in design pedagogy. In their research, Das et al. (2023) analyzed course syllabi from various departments at the Massachusetts Institute of Technology (MIT) from Fall 2019 to Fall 2020. While their work inspires this paper, it employs a different methodology. The main

distinction lies in the data sources; Das et al. (2023) analyzed a substantial amount of first-hand information from their university, making their research more reliable.

In contrast, this study analyses second-hand data gathered from publicly available sources on the internet. Similar to Das et al. (2023), this research underscores the importance of reflecting on university offerings and informs the research question. It also seeks to determine whether the racial, social, and environmental justice movements of 2020 have had any significant impact on design pedagogy. The hypothesis posits that, due to the COVID-19 pandemic, courses may now incorporate more socially conscious practices, but these changes may not profoundly influence pedagogy. A review protocol was developed based on the literature review to analyze the curricula. This protocol investigates 1) the presence and extent of inclusive design in design curricula, 2) the overlap with other terms and approaches, 3) whether intersectionality is addressed, and 4) the most common topics covered in the programs.

3.1 Design the research tool: protocol development

The research protocol consists of an analysis grid summarized in Table 1. The protocol is organized into several columns to capture and analyze course information systematically, as well as to facilitate comparisons among the courses under review:

· General Information: This part includes essential details such as the course name, university, prerequisites or competencies, modality, level of the course, course format, and required outputs.

· Inclusive Approach: This part maps whether the course description mentions accessibility or intersectionality.

· Course Aim and Approaches: details the approaches mentioned, including theoretical aspects, hands-on activities, and outputs required to achieve the course's objectives.

· Levels of Design: categorizes the course content according to Young's (2008) model, designed to capture design tasks' varying scales and complexities. The model distinguishes between three levels of design. The first level is the Product Level, which involves design within a specific context and focuses on tangible, micro-level design outputs. This dimension represents the traditional approach to designing artefacts and objects. The second level, Systems Thinking, addresses design within a broader context. It emphasizes the design of services and systems, incorporating a holistic perspective that considers the interactions and relationships among components within a system. The third level is the Policy Level, which deals with creating meaning and purpose. This dimension involves macro-level design dimensions, including developing policies and ideologies to address large-scale, systemic issues. The idea was to map the outputs required by the course syllabi and understand the main outputs required by future designers.

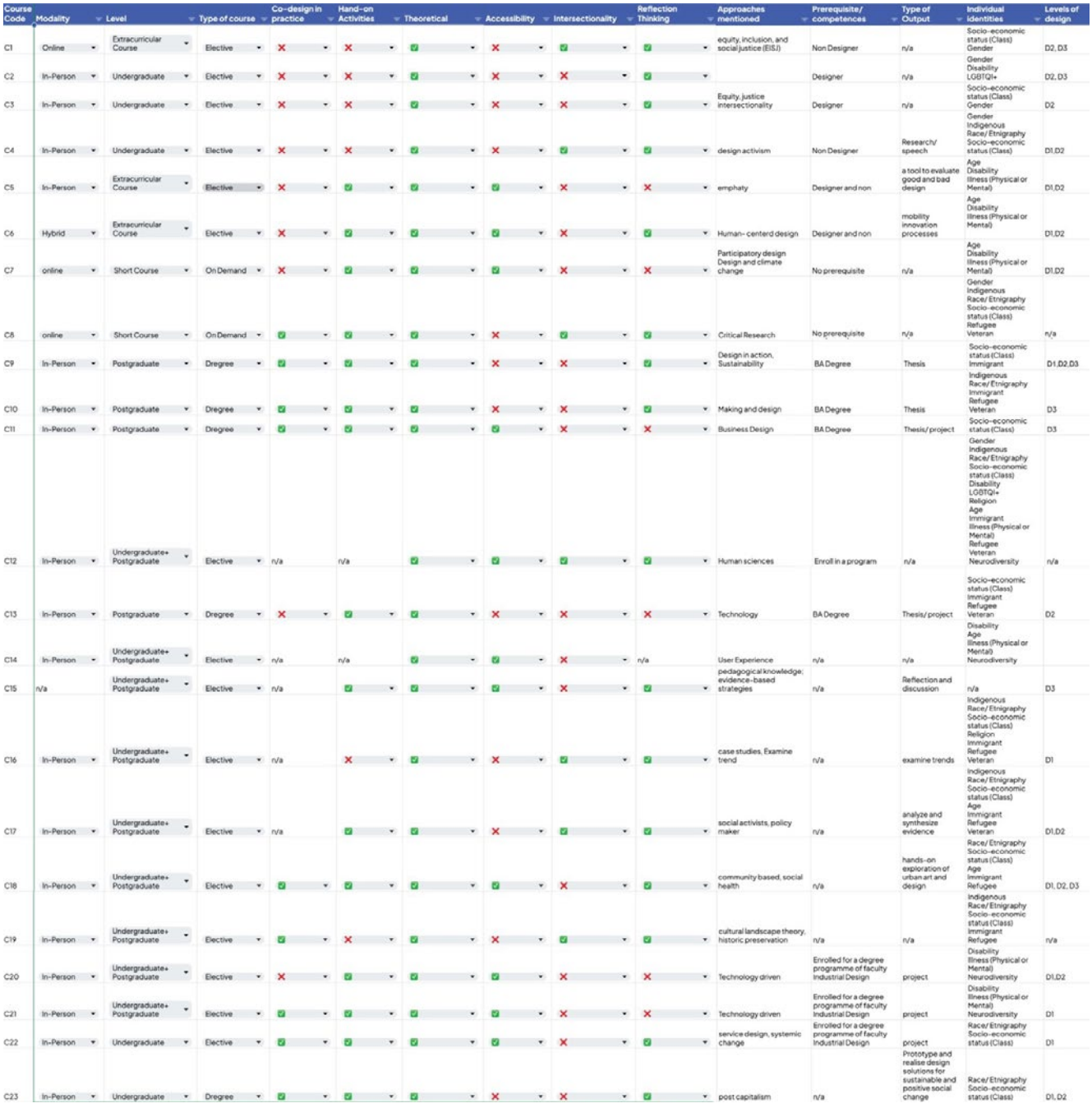
· The 13 individual identities in diversity, as identified by Wilson (2023), were integrated into the analysis to understand how courses address multiple perspectives of diversity. This includes mapping whether characteristics such as gender, Indigenous status, race/ ethnography, socio-economic status (class), disability, LGBTQI+, religion, age, immigrant status, physical or mental illness, refugee status, veteran status, and neurodiversity are present in the course descriptions.

This structured organization offers a comprehensive mapping tool to understand each course's

Table 1. Parameters used to analyze curricula integrated with the design levels proposed by Young (2008) and the 13 individual identities in diversity introduced by Wilson (2023).

General Information	**Inclusive approach**	**Course aim and approaches**	**Levels of design (Young, 2008)**	**The 13 individual identities in diversity (Wilson, 2023)**
Course name	Design with community	Approaches mentioned	D1: Product level	Gender
University	Accessibility	Prerequisites/ Competencies	D2: System level	Indigenous
Modality	Intersectionality	Theoretical aspects	D3: Policy level	Race/ Ethnography
Couse Level	Reflection practice	hands-on activities		Socioeconomic status (Class)
Course Format		Outputs Required		Disability
				LGBTQI+
				Religion
				Age
				Immigrant
				Illness (Physical or Mental)
				Refugee
				Veteran
				Neurodiversity

framework and approach to inclusive design education. An Excel file was used for the analysis to speed up the process and provide a visual comparison of all the courses analyzed. Figure 1 illustrates the Excel file's structure and the courses' final compilation.



Course Code	Modality	Level	Type of course	Co-design in practice	Hand-on Activities	Theoretical	Accessibility	Intersectionality	Reflection Thinking	Approaches mentioned	Prerequisite/ competences	Type of Output	Individual identities	Levels of design
C1	Online	Extracurricular Course	Elective	✗	✗	✓	✗	✓	✓	equity, inclusion, and social justice (EISJ)	Non Designer	n/a	Socio-economic status (Class) Gender	D2, D3
C2	In-Person	Undergraduate	Elective	✗	✗	✓	✗	✗	✓		Designer	n/a	Gender Disability LGBTQI+	D2, D3
C3	In-Person	Undergraduate	Elective	✗	✗	✓	✗	✗	✓	Equity, justice intersectionality	Designer	n/a	Socio-economic status (Class) Gender	D2
C4	In-Person	Undergraduate	Elective	✗	✗	✓	✗	✓	✓	design activism	Non Designer	Research/ speech	Gender Indigenous Race/ Etnigraphy Socio-economic status (Class)	D1,D2
C5	In-Person	Extracurricular Course	Elective	✗	✓	✓	✓	✗	✗	emphaty	Designer and non	a tool to evaluate good and bad design	Age Disability Illness (Physical or Mental)	D1,D2
C6	Hybrid	Extracurricular Course	Elective	✗	✓	✓	✓	✗	✓	Human- centerd design	Designer and non	mobility innovation processes	Age Disability Illness (Physical or Mental)	D1,D2
C7	online	Short Course	On Demand	✗	✓	✓	✓	✗	✗	Participatory design Design and climate change	No prerequisite	n/a	Age Disability Illness (Physical or Mental)	D1,D2
C8	online	Short Course	On Demand	✓	✓	✓	✗	✓	✓	Critical Research	No prerequisite	n/a	Gender Indigenous Race/ Etnigraphy Socio-economic status (Class) Refugee Veteran	n/a
C9	In-Person	Postgraduate	Dregree	✓	✓	✓	✗	✗	✓	Design in action, Sustainability	BA Degree	Thesis	Socio-economic status (Class) Immigrant	D1,D2,D3
C10	In-Person	Postgraduate	Dregree	✓	✓	✓	✗	✗	✓	Making and design	BA Degree	Thesis	Indigenous Race/ Etnigraphy Immigrant Refugee Veteran	D3
C11	In-Person	Postgraduate	Dregree	✓	✓	✓	✓	✗	✗	Business Design	BA Degree	Thesis/ project	Socio-economic status (Class)	D3
C12	In-Person	Undergraduate+ Postgraduate	Elective	n/a	n/a	✓	✓	✓	✓	Human sciences	Enroll in a program	n/a	Gender Indigenous Race/ Etnigraphy Socio-economic status (Class) Disability LGBTQI+ Religion Age Immigrant Illness (Physical or Mental) Refugee Veteran Neurodiversity	n/a
C13	In-Person	Postgraduate	Dregree	✗	✓	✓	✗	✗	✗	Technology	BA Degree	Thesis/ project	Socio-economic status (Class) Immigrant Refugee Veteran	D2
C14	In-Person	Undergraduate+ Postgraduate	Elective	n/a	n/a	✓	✓	✗	n/a	User Experience	n/a	n/a	Disability Age Illness (Physical or Mental) Neurodiversity	
C15	n/a	Undergraduate+ Postgraduate	Elective	n/a	✓	✓	✓	✗	✓	pedagogical knowledge; evidence-based strategies	n/a	Reflection and discussion	n/a	D3
C16	In-Person	Undergraduate+ Postgraduate	Elective	n/a	✗	✓	✗	✓	✓	case studies, Examine trend	n/a	examine trends	Indigenous Race/ Etnigraphy Socio-economic status (Class) Religion Immigrant Refugee Veteran	D1
C17	In-Person	Undergraduate+ Postgraduate	Elective	n/a	✓	✓	✗	✓	✓	social activists, policy maker	n/a	analyze and synthesize evidence	Indigenous Race/ Etnigraphy Socio-economic status (Class) Age Immigrant Refugee Veteran	D1,D2
C18	In-Person	Undergraduate+ Postgraduate	Elective	✓	✓	✓	✓	✗	✓	community based, social health	n/a	hands-on exploration of urban art and design	Race/ Etnigraphy Socio-economic status (Class) Age Immigrant Refugee	D1, D2, D3
C19	In-Person	Undergraduate+ Postgraduate	Elective	✓	✗	✓	✗	✓	✓	cultural landscape theory, historic preservation	n/a	n/a	Indigenous Race/ Etnigraphy Socio-economic status (Class) Immigrant Refugee	n/a
C20	In-Person	Undergraduate+ Postgraduate	Elective	✗	✓	✓	✓	✗	✗	Technology driven	Enrolled for a degree programme of faculty Industrial Design	project	Disability Illness (Physical or Mental) Neurodiversity	D1,D2
C21	In-Person	Undergraduate+ Postgraduate	Elective	✓	✓	✓	✓	✗	✗	Technology driven	Enrolled for a degree programme of faculty Industrial Design	project	Disability Illness (Physical or Mental) Neurodiversity	D1
C22	In-Person	Undergraduate	Elective	✓	✓	✓	✓	✗	✓	service design, systemic change	Enrolled for a degree programme of faculty Industrial Design	project	Race/ Etnigraphy Socio-economic status (Class)	D1
C23	In-Person	Undergraduate	Dregree	✓	✓	✓	✗	✗	✓	post capitalism	n/a	Prototype and realise design solutions for sustainable and positive social change	Race/ Etnigraphy Socio-economic status (Class)	D1, D2

Figure 1. The Excel file was used to analyze the courses, showing how the protocol was structured and how the tool was used. The screenshot shows both the tool and the appearance of the final compilation with the course information entered.

3.2 Sample selection and data collection

The research focused on the top 10 universities in 2023 according to the QS World University Ranking by Subject: Art and Design (Table 2). Data were collected second-hand by analyzing the program syllabi and main descriptions from university website databases. Based on the literature, a list of 15 terms referring to design justice and inclusive design was searched within the course descriptions (Figure 2).



Figure 2. List of the15 terms used to perform the design curricula analysis

This list of terms helped the selection process, as the first screening was conducted to identify relevant courses. The study is based on the available information: not all universities describe the courses in detail. Courses that did not provide enough information to understand the course requirements and goals were excluded. Additionally, courses that seemed out of scope based on their descriptions were eliminated, allowing for a final filtering. A total of 23 courses, both undergraduate and postgraduate programs, were analyzed.

Table 2. Top 10 universities analyzed in the QS World University Rankings by Subject 2023 in the session Art & Design

Position	University	Country
1	Royal College of Art United Kingdom	United Kingdom
2	University of the Arts London	United Kingdom
3	Rhode Island School of Design (RISD)	United States
4	Parsons School of Design at The New School	United States
5	Massachusetts Institute of Technology (MIT)	United States
6	Aalto University	Finland
6	Pratt University	United States
8	Politecnico di Milano	Italy
9	Design Academy Eindhoven	Netherlands
10	Tongji University	China (Mainland)

4. Analysis results

The analysis of inclusive design courses across university programs provides several key insights, summarized in Table 3 and detailed in the following text.

Out of the 23 courses examined, 18 are integrated into degree programs. Of these, 9 are available to both postgraduate and undergraduate students, 4 are exclusively for postgraduates, and 5 are exclusively for undergraduates. Additionally, 5 courses are offered ondemand or as extracurricular options, indicating their presence beyond formal degree programs. Regarding the mandatory nature of these courses, only 5 out of the 18 integrated courses are compulsory, while the remaining 13 are elective. This trend suggests that inclusive design education is often treated as an optional rather than a required part of the curriculum.

The analysis also highlights the inclusion of intersectional and related topics such as antioppression, power dynamics, inequity, and positionality. These topics are explicitly covered in 6 of the 23 courses: 5 are elective, and 1 is an on-demand extracurricular course. However, practical activities related to intersectionality are less prevalent, with only 2 courses explicitly mentioning to incorporate hands-on activities. These practical elements are linked to ongoing projects or supported by teaching labs focused on social innovation.

Regarding addressing critical social issues, 4 out of the 10 universities reviewed offer master's programs focusing on significant challenges such as climate change, racial inequality, and poverty. This reflects a solid commitment to tackling pressing societal issues through advanced educational programs.

The presence of inclusive terminology in course descriptions is noteworthy. Terms such as "inclusive", "inclusivity" and "inclusion" appear in 10 of the 23 courses. Additionally, "ethics" is mentioned in 4 courses, "equity" in 6 courses, and "social innovation" in 16 courses, highlighting the emphasis on ethical considerations and social impact within the curriculum.

Examining the design dimensions covered in these courses revealed that obtaining clear and consistent information was challenging, as course descriptions often did not specify the outputs. Only 3 out of the 23 courses address the product dimension of design, and the same number address the policy dimension. Furthermore, 7 courses address a second design dimension, with 4 offering a hybrid approach that integrates product or service skills and policy considerations.

Finally, the analysis of individual identities addressed in these courses reveals a diverse range of focus areas. Gender and LGBTQI+ identities are covered in 6 courses, socio-economic status in 14 courses, age and disability in 10 courses, and religion in 2 courses. This distribution suggests a varied emphasis on different topics, with some identities receiving more attention than others. Notably, the courses that address individual identities do so in a manner consistent with an intersectional approach. However, further investigation is needed to explore how these focus areas intersect and to understand why some identities, such as religion, are less frequently considered than others.

Table 3. Summary of data analyzed derived from the grid and the comparison of the courses

Analysis factor	Numbers	Comments and considerations
Included Courses on inclusive design within their degree programs as elective courses	18/28 (courses analyzed)	Of the 18 courses integrated into the design curricula, 9 were accessible to postgraduate and undergraduate students, 4 were exclusively for postgraduates, and 5 were exclusively for undergraduates.
Courses on inclusive design offered by the university on demand or extracurricular	2/28 (courses analyzed)	This category covers on-demand and extracurricular courses that have been mapped because they are present in the universities offerings but not strictly related to design programs such as bachelor's or master's degrees.
Included Courses on inclusive design within their degree programs as mandatory	5/18 (just considering the courses on demand or extracurricular)	3 courses are elective, only 5 mandatory.
Courses explicitly mention concepts related to intersectionality or associated tools (such as and access on, power dynamics, inequity, and positionality)	6/28 5 elective courses 1 assessment	Of these 6 courses, 5 are elective / assessment, an extracurricular course organized periodically and open to other participants, not only enrolled students.
Courses explicitly mention concepts related to intersectionality with hands-on activities.	2/28 (courses analyzed)	The courses proposed are presenting hands-on activities, and only 2 offer hands-on activities. In this case, they either offer the course by means of an ongoing project or have a teaching strategy related to social innovation that supports students.
Universities offer master's degree programs centered on addressing critical social issues	4/10 (universities under analysis)	Programs centered on addressing critical social issues, including climate change, racial inequity and poverty.
Presence of the terms "inclusive", "inclusivity", "inclusion" in courses	10/28	Number of the courses that are mentioned these terms in the course overview description
Presence of the term "equity" in courses	6/28	
Presence of the term "social innovation" in courses	10/28	
Presence of the term "access" in courses	4/28	
Individual identities working on gender and LGBTQI+	6/28	Individual identities mentioned (directly or indirectly) in the course description
Individual identities working on socio-economic status	1/28	
Individual identities working on Age / Disability	1/28	
Individual identities Working on Religion	2/28	

5. Discussion and consideration

5.1 Emerged consideration

From this analysis, three primary considerations emerged:

1. **Positioning of inclusive design in design curricula**: In all the universities considered in the sample, at least one course related to inclusive design was identified. However, the predominance of elective courses poses a challenge in fully integrating inclusive design into the curricula, necessitating further consideration. While standalone courses risk limiting its perception as a peripheral subject, seamlessly incorporating its principles into existing syllabi is complex. Although relevant theories and principles can be introduced through lectures on inclusive design, it is crucial to incorporate practical applications into education, ensuring students have opportunities to apply these principles (Dong, 2010). It is well recognized that inclusive design addresses specific issues but follows a general design process, emphasizing user involvement to create solutions accessible to a broad audience (Dong, 2010).

2. **Integration of Accessibility and Social Inclusion in Design Education:** The curriculum often treats accessibility and social inclusion as separate topics, with only six courses explicitly addressing concepts related to intersectionality, such as anti-oppression, power dynamics, inequity, and positionality. While these courses focus on social inclusion, they frequently overlook accessibility, and vice versa. This separation highlights a significant gap in the curriculum, underscoring the need for a more integrated approach that encompasses both accessibility and social inclusion through the lens of intersectionality. Some courses address inclusion by linking it to equity and social change. For instance, these courses may be associated with ongoing projects or feature dedicated educational labs focused on social innovation that support student engagement. These approaches enable co-design with communities and emphasize the importance of community engagement and equity. One of the primary challenges in implementing inclusive design in an educational context is the difficulty of applying projects to real-world situations, compounded by ethical considerations. Although these courses may effectively address the concept of intersectionality, they often fail to incorporate accessibility, indicating a lack of a comprehensive, holistic perspective in the curriculum.

3. **Linking with Environmental Sustainability and Social Innovation**: It emerged that universities often offer master's degree programs targeting critical social issues like climate change, racial inequality, and poverty. While these programs align with intersectionality, they often neglect identity-related aspects. Nevertheless, they stress the link between social innovation and environmental sustainability, echoing the objectives of the 2030 Agenda.

This alignment advocates for a holistic approach that challenges traditional power dynamics and consumption patterns, promoting economic and environmental sustainability while addressing human factors like poverty reduction and community needs. Indeed, sustainability and inclusion are intertwined; by questioning consumerist and Western economic paradigms, these programs endorse a comprehensive approach considering power dynamics and striving to foster sustainable attitudes benefiting communities. However, it is essential to note that sustainability cannot replace justice (Das et al., 2023), and often, this correlation is absent in program descriptions.

5.2 Limitations

This analysis is primarily interpretative and relies on secondary research data, which introduces several limitations typical of qualitative research. As detailed in the methodology section, the study faces constraints related to the availability of information and the challenges associated with conducting a thorough exploration of each design education program and its related courses. Consequently, this paper represents an initial effort to observe and examine this specific area of education, aiming to stimulate reflection and promote meaningful participation in understanding, initiating, and implementing solutions.

A notable limitation of this research is the relatively small sample size of the courses analyzed, which may offer a partial view. This suggests that a larger sample size could provide more robust insights. Additionally, the reliance on programs and course descriptions to assess the integration of inclusive design content is constrained by the limited access to materials and the incomplete nature of publicly available information. More than Syllabi is required to fully capture a course's pedagogical approach and learning experiences, highlighting the need for more detailed and varied data sources.

5.3 Conclusion and Future Works

Beyond the data presented, what could be particularly valuable for future research is the analytical protocol itself. This protocol could serve as a model for conducting similar studies or as a guide for educators to understand the trajectory of their courses. Additionally, the data provide a partial yet significant overview of the current state of design education at leading universities.

To build on this research, several actions could be taken:

- Update the Analysis: Repeat the analysis using the latest rankings, such as those from 2024, to determine if other universities now address inclusive design differently or more effectively.
- Expand the Scope: Examine additional universities beyond the top-ranked institutions, possibly selecting them based on literature where authors have highlighted relevant teaching practices.
- Conduct In-Depth Interviews: Conducting in-depth, semi-structured interviews with educators and scholars would be beneficial. These interviews aim to explore how experts implement inclusive design, manage biases within the design process, and interpret key research terms related to inclusive design. Such qualitative insights could illuminate behavioral models and practices in greater detail.
- Obtain First-Hand Data: Conduct detailed investigations of syllabi and entire course programs to better understand the educational landscape.

These steps provide a more comprehensive view of how inclusive design is taught and applied across different institutions and contribute to a more robust analysis of the current educational practices. Integrating inclusive design into design education is an ongoing process requiring substantial effort and commitment from educational institutions. By embedding inclusive design principles into the core curriculum, fostering practical applications, and adopting a holistic approach that merges social inclusion with environmental sustainability, design education can better prepare students to address the complex and impactful challenges of today's world. This comprehensive reform is essential for nurturing a new generation of designers equipped to create innovative, equitable, and sustainable solutions for the future.

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A CONTRASTIVE STUDY OF SERVICE DESIGN IN PUBLIC TRANSPORTATION SYSTEM IN SHANGHAI AND TURIN

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ABSTRACT | As urban populations continue to rise, the efficiency and effectiveness of public transportation systems have become pivotal in urban livability and environmental sustainability. This paper, with an integration of service design principles into public transit systems, focuses on the deployment of service design tools including service blueprints, real-time monitoring systems and passenger flow analytics aims to innovate and refine the delivery of public transportation services with higher operational efficiency and better passenger experiences . Service design offers a systematic approach to understanding and catering to users' needs, facilitating collaboration across various stakeholders in the public transit ecosystem. With the help of service blueprints, transportation agencies can visualize the entire journey of a passenger and then identify critical touchpoints where improvements are needed. This visualization helps in pinpointing inefficiencies and designing targeted interventions that can significantly reduce wait times and improve service reliability. Furthermore, the adoption of real-time monitoring systems enables transit operators to respond dynamically to on-the-ground conditions. These systems use GPS and other sensor-based technologies to track vehicles, allowing for adjustments in service frequency and routes in response to real-time traffic or passenger loads. This responsiveness not only enhances operational efficiency but also reduces overall travel time and make public transit more popular as a viable alternative to private vehicles. Passenger flow analytics play a crucial role in understanding patterns of use across different times and routes. Based on these data, transit agencies can optimize resource allocation and thereby improve service capacity and reduce overcrowding. This strategic approach not only improves passenger comfort but also makes full use of assets, which is conducive to the economic sustainability of the transit system.
The challenges and opportunities of integrating service design herein involve diverse cultural

and geographical contexts. It is proposed that local cultural dimensions should be taken into consideration in service design to ensure that solutions are appropriately adapted to meet the specific needs of different populations. This is crucial for inclusive design practices that accommodate and respect the diversity of users in global cities.

In conclusion, service design, as a powerful tool for transforming public transit systems, not only contributes to the efficiency and effectiveness of these systems but also plays a vital role in making them more user-friendly and environmentally sustainable. The findings of this study underscore the potential of service design to act as a catalyst for innovation in public transportation in a more connected and accessible way. In this sense, public transit, as the backbone of urban mobility, is conducive to the shift towards more sustainable and equitable urban environments.

KEYWORDS | SERVICE DESIGN, PUBLIC TRANSPORTATION, SERVICE BLUEPRINTS, REAL-TIME MONITORING, PASSENGER FLOW ANALYTICS, CULTURAL ADAPTATION

1. Introduction

As urban populations continue to grow, the importance of efficient public transportation systems has become increasingly evident. Urban centers around the world face significant challenges in managing traffic congestion, reducing environmental pollution, and ensuring equitable access to transportation (Cervero, 2013). Efficient public transportation is not only pivotal for urban livability but also for environmental sustainability by reducing the reliance on private vehicles, thereby lowering greenhouse gas emissions and improving air quality (Litman, 2021). An effective public transportation system supports economic productivity by facilitating the smooth movement of people and goods, which is essential for the economic vitality of cities (UITP, 2019).

Service design is an interdisciplinary approach that focuses on the planning and organizing of a service's components to improve its quality and the interaction between the service provider and its users. It encompasses a wide range of tools and methods, such as service blueprints, customer journey mapping, and real-time monitoring systems, to visualize and optimize service delivery processes (Stickdorn & Schneider, 2011). Service design principles emphasize understanding user needs, co-creation with stakeholders, and iterative testing and refinement of service components. In the light of these principles, public transportation systems can be made more efficient, user-friendly, and responsive to the needs of diverse populations (Moritz, 2005).

This study, with an integration of service design principles, aims to enhance public transportation systems with higher operational efficiency and better passenger experiences. The scope of the research includes the deployment of various service design tool including service blueprints, realtime monitoring systems, and passenger flow analytics to innovate and refine the delivery of public transportation services. By examining these tools in different urban contexts, the study seeks to provide a comprehensive understanding of how service design can transform public transit systems into more efficient and user-centric services.

The primary research questions of this study include: How can service design principles be integrated into public transportation systems to enhance operational efficiency? What are the specific tools and methods of service design that can be deployed to improve passenger experiences in public transit? How do real-time monitoring systems and passenger flow analytics contribute to optimizing resource allocation and service delivery in public transportation? What are the possible challenges and opportunities of the service design in diverse cultural and geographical contexts?

2. Literature Review

Service design has become a key aspect of public transportation systems with an aim to enhance user experience and at the same time improve efficiency and accessibility. Scholarly attention has already been on the service design in public transportation mainly in terms of strategies and practices to meet the diverse needs of urban populations. Historically, public transportation systems were designed with a focus on operational efficiency rather than user experience. According to McKinsey (2020), many cities' public transportation systems initially prioritized speed and reliability to ensure quick and predictable transportation for passengers.

However, it is gradually realized that human-centered design can not only enhance user experience, but also improve the efficiency of public transportation systems. This shift stems from understanding user needs and behaviors so that these needs can be better met during the design process, thereby achieving higher operational efficiency and user satisfaction. For example, the application of design thinking methods in public transportation has achieved remarkable results in many places. Singapore's Land Transport Authority (LTA) has improved the public transportation user experience through design thinking, including redesigning station layouts, improving signage systems, and enhancing digital tools. As a result, passenger satisfaction and usage rates have increased significantly (Design Thinking Association, 2023). Similarly, in Minneapolis, design thinking methods were used to transform bus stops to make them more responsive to residents' needs, significantly improving the user-friendliness of the bus system (Design Thinking Association, 2023).

In addition, studies have shown that human-centered design plays an increasingly important role in improving the efficiency of public transportation systems. For example, a case study in Istanbul showed that improving public transportation comfort through human-centered design methods not only improved user experience but also optimized overall system efficiency (Deb et al., 2019). This approach continuously iterates and improves transportation facilities and services through in-depth understanding of user needs and prototype design, thereby improving user satisfaction and the overall efficiency of the transportation system.

Previous studies also cover service design applications in various urban settings. Service design in public transportation aims to enhance user experience and operational efficiency. It encompasses the planning and organizing of transportation services to meet the needs of urban residents. In metropolitan areas, service design often focuses on integrating multiple modes of transport, such as buses, trains, and bicycles, to provide seamless mobility. For instance, cities like New York and London have implemented integrated ticketing systems that allow passengers to switch between different modes of transport with ease, enhancing the overall travel experience (Smith & Clark, 2020). In smaller urban settings, the focus shifts to optimizing routes and schedules to match the specific demands of the population. For example, in cities like Portland, Oregon, the emphasis is on creating sustainable and user-friendly public transportation systems that encourage the use of public transport over private cars. This includes the development of dedicated bus lanes and real-time tracking systems that inform passengers of arrival times, thus reducing waiting times and improving reliability (Jones et al., 2019).

The role of cultural adaptation in service design is another perspective. Cultural adaptation plays a crucial role in the successful implementation of service design in public transportation. Understanding and addressing the cultural preferences and behaviors of local populations can significantly enhance the usability and acceptance of public transportation services. For example, in cities with a high reliance on bicycles, such as Amsterdam and Copenhagen, service design incorporates extensive cycling infrastructure and bike-sharing programs to complement public transit options (Cultural Adaptation and Service Design, 2020). Cultural adaptation also involves accommodating local social norms and practices. In many Asian cities, where punctuality and cleanliness are highly valued, public transportation systems emphasize timely services and stringent maintenance standards. Additionally, in regions with diverse linguistic populations, providing multilingual information and customer support is essential for ensuring accessibility and user satisfaction (Polaine, Løvlie, & Reason, 2013). Technological advancements are undoubtedly important in service design. Technological advancements have revolutionized service design in public transportation, making systems more efficient, reliable, and user-friendly. Real-time monitoring and data analytics are at the forefront of these innovations, providing valuable insights into passenger flow, system performance, and operational efficiency. For instance, real-time tracking of buses and trains allows for dynamic scheduling adjustments and accurate arrival predictions, reducing wait times and enhancing the overall user experience (Berger, 2016). Mobile applications and digital platforms have also transformed how users interact with public transportation services. Features such as route planning, real-time updates, and mobile ticketing streamline the travel experience, providing users with greater control and convenience. Additionally, the integration of IoT devices and sensors facilitates predictive maintenance,

ensuring that vehicles and infrastructure remain in optimal condition, thus minimizing disruptions and improving reliability (Trischler & Scott, 2016). Moreover, advancements in AI and machine learning are driving the development of intelligent transportation systems. These systems can analyze vast amounts of data to optimize routes, predict demand, and identify potential issues before they arise. Autonomous vehicles and electric buses are also emerging as sustainable solutions that further enhance the efficiency and environmental performance of public transportation systems (Ma, 2020).

In summary, the evolution of service design in public transportation has shifted from operational efficiency to a user-centric approach, influenced by various urban settings and cultural contexts. Technological advances have played a key role in supporting these developments, making work more manageable for workers and more efficient and reliable for users.

However, despite these advancements, research gaps remain. First, there is a lack of comparative studies on the impact of service design in public transportation systems across different urban settings. Existing research primarily focuses on single cities or specific regions without systematic comparisons across multiple cities. Second, there is also a need for more research on how service design can be effectively implemented in local public transportation systems. While some studies have explored the theoretical frameworks and general principles of service design, further empirical research and case studies are needed to understand how to tailor and implement these designs according to local needs, cultures, and environments. By addressing these research gaps, we can better guide the practice of public transportation service design, ensuring its effectiveness and sustainability across different urban and cultural contexts. This will not only enhance user experience and efficiency in public transportation systems but also promote broader social and environmental benefits.

3. Case Studies: Service design of Bus Transportation in Shanghai and Turin

Public transportation is a vital aspect of urban life, offering travel solutions that support economic activity, reduce traffic congestion, and promote sustainable development. Selecting Shanghai and Turin as case studies for analyzing public transportation service design allows us to explore how distinct urban environments shape and are shaped by innovative design strategies. These cities represent two contrasting contexts—Shanghai's rapid urban growth and Turin's balance of modernization and heritage—which offer valuable insights into the effectiveness of service design in addressing diverse urban challenges. Shanghai, as one of the largest and fastest-growing megacities globally, serves as a model for understanding the challenges and innovations required to manage high-volume public transportation systems in a dynamic and rapidly evolving urban context. In contrast, Turin, with its rich

industrial heritage, represents a European city navigating the complexities of modernization and sustainability. This juxtaposition provides a unique opportunity to examine how service design principles can be adapted to different scales, cultural contexts, and developmental stages. Several aspects of public transportation service design in these two cities are to be explored, specifically including their service blueprinting, real-time monitoring, passenger flow analysis, touchpoints, and cross-cultural characteristics.

Shanghai's public transportation system is highly developed with an extensive network of buses, subways, and ferries that serve over 24 million residents. The bus network is crucial for connecting the surrounding areas with the city center. It operates approximately 1,000 routes with over 17,000 buses (Shanghai Public Transport Group, 2020). This network complements the integrated subway system and helps to reduce road congestion. In contrast, Turin, with a population of about 900,000, has a much smaller but well-structured public transportation system. The city's bus network comprises around 100 routes and, though smaller in scale compared to Shanghai, it integrates fully with the tram and subway lines. This system emphasizes reliability and accessibility, striving to modernize public transportation to make it more appealing to residents (GTT - Gruppo Torinese Trasporti, 2019).

Aspect	Shanghai	Turin
City Population	Over 24 million residents	Approximately 900,000 residents
Public Transportation Modes	Buses, subways, ferries	Buses, trams, subways
Bus Network Size	Approximately 1,000 routes	Approximately 100 routes
Number of Buses	Over 17,000 buses	Around 1,000 buses
Integration with Other Systems	Complements integrated subway system, reduces congestion	Fully integrates with tram and subway lines

Figure1. Comparison of public transportation in Shanghai and Turin

3.1 Passenger Flow Analytics of Bus Transportation in Shanghai and Turin

Shanghai's public transportation system employs advanced passenger flow analytics to optimize bus operations. The city leverages a variety of data sources, including smart card transactions, GPS data, and passenger counting systems, to monitor and analyze passenger flow patterns. This data is integrated into the Suishenxing platform, which provides real-time information and supports dynamic scheduling and route adjustments. The platform aids in managing passenger loads and minimizing delays, thereby enhancing the efficiency and reliability of bus services (Shanghai.gov.cn, 2023). The analytics system in Shanghai is designed to capture the spatiotemporal dependencies of passenger flows across different bus lines. By using advanced models such as the Diffusion Convolution Recurrent Neural Network (DCRNN), the system can predict short-term passenger flow with high accuracy. This enables better resource allocation and service planning, ensuring that buses are dispatched based on real-time demand (Zhai & Shen, 2023).

Turin's public transportation system also utilizes sophisticated passenger flow analytics to enhance service design. The Gruppo Torinese Trasporti (GTT) integrates data from electronic ticketing systems, passenger surveys, and GPS tracking to analyze and predict passenger flow. This data-driven approach helps in optimizing bus frequencies, adjusting routes, and improving overall service reliability (Muoversi a Torino, 2023). Turin employs machine learning algorithms, including Extreme Gradient Boosting (XGBoost), to forecast passenger demand and adjust bus schedules accordingly. This approach not only improves the accuracy of predictions but also allows for more efficient use of resources by ensuring that buses are available where and when they are needed most (Lv et al., 2022).

In Shanghai, the implementation of passenger flow analysis has significantly improved the city's public transportation service design. With accurate forecasts of passenger demand, the system enables dynamic scheduling and route optimization, which reduces congestion and minimizes waiting times. This data-driven approach ensures efficient bus dispatching, thereby enhancing overall user experience and operational efficiency (Shanghai.gov.cn, 2023; Yin et al., 2022). The analysis system also supports strategic planning and policy-making by offering insights into travel patterns and passenger behavior. This helps urban planners and transportation management make informed decisions regarding infrastructure development and service improvements, ultimately creating a more resilient and adaptable public transportation system (Zhai & Shen, 2023).

In Turin, passenger flow analysis plays a crucial role in enhancing the efficiency and reliability of bus services. Predictive models enable GTT to adjust bus schedules in real-time, ensuring that services align with actual passenger demand. This reduces the

likelihood of overcrowding and increases service reliability, which is vital for maintaining high levels of passenger satisfaction (Muoversi a Torino, 2023). Turin's analysis system also promotes better resource management by optimizing bus frequency and routes based on demand patterns. This ensures that buses are deployed where they are most needed, improving the overall efficiency of the public transportation network. Additionally, insights gained from passenger flow data aid in the long-term planning and development of the transportation system, making it more responsive to the needs of the city's residents (Lv et al., 2022).

A comparative analysis of the passenger flow analysis systems in Shanghai and Turin reveals significant differences and similarities in how these cities leverage data to optimize public transportation services. Both cities employ advanced analytical technologies to monitor and predict passenger flow, which is vital for enhancing the efficiency, reliability, and user experience of their respective transportation systems. Shanghai's strategy is characterized by comprehensive integration and the use of advanced predictive models. The Suishenxing platform provides a holistic solution that encompasses various modes of transport and offers real-time updates, facilitating a seamless travel experience for users. The DCRNN model used in Shanghai enhances the accuracy of passenger flow predictions, which is crucial for managing the city's high commuter volumes. This data-driven approach enables dynamic scheduling and route optimization, reducing congestion and wait times, thereby improving overall operational efficiency and user satisfaction. Turin focuses on operational flexibility and efficient resource management. The city's real-time monitoring system allows for quick adjustments to bus schedules and routes based on real-time data, ensuring that services align with actual passenger demand. This flexibility helps maintain high levels of service reliability and passenger satisfaction, even with varying demand patterns. The use of predictive models like XGBoost, while slightly less accurate than Shanghai's DCRNN, still provides valuable insights that support effective resource allocation and service planning.

The comparison between Shanghai and Turin's passenger flow analysis systems highlights each city's unique challenges and priorities. Shanghai's approach is distinguished by its comprehensive integration and advanced predictive modeling, addressing the needs of a densely populated city with high passenger volumes. In contrast, Turin emphasizes operational flexibility and efficient resource management, catering to a city with diverse and fluctuating demand patterns. Both cities demonstrate how advanced analytical technologies can significantly enhance public transportation systems, improving efficiency, reliability, and overall user experience.

3.2 User Journey Map of Bus Transportation in Shanghai and Turin

In Shanghai, a passenger's bus journey begins by using mobile applications like "Shanghai Bus" to check bus routes and schedules. These digital touchpoints provide real-time bus locations, estimated arrival times, and traffic conditions. Although these apps are convenient and easy to use, passengers often face issues with inaccurate real-time information, leading to concerns about missing the bus. As passengers walk to the bus stop, they encounter physical touchpoints such as bus stop signs, which provide important information about routes and schedules. While waiting at the bus stop, passengers rely on electronic display screens to know the bus arrival times. Long waiting periods and sometimes unclear signage can cause anxiety during this stage. When boarding the bus, passengers interact with physical touchpoints like the bus front door and footboard. Passengers must swipe their bus cards on a card reader, but this process can sometimes fail, causing frustration. Once on board, passengers look for seats or handrails to ensure a comfortable journey. Overcrowding on buses can reduce comfort, highlighting the need for improved space management. During the ride, passengers use onboard displays and audio announcements to check station information. Ensuring they get off at the correct stop requires careful attention, and any malfunction in the display system can cause anxiety. After disembarking, passengers often use mobile applications or social media to review bus services and provide feedback for continuous improvement. However, inefficient feedback channels can lead to dissatisfaction. When planning their next trip, passengers need to check updated routes and schedules, hoping for more accurate real-time information.

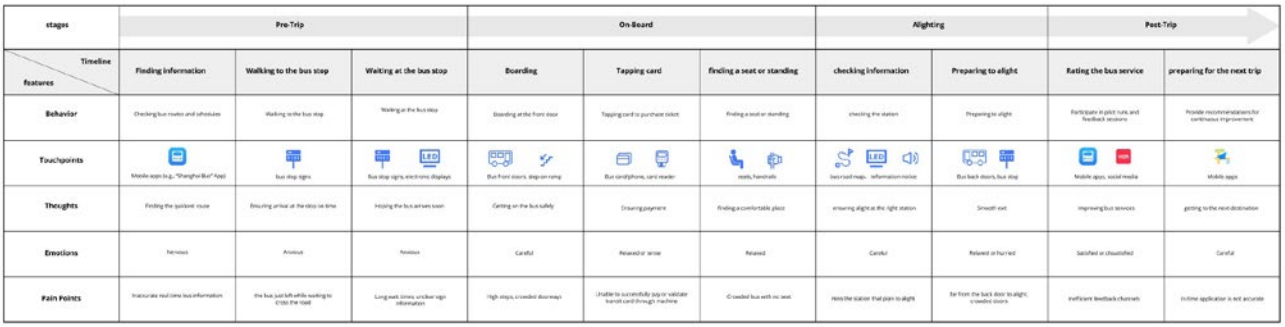


Figure2. User journey map of passengers taking bus in Shanghai

In Turin, a passenger's journey on a bus typically begins with checking routes and schedules via the "GTT" app. This application, along with others like Moovit, provides highly accurate real-time information, alleviating the anxiety about bus arrival times. An additional step for passengers is purchasing tickets before their trip. Tickets can be bought through various means, including mobile apps and physical kiosks. Ensuring they have the correct ticket type and remembering to

carry it can cause confusion and anxiety. As passengers walk to the bus stop, they interact with bus stop signs similar to those in Shanghai. While waiting, they scan QR codes to receive real-time bus information and confirm arrival times. This digital interaction helps reduce anxiety but relies on the availability of smartphones and internet connectivity. In Turin, boarding may require extra interaction, such as signaling the driver if the bus does not stop automatically. Physical touchpoints like bus doors and ramps facilitate boarding. Once on board, passengers use ticket validators and look for seats or handrails. The well-maintained facilities usually ensure a comfortable ride. Passengers in Turin can also use stop request buttons to signal the driver when they wish to disembark. This interaction ensures timely stops but can occasionally malfunction or be misused. During the journey, passengers use onboard displays and audio announcements to monitor their trip and ensure they are alight at the correct stop. After disembarking, passengers often provide feedback on bus services through mobile apps and social media, similar to practices in Shanghai. Although these feedback channels can be inefficient, they are crucial for service improvements. Before planning the next trip, passengers recheck schedules and routes to ensure timely arrival.

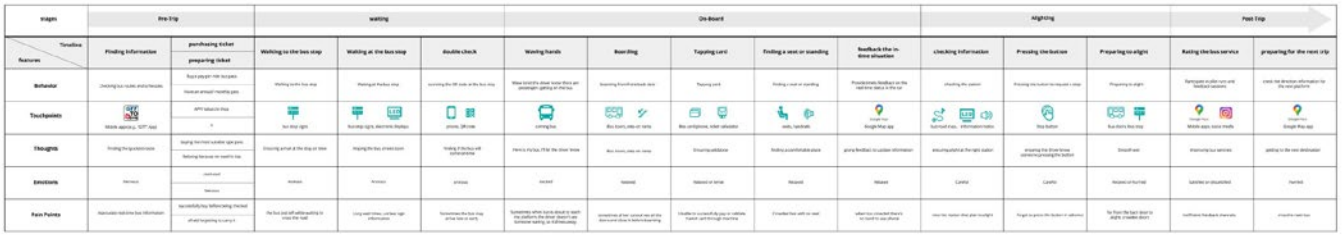


Figure 3. User journey map of passengers taking the bus in Turin

Similar to public transportation in other Europe cities, Turin's service design interventions focus on enhancing user experience through better route planning and real-time information systems. With the help of software to convey information more promptly and accurately to passengers and connect with instant public transportation information apps such as Google Maps, Turin provides accurate travel route planning and scheduling. Additionally, public transportation hardware facilities enable passengers to communicate stop information to drivers and other staff, reducing unnecessary stops and improving overall service efficiency.

Compared to Shanghai's fixed routes, Turin has introduced more flexible bus route schemes, such as setting AB routes in the same direction and differentiating stops for weekdays and weekends to meet varying passenger needs, especially during off-peak hours (Bartolini et al., 2017). These flexible route and schedule settings enhance service reliability and increase passenger satisfaction.

The comparison between the bus systems in Shanghai and Turin reveals different strategies in service design and user experience. Despite issues with accuracy, Shanghai passengers rely on digital

touchpoints for real-time information. On the other hand, Turin has invested significantly in technology to provide high-quality, modern facilities and ensure real-time information updates.

3.3 Real-time Monitoring of Bus Transportation in Shanghai and Turin

Shanghai employs a sophisticated real-time monitoring system integrated with its extensive public transportation network, which includes buses, metros, ferries, and bike-sharing services. The core of this system is the Suishenxing app, developed by the Shanghai Mobility Service Technology Company. This app provides comprehensive real-time updates and services, such as public transportation schedules, taxi hailing, smart parking, and payment options through Alipay or WeChat Pay (Shanghai.gov.cn, 2023). Supporting over 1,560 bus lines and 20 metro lines, the app offers a seamless travel experience by consolidating various transportation modes into a single platform (Shanghai Municipal Transportation Commission, 2022). The real-time monitoring system in Shanghai is designed to enhance operational efficiency and passenger convenience. It provides realtime data on bus and metro locations, arrival times, and service updates through electronic displays at stations and within vehicles, as well as through the Suishenxing app. This system helps manage the city's vast transportation network by enabling dynamic scheduling and rapid response to service disruptions (Shanghai.gov.cn, 2023).

Turin's public transportation system also features a robust real-time monitoring system that utilizes GPS technology to track buses and trams. Managed by Gruppo Torinese Trasporti (GTT), this system provides real-time updates through mobile applications and digital displays at bus and tram stops. Passengers can scan QR codes at bus stops to access real-time arrival information, facilitating journey planning without relying solely on mobile apps (Muoversi a Torino, 2023). The real-time monitoring system in Turin enhances the passenger experience by ensuring accurate and timely information on bus and tram arrivals. It helps reduce waiting times and improves overall service reliability. Additionally, onboard electronic displays provide real-time updates on current and next stops, including whether the bus or tram will stop, which is particularly useful for passengers unfamiliar with the route (Muoversi a Torino, 2023).

In Shanghai, the real-time monitoring system plays a crucial role in optimizing the public transportation network. By providing real-time data, the system can better manage passenger flow and minimize delays. This results in more reliable and efficient services, which is essential for a city with such a high daily commuting volume. The integration of various transportation modes into a single platform via the Suishenxing app offers a unified solution for all public transportation needs, enhancing the user experience (Shanghai.gov.cn, 2023; Xu & Zhao, 2020). The system also supports data-driven decision-making in urban

transportation planning. By analyzing travel patterns and passenger behavior, the city can make informed adjustments to routes and schedules, improving service coverage and efficiency (Shanghai Municipal Transportation Commission, 2022).

Turin's real-time monitoring system improves public transportation service design by enhancing transparency and communication with passengers. Accessing real-time information through QR codes and mobile applications ensures that passengers can make informed travel decisions, reducing uncertainty and waiting times. This contributes to a more user-friendly and reliable public transportation system (Muoversi a Torino, 2023). Additionally, the real-time monitoring system allows for dynamic adjustments to bus and tram schedules based on real-time data, increasing operational efficiency. This flexibility helps address service disruptions promptly and maintain high service reliability. Detailed onboard displays further assist passengers by providing clear and timely information about their journey, enhancing overall satisfaction (Muoversi a Torino, 2023).

3.4 Touchpoints of Bus Transportation in Shanghai and Turin

Shanghai and Turin's public transportation systems exhibit significant differences in touchpoints, reflecting their unique approaches to addressing city-specific challenges. A comprehensive touchpoint analysis reveals these differences, focusing on passengers' digital and physical interactions throughout their journey from platform to onboard experience and back to platform.

In Shanghai, digital touchpoints like mobile applications and real-time information systems are crucial. Major applications such as "Shanghai Bus" App, Gaode Map, and Baidu Map provide route maps, real-time bus locations, estimated arrival times, and traffic conditions. These applications are widely accessible, catering to the high smartphone penetration among Shanghai residents. However, the accuracy of the provided information can sometimes be lacking, with occasional delays in data updates reducing user trust. Electronic display screens at bus stops complement these digital systems by providing real-time updates on upcoming buses and expected arrival times. While these screens are common in major areas, they are less prevalent in remote regions, limiting their utility for all passengers. In contrast, Turin's digital touchpoints are characterized by high accuracy and user trust. Primary applications, such as the "GTT" app, supported by auxiliary apps like Moovit, offer highly accurate real-time bus locations, route maps, and arrival times. These systems are known for frequent updates, providing reliable information that enhances user experience. Additionally, Turin has implemented QR codes at bus stops, allowing passengers to quickly scan for real-time information and records of this bus station. This innovative approach ensures passengers can instantly access essential information, though it requires a smartphone and internet connection.

Shanghai's physical touchpoints include well-distributed bus stops equipped with shelters, seating, and electronic display screens. These stops provide essential information such as bus arrival times, route maps, and public announcements. Despite the extensive network, some remote stops have outdated facilities that need better maintenance. Shanghai buses are equipped with well-arranged seating, handrails, onboard display screens, and audio broadcast systems that effectively convey route information and the next stop.

However, during peak hours, buses can become overly crowded, reducing passenger comfort. Turin's physical touchpoints are marked by modern, well-maintained facilities. Bus stops are equipped with comfortable seating, high-quality shelters, and electronic display screens that provide detailed bus information and public notices. The high standards of these facilities significantly enhance passenger comfort and satisfaction. Turin buses feature seats in different orientations and sizes and clear display screens that provide timely updates on routes and the next stop. Additionally, buses are equipped with multiple stop buttons for passengers to request stops conveniently. While this system is efficient, it requires ongoing maintenance to prevent malfunctions or accidental activations.



Figure 4. Touchpoints in the process of taking bus in Turin

This comparative touchpoint analysis highlights the distinct strategies employed by Shanghai and Turin in designing and managing their public transportation systems, tailored to meet the specific needs and challenges of their urban environments.

3.5 Differences in Service Design Interventions

The comparative analysis of bus transportation service design in Shanghai and Turin highlights significant differences in how each city addresses its unique public transportation challenges through innovative service design interventions. The study identifies several key aspects:

1. Stop Request Systems: Turin's buses are equipped with stop request buttons that allow buses to bypass stops if no passengers need to disembark, which saves time and improves efficiency. In contrast, Shanghai's buses stop at every designated stop, potentially leading to longer travel times and reduced operational efficiency (GTT, 2023; Shanghai Municipal Transportation Commission, 2022).

2. Bus Configuration and Accessibility: Turin's buses feature multiple-door entry and exit options, which reduces the walking distance within the bus and enhances passenger convenience. Shanghai's buses typically require passengers to board through the front door and exit through the rear door, which can increase walking distance and inconvenience passengers (GTT, 2023; Shanghai Public Transportation Group, 2020).

3. Real-Time Information Accessibility: Turin provides real-time bus arrival information through QR codes at bus stops, which is particularly useful for passengers without access to mobile applications. Shanghai also offers real-time updates via mobile apps and electronic displays, but the addition of QR codes could further enhance accessibility (GTT, 2023; Shanghai Municipal Transportation Commission, 2022).

4. Onboard Displays: Turin's buses feature electronic displays that provide real-time updates on the current and next stops, including whether the bus will stop. This helps passengers unfamiliar with the route to stay informed. Shanghai's buses also have electronic displays, but Turin's system offers more detailed and user-friendly information (GTT, 2023; Shanghai Public Transportation Group, 2020).

As is discussed, the case studies of Shanghai and Turin illustrate how different service design interventions can significantly impact public transport systems. These insights highlight the importance of tailoring service design to local conditions and needs. However, we need to more systematically study how successful interventions in one city can be adapted and applied to another, as understanding and discovering cross-cultural applicability can help establish broader application scenarios, thereby leading to more effective and sustainable public transport systems around the world.

4. Discussions

Based on the differentiated perspectives of these two cities, the following discussion will delve into the specific impacts of these service design strategies, structured around four key criteria: operational efficiency,

user satisfaction and engagement, cultural adaptation, and the challenges and opportunities within diverse city contexts.

4.1 Impact of service design on operational efficiency.

The implementation of service design methodologies has significantly affected the operational efficiency of public transportation systems in both Shanghai and Turin. In Shanghai, the integration of real-time monitoring and passenger flow analytics through the Suishenxing platform has optimized bus operations by enabling dynamic scheduling and reducing idle times. The use of advanced predictive models like the Diffusion Convolution Recurrent Neural Network (DCRNN) has enhanced the accuracy of passenger demand forecasts, leading to more efficient bus dispatching and resource allocation (Zhai & Shen, 2023).

In Turin, the use of stop request buttons and multiple entry/exit doors has streamlined bus operations, reduced unnecessary stops and improved passenger flow within the vehicles. This has led to shorter travel times and increased operational efficiency. Additionally, the implementation of real-time information systems, including QR codes and onboard displays, has enabled more flexible and responsive service adjustments, further enhancing operational performance (Muoversi a Torino, 2023).

Overall, both cities have demonstrated that thoughtful service design can lead to significant improvements in the efficiency of public transportation systems by optimizing resource use and reducing operational delays.

4.2 Impact on user satisfaction and engagement

User satisfaction and engagement have also been positively impacted by the service design interventions in both cities. In Shanghai, the Suishenxing platform provides comprehensive real-time updates and multiple payment options, which have enhanced the convenience and reliability of the public transportation system. The integration of different modes of transport into a single platform has simplified the user experience, leading to higher levels of satisfaction and increased usage (Shanghai.gov.cn, 2023).
Turin's focus on user-friendly features, such as multiple door access and real-time information through QR codes and displays, has similarly improved passenger satisfaction. These features make the system more accessible and reduce the physical and informational barriers to using public transportation. The positive feedback from users indicates that these design elements have successfully increased engagement and loyalty to the public transit system (Muoversi a Torino, 2023).
By addressing the specific needs and preferences of users through targeted service design interventions, both cities have managed to create a more user-centric public transportation system that encourages greater use and satisfaction.

4.3 Cross-cultural features and service Adaptation of Bus transportation in Shanghai and Turin

Shanghai is a rapidly developing megacity with a public transportation system designed to handle a large number of passengers efficiently. This system prioritizes extensive coverage and frequent service to meet the diverse needs of its users (Shanghai Municipal Transportation Commission, 2022). Reflecting the city's swift modernization and technological advancements, Shanghai's public transportation system places a high value on efficiency and scale. In contrast, Turin's public transportation system balances modern demands with the city's historical context. The overall aim is to integrate public transportation into the urban structure sustainably and conveniently, emphasizing quality of life and user experience (GTT - Gruppo Torinese Trasporti, 2019).

In Shanghai, the public transportation system enhances efficiency by integrating technology, such as applications providing comprehensive traffic information and payment options in multiple languages to cater to both local and international users (Shanghai Government Website, 2023). Interventions include multilingual information systems and services tailored to the needs of international tourists and expatriates. These measures make the bus system more accessible to non-Chinese speakers, enhancing overall service inclusivity (Xu et al., 2020).

Turin's service system focuses more on passenger convenience, including multiple entrances and features like QR codes for real-time information. These adjustments consider local passengers' cultural and behavioral patterns, thereby improving the overall user experience (Muoversi a Torino, 2023). Turin has also implemented cross-cultural features similar to those in Shanghai, such as multilingual information and training staff to assist foreign passengers. These efforts ensure the public transportation system is welcoming and user-friendly for all passengers, including tourists and international residents (Bartolini et al., 2017).

Cultural differences play a significant role in shaping the service design strategies of Shanghai and Turin. Shanghai, as a rapidly growing megacity, prioritizes efficiency and technological integration to manage its large and diverse population. The use of advanced technology and comprehensive data analytics reflects the city's focus on innovation and high-capacity solutions (Shanghai Municipal Transportation Commission, 2022). In contrast, Turin's service design is influenced by its historical and cultural context, which emphasizes accessibility, user-friendliness, and flexibility. The city's approach to service design includes features that cater to the specific needs of its residents, such as stop request buttons and multiple entry/exit doors, which enhance the overall user experience in a culturally appropriate manner (Muoversi a Torino, 2023). Both cities have successfully adapted their service design strategies to align with their unique cultural and urban contexts,

demonstrating the importance of cultural adaptation in the implementation of effective public transportation solutions.

In summary, the comparative analysis of bus service design in Shanghai and Turin reveals how local contexts and cultural differences influence public transportation systems. Both cities have implemented service design interventions tailored to their unique needs and challenges. Shanghai's approach focuses on managing its vast, densely populated urban environment through advanced technological solutions and extensive real-time monitoring. Conversely, Turin emphasizes accessibility, reliability, and cultural integration, reflecting its smaller size and historical context.

4.4 Challenges and opportunities of service design in diverse urban contexts

Implementing service design in diverse urban contexts presents both challenges and opportunities. In Shanghai, the main challenges include managing the sheer volume of passengers and the complexity of integrating multiple transportation modes. However, these challenges also present opportunities to leverage advanced technologies and data analytics to create innovative solutions that can be scaled to other megacities facing similar issues (Yin et al., 2022). Turin faces challenges related to balancing modern service design with its historical infrastructure and catering to a smaller, yet diverse, population. Opportunities here lie in the potential to innovate within a more flexible framework, allowing for the testing and refinement of user-centric design features that can enhance the overall public transportation experience (Lv et al., 2022). Both cities illustrate that while the specific challenges of service design may vary, the fundamental principles of user-centric and datadriven approaches remain crucial for developing effective and sustainable public transportation systems.

The case studies of Shanghai and Turin provide valuable insights into the role of service design in enhancing public transportation systems. These findings have several implications for public transportation policy and practice. First of all, integration of advanced technologies such as leveraging real-time monitoring and predictive analytics can significantly improve operational efficiency and user satisfaction. Secondly, user-centered Design to meet the specific needs and preferences of local populations is vital to enhance user engagement and satisfaction. Thirdly, successful service design requires understanding and integrating cultural differences to create solutions that are both effective and acceptable to the local context. Moreover, developing scalable solutions that can be adapted to different urban contexts is crucial for addressing the diverse challenges faced by global cities.

5. Conclusion

This study highlights the significant impact of service design on the operational efficiency and user satisfaction of public transportation systems in Shanghai and Turin. By integrating advanced technologies and adopting user-centric design principles, both cities have managed to produce more efficient and reliable public transportation networks. The findings are expected to contribute to transportation system with an analysis of the importance of cultural adaptation and the potential of data-driven approaches in service design.

Service design has the potential to transform urban public transportation systems with more efficient, user-friendly, and adaptable transit networks. The experiences of Shanghai and Turin illustrate that thoughtful design interventions can address specific urban challenges and enhance overall service quality. Future research should focus on the scalability of these solutions to other urban contexts and the possible long-term impacts of service design on public transportation patterns. By means of constantly innovative and adaptive service designs, cities around the world can draw on each other and develop public transportation systems to not only meet the current needs of the residents but also to anticipate and respond to future challenges.

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COLLABORATIVE DESIGN EXPLORATIONS WITH AUGMENTED REALITY

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ABSTRACT | Immersive technologies for augmented reality allow interaction with virtual or digital objects, which appear in the operator's vision, and with which they interact through electronic equipment that can be controlled both gesturally and vocally by the user; This capacity for interaction makes it suitable for the practice of formal and functional design of models at any scale. This work explored the use of augmented reality in collaborative design exercises, starting with ideation until reaching the physical and digital prototyping of the model. Exploratory in nature, with contemporary design, the work was developed with the participation of students from the schools of Architecture and Habitat Sciences, and Art and Design, at the University of Monterrey, in Mexico. It was carried out in two phases: a first stage of exploration of collaborative design mediated with augmented reality, in the Experimental Study course, for the formal creation of a three-dimensional object with use and feasibility of seating, designed in an interdisciplinary manner, applying the Bottom-up methodology, using the Rhinoceros software with the Fologram plugins; In the second stage, alternatives were studied for the physical materialization of the object, through digital printing and the development of proposals, with the premises being: detailing the modeled three-dimensional explorations; evaluate and select the proposal to be physically developed; adapt the geometries of the chosen object to improve its formal characteristics, dimensions, and ergonomic stability; as well as carrying out 3D printing tests on a scale of the model to contrast the digital model with the physical one. The entire process concluded with proposing a prototyping system for constructing the object. The results demonstrate that augmented immersive technologies motivate the involvement of students in the creative process, due to their innovative nature, in addition to allowing them to organize their participation and performance in the design phases. The immersion in mixed scenarios made it possible to align the exercise with the interdisciplinary approach and explore new frontiers of digital design for its conceptualization, and modeling.

KEYWORDS | AUGMENTED REALITY, COLLABORATIVE DESIGN, DIGITAL MANUFACTURING, DIGITAL MODEL, PROTOTYPING.

1. Introduction

The study of function and space, just like its representation, is one of the purposes of design, which, as a discipline, allows students to develop spatial-logic skills through technical expression, with which they can observe, comprehend, and communicate figures in the geometric space, through concepts, abstractions, and approximations.

However, said observation or study requires practice and training, mostly in the early stages of any undergraduate-level professional career in technical and creative design, for which it is necessary to be able to comprehend and imagine objects in two and three dimensions, which after a tedious process transforms into the fabrication of products, tangible volumes, materialized through inventiveness and creativity.

The technical study of design therefore adds to the creative process with the conditions necessary for the representation and the visualization of the figures, relying on different projection systems, which, as methods, provide a standardization of steps to reach the result or product.

In the specific case of creative careers, the subject of design becomes even more relevant, since each construction process goes through representation and visualization, through flat and orthogonal forms, to generate views that constitute the communication of essential parts of the object to be built.

Moreover, as a professional discipline, design relies on geometry for the technical study of form and space, which is applied not only to the structure but also to the calculation of materials, the estimate of the area, and the physical volume of what is built, as well as to the development of graphic thinking, as a professional competence.

However, according to the works of Mataix et al. (2015), Gómez (2019), and Suter (2020), one of the greatest weaknesses of students the moment they begin their professional studies on design is precisely the lack of spatial practice on shapes, to the learning of their articulation or variation, to which is also related to underdevelopment in other areas such as mathematics, physics, and drawing.

It is therefore necessary to strengthen the study of design during the first semesters of professional study, since, as a creative exercise, it allows students to acquire and train spatial-logic skills on which the career is based as a technical and constructive practice of form and space and its habitable and functional elements. In addition, it allows the development of visual graphic understanding, through which design ideas are communicated, and systematized in a project.

For this reason, the design technique is constituted as the starting point for the development of the student's visual and graphic thinking during their first semester of a creative career, because through analogical practices of representation and visualization, they understand and apply concepts of the discipline, such as form, space, volume, scale, and proportion, to mention a few.

The design student is generally introduced gradually to digital tools for visualization, representation, and project management after having previously developed logical-spatial skills that allow them to understand the architectural object in its primary dimensions of form, space, and function.

Therefore, three-dimensional design is the basis on which the application of technology is based during the practical learning process, thus completing the range of possibilities to be used in professional design work, a process generally achieved through vectorized drawings, renders, digital modeling, and simulation exercises among others, which are means or channels of communication used to design, manage, and make functional objects.

Doing, and much more, learning design as a professional craft in all its areas, goes through the practice of modeling and the application of digital software, which according to the authors Jin-Kook et al. (2023) not only permeates the projective work but more so influences the designer's thinking itself.

Therefore, this research focused on the incorporation of immersive technologies into the study of creative design, since this is the appropriate scenario to develop visual graphic thinking and spatiallogic skills in first-year students in the career of professional studies, through practical exercises that introduce them to the subject of planes and volumes as spatial elements.

Adding on, the technological component as a pedagogical tool, valid for the introduction to the processes of digitalization and modeling that arise from the study of forms in space, as a documented design craft, and communicated in physical and digital pieces such as plans, digital models, renders, and simulations.

Digital design, therefore, as a technical area of professionalization reinforces graphic thinking, strengthens, and trains the development of spatial skills, and constitutes a transversal component in design courses and workshops, where the students form criteria and foundations to propose feasible solutions.

Although the concept of digital design is broad, this study explores it with two emphases, the first from the immersive through simulation technologies of mixed and combined realities, and the second from the digital modeling as an object of study, which evolves and is transformed into an image with operational feasibility of the design.

1.1 Augmented reality applied to design.

Immersive technologies are becoming a real instrumental challenge for the development of design, not only because of the procedural processes of creation or rendering of images or videos but also because they lead the professional discipline to unexplored frontiers. This is one of the motivations of the work presented by Bernasconi et al. (2023), which is a literature review of the scientific production on the subject because of the post-COVID-19 scenarios.

In the paper, the authors state that virtual, augmented, mixed, and augmented realities are an effective opportunity for architectural design since they allow overcoming physical spatial barriers, bringing experimentation into simulated scenarios, generated by the ubiquity in the use of the immersion of these tools. However, they point out that in this process the human experience must prevail, that is, the consideration of the user as the recipient of the design and the creative effort.

An example of such practice is the design proposal applied by Jin-Kook et al. (2023) using immersive technologies, including augmented reality, for 360° interactive experiences. The work consisted of the interior design of the hall of an existing library, which was adapted and renovated, to be toured and digitally validated by users. The conclusions allowed us to verify the effective use of these technologies, especially in the visualization approach, ensuring a high sense of realism and immersion using lights, shadows, textures, and materials in the design of the simulated reality.

Dan et al. (2021) will also test augmented and mixed realities for design, doing an in situ practice, where the user is placed in the real context and through immersive technologies tests the various design options; their work stands out not only for considering such technology as a useful tool but for associating it with the operational and participatory design of the user as the recipient, who finds in the immersive experience the opportunity to become more actively involved in the design and the solution.

A particular feature of the use of these technologies in creative processes is that they are not applied alone but are generally accompanied by other visualization processes related to modeling and rendering, which turns the experience into a true ecosystem of digital tools and techniques at the service of design.

1.2 . Collaborative design mediated by immersive technologies.

Collaborative design is the process characterized by the participation of various agents who contribute their points of view, criteria, and options on the design solution generated. It is based on teamwork, synergy and communication of all the members involved that guarantee the collegial experience of integrating the opinions of many in a single proposal.

As a projective strategy, collaborative design is often associated with participatory design, as the idea of consulting and integrating the creative process, the generation of ideas and the technical solution, the inclusion of various actors ranging from users, recipients, interdisciplinary technicians, and design professionals in a positive environment for the creation of an orchestrated solution. As mentioned above, the key points of the process are integration, good team communication, active participation of all members, and the organization of the work by stages to make the process more efficient. That is why the collaborative design process is associated with the Bottom-up design methodology, which consists of an emergent solution based on a reaction, where the key is in the integration proposal.

Collaborative design is also associated with interdisciplinarity because if what is addressed is the complexity of design as a solution to an emerging event, the participation and involvement of the participants are an essential task to detect the causes and consequences that have generated such a situation that must be responded from the technical and professional design.

An example of this is the work developed by Belaroussi et al. (2023) on participatory and collaborative design with a focus on urban issues, where virtual reality technologies were used to consult experts and residents on neighborhood design, through the modeling of emblematic places in the neighborhood, which could be toured and evaluated based on the design solutions applied in each of them. The experience is interesting because it considers as a key element of the design process, the active participation of various members who were involved in the design process through virtuality.

In the same way, the work of Han et al. (2023) applied immersive technologies as a mediator of collaborative experiences for design, by experimenting with an algorithmic design that relates the interactivity of the person with the computer, reacting to visual stimuli related to cultural design in urban and architectural spaces. Although their proposal is entirely technical, they apply virtual reality focusing on the possibilities of integration that this allows in a modeled and simulated scenario, which can be accessed through input and output devices, sensitive to movement and sound.

Although the work focuses on explaining the algorithmic design of the platform in which the layout of the simulation experience has been designed, its direct users used immersive Ness to validate its operation

It can be understood that the application of immersive technologies in the collaborative design process is useful because it ensures effective understanding and therefore, the successful participation and integration of members with the same purpose of validating and providing timely design solutions and consequently close to the sensitivities of users who in most cases, are the recipients of the same creative effort.

1.3 . Augmented reality in learning design.

The use of new digital design tools has given rise to an enthusiastic impulse in the application of emerging technologies in teaching and collaborative learning processes, which has led to immediate references when it comes to courses related to the operative practice of design; such is the case of augmented reality, a technology characterized by relating virtualization with the physical environment, through the use of electronic instruments that generate a relative immersion of the operator.

Collaborative design learning is understood as when the emerging solution does not come from the inventiveness of a single person but from the synergy and communication of the team working on the same model, which, in the specific context of augmented reality, allows the visualization of several participants in a synchronous and real way simultaneously.

Augmented reality is a digital immersion alternative, which combines “digital information and physical information in real-time through different devices” (Cabrero et al., p. 10, 2022) these react to the user’s indications that operate them through gestures, movements, and sounds, with which it is possible to experience and interact with physical and digital elements at the same time, finding in it, the main difference in regards to virtual reality, which generates the total isolation of the subject in a digitally simulated world.

It is also worth noting that both technologies share three fundamental aspects: immersion, navigation, and interaction. Fernández & Ampuero (2020) define augmented reality as a “media scenography that combines physical and digital information in real-time, through the use of different technological devices... such as computers with webcams, tablets, video cameras, smartphones, video game consoles with cameras”, among others (p. 30).

Therefore, the diversity of its use and application is not only referred to the image or the development of immersive content, but rather to the equipment that is used for the experience (Navarro et al., 2018), this becomes by the user’s indication activators, to see and do, transform, and compose, physical and digital realities in the same plane of vision.

Augmented reality, although it maintains the potentiality of the subject in a visible physical place, involves all the senses in

the experience, as it considers sight for interaction with digital forms, sound for navigation and control of the equipment, as well as touch for immersion in digital reality and kinesthetic movements for the activation of commands.

However, the referred works emphasize the use of immersive tools as a proposal for design validation and even as a strategy for user participation, so for this research, we began with the following question: How does one start a design exercise from the immersion of augmented reality?

Can the design go through the path of immersion and then move on to the technical specificity of the object to be manufactured?

This work validated the hypothesis of using augmented reality as a starting point for the design of a three-dimensional object as a conceptual reference to be developed in a more specific phase, applying the bottom-up methodology and collaborative design, as an academic experience.

2. Methodology

The exploratory research was based on the general objective of exploring the use of augmented reality in collaborative design exercises, starting with the ideation until reaching the physical and digital prototype of the model. The specific objectives were to test the use of augmented reality for three-dimensional design through the bottom-up methodology. Systematize the design process from the digital immersion to the use approach of the designed object. Establish the design stages of an object created digitally its prototype as a model for its implementation.

The work was carried out in two stages: a first phase during the first half of 2023, applying an open and self-directed collection instrument, which gathered the opinions of the informants in terms of strengths, opportunities, weaknesses, and threats (SWOT) considered in the first stage of the process to adapt this technology to the design.

The second stage dealt with the indicative and characteristic design and the testing of the digital and physical object, carried out in the first half of 2024. It is worth adding that the work is part of a research project still under development, to deepen the study and application of immersive technologies in design.

The designers who served as informants in the first stage were 16 students from the schools of Architecture and Habitat Sciences (EACH) and Art and Design (EAD), of the University of Monterrey (UDEM), who took the subject Experimental Study, Common Core for the eight careers of the schools: Architecture, Interior Design, Industrial Design, Energy and Sustainable Innovation, Graphic Design, Arts, Fashion and Textile Design, and Digital Animation. Hence, the interdisciplinary nature of the exercise approached the implementation; the sample is classified as non-probabilistic, self-directed, with mixed and homogeneous characteristics.

For the second stage, a design team composed of two students from the same School of Architecture oversaw materializing and operationalizing the selected proposals. This second team also has expertise in digital fabrication, parametric and digital design.

The analysis of the qualitative information from both stages was done through the design of matrices, which organized the comments by categories that were then coded and grouped, adding a description, and the frequency of repetition of the theme, for a more detailed explanation according to the findings.

3. Procedure

The first phase of ideation and design was applied in two three-hour sessions, with the basic goal of organizing four interdisciplinary teams, who, collaboratively, had to design an object with eight volumes (holograms), previously configured. Although they shared the same virtual model, each participant visualized the shapes in their environment, being able to observe in real-time the changes suggested by the other participants and verify the work during the grouping of the holograms.

The glasses used were the HoloLens 2, which has a resolution of 2k 3:2, a density of more than 2.5k radians, 4 visible 1080p cameras, and a microphone with built-in speakers, sensitive to human vocalization. The software applied for the modeling and grouping of the shapes was Rhinoceros 7.0 with the Fologram plugin, accessed by scanning a QR code.

At the end of the exercise, the instrument was applied to the participants for feedback and reflection. The starting point was to identify the categories of the four aspects of SWOT to evaluate the instructional design of the augmented reality sessions. Thus, the comments were grouped to obtain the highest frequency of thematic repetition and, therefore, like each other.

The second stage started with the review of the models made, to evaluate the proposal that was best adapted to 3D printing and digital fabrication, ensuring its design quality in terms of construction and ergonomics, since the proposals dealt with the design of a functional seat for two or three people.

This phase took approximately 4 months, which not only represented the study of the form but also the due bibliographic review, the establishment of the design criteria, the evaluation and selection of the proposal, as well as the development of the creative operability of the design in terms of its approach, to move from the digital model or mock-up to an understandable object with a defined use, concerning the human scale and some daily activity.

The entire work process can be summarized in the following steps:

Stage 1. Conceptualization and invention.

1. Initiation phase, selection of volumes: In which 6 volumes characterized by their transformations and extrusions were identified as solids that could be added to assemble a free composition, without any indication of their own, only the proximity between their contours, edges, and profiles.

2. Instructions on exercises and technology: design teams were configured, and instructions and training were given on the use of augmented reality technology, HoloLens handling, and Rhino-accessible commands from Fologram. This stage was of utmost importance since in many cases it was the students' first approach to immersive technologies.

3. Three-dimensional explorations: The four three-dimensional approximations were carried out using the bottom-up methodology, whereby aggregation of components, and parts were incorporated into the model, following the coordination and communication of the team members in real-time. The typology to be designed and the use to be made of it were decided synchronously, having only the premise of grouping components in the digital scenario with the mediation of augmented reality and the physical context.

Stage 2. Design and operationalization.

4. Proposal selection: The 4 proposals generated in stage one was studied to find the most appropriate model to continue development. In which the adaptations would be minor, the morphological proposals of the object could be maintained, and the design proposal initiated would be operationalized. The purpose of the evaluation was not to reject any of the proposals, but to select the most appropriate one to continue the process. For this purpose, a matrix of criteria with three values was established: 1 for the highest, 0 for neutral, and -1 for the lowest.

5. Adequacy of the geometries of the selected proposal: Having selected the model with the highest valuation, the geometries of the model were adapted. This work was performed with the Rhinoceros 7.0 desktop application. Various commands were applied. In addition, the Grasshopper algorithm described in the tutorial 'Parametric Bench' (Rhino Grasshopper, 2020) was used.

6. Digital model proposals: At the center of the whole process is the digital model, since it is the effective means that translates the designed object, this, although initiated from augmented reality, is reinterpreted to convert into a three-dimensional object that can approach a suitable effective use.

The diagram below will serve as a map to indicate the stages and steps of each of the design stages, and the most important aspects or criteria to be considered at each of the moments described in the process are also indicated.



Figure 1. Stages of the design process. The process establishes the phases of exercise preparation, technological training, and experimentation in the modeling process. The sequence generated was not determined until after the experience so in a way it also reflects the bottom-up methodology applied.

4. RESULTS AND DISCUSSION

To better organize the results, they are organized following the same sequence of activities described in the previous section, because, although the process was carried out comprehensively and uninterruptedly, the proposed classification and organization emerged after the practical study and applicability of these technologies.

4.1 . Stage 1. About augmented realities in the design process.

The possibility of teamwork in real time was one of the strengths pointed out in the first stage, highlighting the interdisciplinary sense, since the augmented reality tool used allowed group work on the same model. The model can be modified and revised immediately by all members, thus requiring coordination, communication, and collaborative work skills. The value of the tool also appears in this section due to its innovative nature in the teaching and learning process, since in most cases, it was the first time that they faced the use of augmented reality with a pedagogical sense for design.

Regarding the weaknesses, the informants pointed out the need to have previous practices or training to become familiar with the software and the handling of the commands, because, although the temporality of the exercise was positively valued, minimum training is required to adapt to the equipment and to adapt to the gestures that allow the relationship with the holograms in the physical world. Linked to the issue of temporality, the need for intermediate breaks during the development of the sessions was identified.

On the other hand, the opportunities focused on the usability of the software and the technical failures of the equipment to calibrate concerning the eyesight of each user, since, in some cases, it required constant verification by the operator; this suggests reviewing the possibility of using other applications that allow precision commands and greater versatility for the movement of the holograms. Concerning threats, the informants referred to the generation of discomfort and dizziness after several hours of use with the equipment, for which reason they pointed out the need to incorporate intermediate breaks.

4.2 . Stage 2. Operational design process considerations.

Among the weaknesses of the first stage in terms of design, was the limitation of the software used for precision scale commands or grouping of components, as the relationships of faces between volumes were not neat and, in many cases, clumsy or inaccurate.

It must be considered that in the work plane of augmented reality and possibly due to the same relative immersion of the technology, the relationship with the design object is merely visual, the scale and approach that the designer has with the volumes is through holograms and hence the difficulty of their grouping or coupling, since no physical or digital reference was used in this regard.

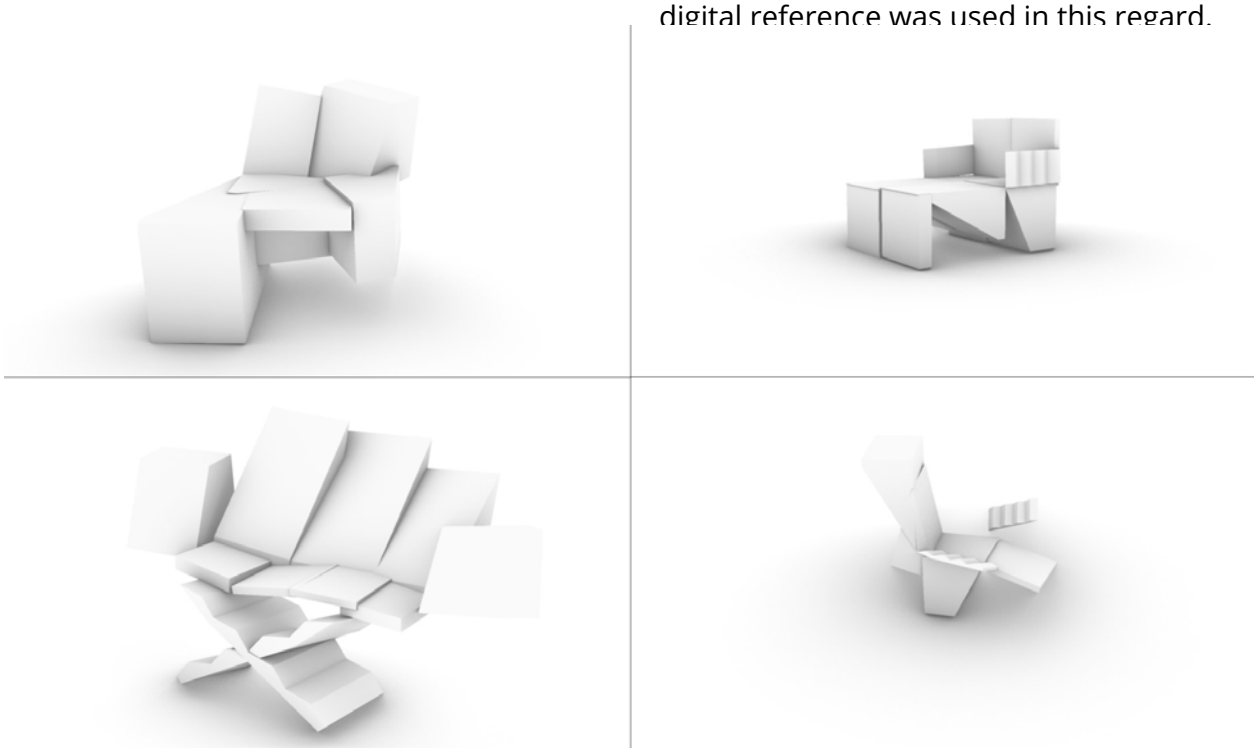


Figure 2. Models generated in augmented reality. The graph reflects the experimentation by the team, the association of shapes, and the design solutions generated, which in this case were associated with using a chair or seat for several people. Again, the theme was deliberate and was only determined by the grouping of components, a determining aspect of the bottom-up methodology.

So, looking at the result, it is natural that the next design stage of shape adaptation consisted precisely of simplifying the morphology, adapting the contours, and scaling the elements to be sure which would be the elements to be considered in the next phase of design and prototyping of the object.

The next step consisted of rethinking the object by interpreting the design criteria proposed in the original model based on the following considerations:

- Maintain the style of the morphology considering the inclinations or angles of the break of the forms.
- Adjust the proposal while maintaining the capacity of the scale according to the ergonomics of the number of people to be served with the designed bench object. In this aspect it was very important to understand the programmatic comfort proposal of the measures in the design, having as key points the minimums provided by Neufert (2013).
- Differentiate between two bodies or elements of the composition: the first supporting elements that will serve as the base or support or structure of the object, and the supported elements that are composed of seats, railings, and backrest of the bench. This classification of differentiation also allows us to make material associations, not only in terms of the logic of the design but also in terms of its actual approach as an object of operational use.
- To achieve a better and more orderly staggering of the proposed forms, it was decided to apply an algorithmic code that would give more order to the proposal. This was a deliberate decision and, although not raised at the beginning, the parametric allows to establish a better systematization of the exploded view, to then develop the proposal for the materialization or manufacture of the object.
- One of the fundamental premises of the whole design process was to maintain the digital character, that is, all approaches should be mediated with digital technologies, although starting with augmented reality, the experience proved that the complementarity of desktop design applications was necessary for the modeling of the forms. Because of the immersion, it was almost impossible to correct the imprecision of contours and couplings of the composition.

Therefore, a series of steps were established to work directly in the design software, to reinterpret the digital model according to the indicated criteria:

- Studies of the shapes of the selected proposal, for the interpretation of these using lines that can be drawn and expanded.
- Simplification of the curves of the model involved adapting the geometries, adapting the joints and the relationship

of the components, and establishing radii, diameters, and sections by the correct proportion and the mathematical relationship between them.

· Working with the modeling from contours, the subject of edges, and the profile, was fundamental for the understanding of the parts and the possible rhythms of variation to be considered.

· From the curves and lines, generate surfaces, and operating planes that configure the components or parts of the bench.

· The extrusion of parts or surfaces, as volumes, considering the thickness associated with the materiality to the physical proposal that later would be worked from the render as a possibility of expression and communication of the modeled object.

· Subdivision of the module, or surface.

· Inclusion of parametric algorithmic code for the subdivision of the parts or components.

· Solution of fixation or union of the parts or components, using the proposal of a tubular linear element that unites, supports, and articulates all the pieces, grouped integrally, and that, in some way, would give body to the volumetric composition.

· Solution of the base using the handling of lines or extrusion, repeating the previous points.

· Generation of the final digital model.

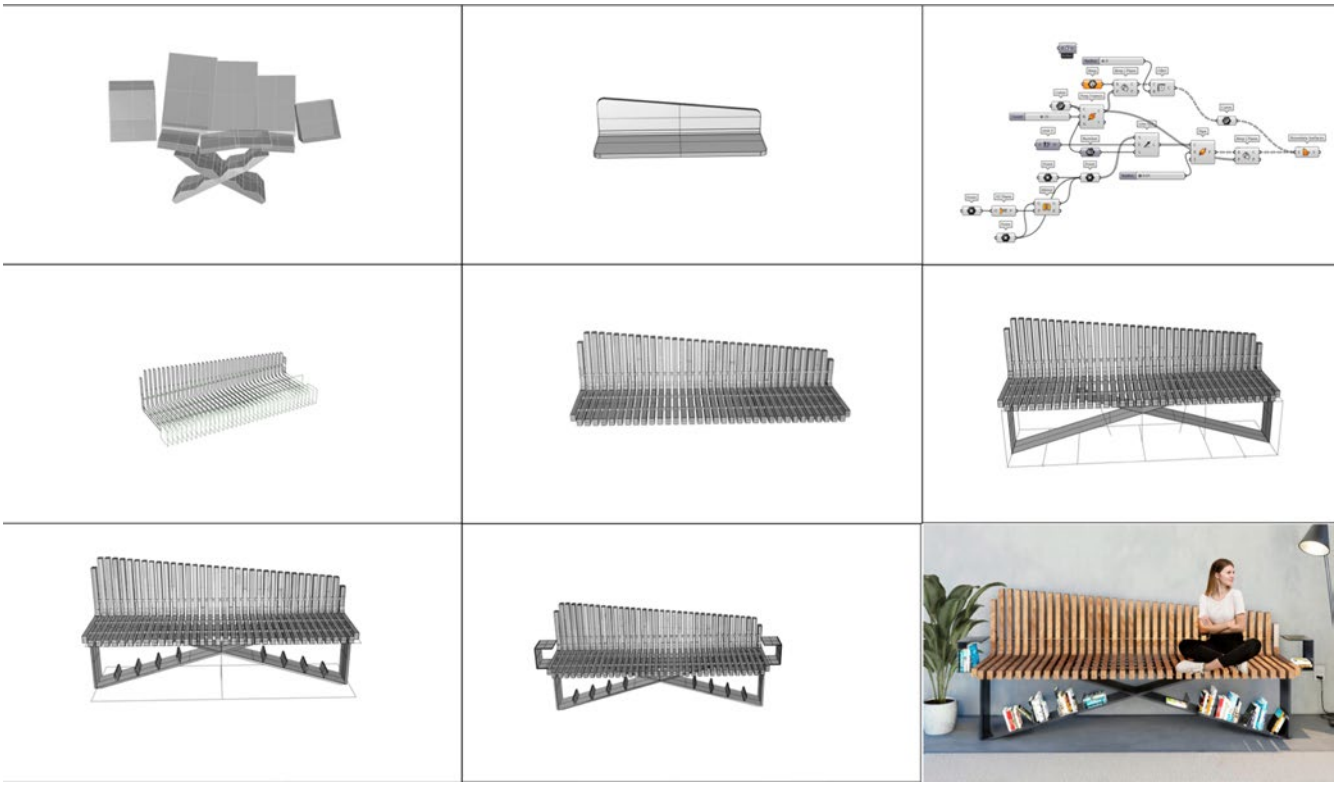


Figure 3. Modeling process. The process of moving from the original model modeled using augmented reality to the final object required adapting the geometries and applying various processes in the software used, as shown in the graphic.

As the process included the modeling and rendering part, as continuous stages of the

Finally, the proposal was modeled by making design approximations using rendering, assigning textures, lights, and materials, and recreating a scene of its use to determine the efficiency of the design, so that an accurate path can be established from the generation of ideas to the concentration of a three-dimensional object of use, based on the applicability of technology and the exploration of various design criteria.

same integrated activity synthesized in the modeling, other software for image management was incorporated to generate maps, textures, colors, materials, lights, and shadows to give realism to the achieved proposal.

For image processing, commands associated with the Twinmotion, and Photoshop software were included, especially for scene editing, the study of lights and shadows, the generation of a realistic illustration of the context of use, and the typology of the designed object, about the human scale.

Conclusions

Based on these results, two priority actions are established for the use of augmented reality in interdisciplinary exercises; the first one refers to correcting weaknesses in terms of opportunities, or in other words, to study the possibility of alternating software and/or applications, as well as technological equipment that allows a more efficient training in terms of the best, establishing stages in the instructional design, before, during and after each session.

The second action to be developed aims at correcting the weaknesses to face the threats, oriented along the same lines as the previous one, since the instructional design should consider breaks and times of appropriation of the user's technology, ensuring their comfort to avoid fatigue and discomfort, which undermines the creative process.

It is also necessary to consider the relevance of the selection of the software to be used, since the versatility and usability of these conditions limit the expected scope, especially considering that any design must address the operability of its execution or manufacture, whether analog or digital, because that is where the greatest challenge for future experiences lies.

Although the multidisciplinary character was due more to the nature of the participants than to the product resulting from the process, it is of utmost importance to find spaces to work with the transversality and interdisciplinarity of design, this not only enriches the creative process but also develops and expands the practice of design beyond disciplines, to emerging solutions, where themes such as place, form, space, clear, empty, full, scales and proportions, are converging points of learning inclusion and not barriers of separation.

Regarding the model because of the project or as a product of the academic exercise developed from beginning to end in digital environments, and therefore new for those involved, some of them, it was the first time they approached such technologies, and in some cases, that they applied them for pedagogical purposes concerning design,

which was worth as a point of honor and distinction of the exercise itself.

Although the work presents the process in an almost linear schematic manner, the process was certainly much more complex and required constant revision of the models for their interpretation and adaptation. Design decisions were based on the proactivity allowed by the technologies and modeling, rather than on the ergonomics of the object for use and relationship with the person, which after all should be the immediate reference to serve. In this case, it only became part of the final phase of adaptation of scales, sizes, and proportions.

This first exploration of design with augmented reality also shows that the key to the process lies in the relationship of various technologies around the digital model, which from the ideation became the protagonist of the process, the central axis on which commands and approximations were operated. Hence the prominence of this as a product and tangible digital object, a mediator between ideas and design.

It is also necessary to consider the relevance of the use of these technologies in academic environments since the study proved that immersive technologies and digitalization practices in design motivate the involvement of students, encourage them to explore new creative frontiers and encourage them to develop critical thinking about design mediated by technology.

The practical study of design as an exercise mediated by digitalization and specifically augmented reality as a scenario for the ideation and creation of digital forms and objects that can be associated with real uses validates the hypothesis put forward in the exploratory study because although the proposed objective was indeed achieved, it is necessary to go deeper into the use of technologies and design, especially to establish key and replicable methodologies that can be adapted by design teams at the professional level.

Therefore, the characteristic of experimenting with academic exercises, which although limited, brings students closer to new work methodologies, synchronous, virtual but with morpho-spatial aspects, is a challenge, not only because of the access or training necessary for the use of such technologies, but also because the idea of associating the exploration of virtuality to gamification or playful learning must be overcome, but rather, to digital design as a necessary and outstanding technical competence of the professional profile of the contemporary designer.

So, the path traced, starting with augmented reality, passing through digital modeling, and landing in a three-dimensional object with apparently real characteristics simulated with rendering, is an ideal example of how to incorporate technology in various moments of learning design, especially as a practical task and trade, which requires from the creative and instrumental point of view of various options to generate the best possible results.

Due to the nature of the bottom-up methodology, selected for academic purposes,

the digital model ended up opting for a three-dimensional object that could well be applied to the disciplines of industrial, interior, or architectural design, however, this is not a limitation, since other disciplines of the arts and design may well apply similar processes in their creative exercises to explore the use of such tools in the practice of design.

It is also worth adding the usefulness of immersive technologies as design tools for collaborative processes, since by their digital nature, the teams allow immediate interconnection for teamwork, the synchronization of modeling in real-time, and the intervention of the participating members on the object instantly so that what any member does on the model is instantly observed by the rest of the colleagues, which opens new possibilities of digital design, usually explored through the computer, but in this case, with augmented reality lenses a more decisive component is added.

This is one of the most decisive points of this work because participatory design was applied not from the user, but applied through augmented reality, for integrated processes of modeling and generation of formal design ideas instantly. Breaking with the linear or sequential inertia that characterizes collaborative processes, but rather experiencing instant integration for action, participation, modeling, and solution.

In addition, it is significant to associate the design methodology proposed through bottom-up, which although it is true is not exclusive or definitive concerning others, nevertheless, it worked satisfactorily in the exploratory exercise with students, considering their experience in digital design issues, and the little or no practice of using immersive technological equipment for learning design.

So, it is right to relate immersive technologies with design methodologies for the experimentation of forms since there are multiple options such as virtual, augmented, and mixed realities that allow such activity, and although this work was conducted for academic purposes of teaching and learning, students from various areas of professionalization gathered precisely to propose an integrated solution, they can well be applied in any design studio for the practicality of their results.

As lines or recommendations for future work are pending the exploration of manufacturing or fabrication for the materialization of objects, either with digital, analog, or hybrid procedures. Although the rendering offered an accurate approach in terms of materiality and scale, it will be necessary to develop a further stage of the process for the actual manufacture of the object and study aspects such as assemblies, supports, and finishes.

In addition, the augmented reality experience was limited to the visualization of objects for docking, but other strategies could be integrated to enrich the immersive experience, such as the use of sounds, smells, textures, or

light and shadow effects on the operator. This is a very interesting area to explore from a design and learning point of view.

Although, in this case, the digital premise supports the entire creative process, through the bottom-up methodology, the experience also showed that any digitization process must involve the real proximity of the manufacture of objects, and their physical materialization as a solution, so that the valuation of augmented reality, immersion, and digital models, go beyond the simple technological appreciation, as they are means and tools that should approach the operational reality of design. And it is at this point where the greatest frontier to be explored lies.

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BIOMATERIALS AND BIODESIGN TRANSFERRING KNOWLEDGE FROM ACADEMIA TO SECONDARY SCHOOLS

Susana Leonor, Carla Paoliello, Derya Irkdas Dogu, Onur Mengi, Américo Mateus, Anil Dinc Demirbilek, Gulizar Caliskan, David Palma and Deniz Deniz

ABSTRACT | Climate change poses a significant existential threat, challenging humanity and future generations. To address this, the EU aims to become the first climate-neutral continent (EU Green Deal), necessitating changes in both industry and education. Reskilling the workforce to build green skills is crucial, particularly in education, where integrating multidisciplinary knowledge and actionable skills is key to tackling climate change. This requires cross-sectional upskilling pathways in bio-based solutions.

This study focuses on transferring knowledge between Biomaterials and Biodesign Research Institutes and Design Educational Institutions. It emphasizes the need for practical and creative skills in addressing climate challenges, using microorganisms, bacteria, and fungi in material production as potential green solutions. The BiomaterialKIT project serves as a practical and pedagogical experiment aimed at promoting sustainable consumption. It explores various scholarly contexts and seeks to [1] improve consumer decision-making behaviors, [2] increase awareness of environmental impact and responsibility, and [3] foster innovation through better use of Biomaterials and their reintegration into the circular economy to mitigate climate change effects.

Employing participatory action research (PAR), participatory design, and co-creation processes, the project engages young citizens and their communities in sustainability practices. By integrating innovative methods and tools into school curricula, the project empowers students to become change agents within their families and communities. Conducted in Izmir and Portimão, this pilot study involved 200 K-12 to K-16 students, implementing sustainability principles and preparing them to influence future environmental practices.

KEYWORDS | BIOMATERIALS AND BIODESIGN LEARNING, SUSTAINABLE CONSUMPTION BEHAVIOR, PARTICIPATORY DESIGN, CO-DESIGN

1. Introduction

Climate change is one of the greatest existential threats to life on earth; this presents a considerable challenge to humanity and generations to come. Under this global threat, the EU aims to be the first climate-neutral continent on Earth (EU Green Deal). To achieve this goal, changes in industry and education need to transpire. To reach our climate targets, we must further educate, reskill the workforce, and build green skills, especially in education. We must address climate change as a complex societal challenge intertwining multidisciplinary knowledge and actionable skills.

The green transition is not just an option but a necessary response to an existential threat. The primary question is how to achieve it effectively. As climate change continues to accelerate, the urgency to adopt sustainable practices becomes more pronounced. This involves a comprehensive approach that integrates policy, technology, education, and community engagement. The design and implementation of education, in particular, can play a crucial role in shaping our capacity to tackle the social and economic challenges that will inevitably arise from this transition. By embedding sustainability into educational curricula, we can equip future generations with the knowledge and skills needed to drive and sustain green initiatives. The motivation for green action is also closely linked with the skills to implement changes, the tools to enable those actions, and, most importantly, creativity. Green solutions in Biomaterials and Biodesign are at the forefront of innovative responses to environmental challenges. These solutions involve creating materials that are not only sustainable but also biodegradable, reducing reliance on traditional, polluting materials like plastics. Harnessing living systems - such as microorganisms, bacteria, and fungi- for material production and design also hold significant potential such as mycelium based materials, which utilize the root structure of fungi, offer sustainable alternatives for packaging, building materials, textiles and even meat substitutes.

Green solutions also need to play a more prominent role in the European education system. This requires cross-sectional upskilling pathways towards the field of bio-based solutions. However, the green solutions in Biomaterials and Biodesign currently confined to university labs should be made accessible to a wider audience. This requires cross-sectional upskilling pathways towards the field of bio-based solutions to

bridge the gap between advanced research and everyday application. By enabling access to these practices, The BiomaterialKIT aims to contribute to the broader objectives of the EU Green Deal, thereby accelerating the adoption of sustainable behavior and awareness. Additionally, it provides training for innovation by encouraging the better use of Biomaterials and their reintegration into the circular economic cycle.

This comprehensive approach not only enhances understanding but also helps mitigate the effects of climate change by fostering sustainable practices and slowing down environmental degradation. For this reason, the project focuses on the transfer of knowledge between Biomaterials and Biodesign research institutes and design education institutions; and on the creation of innovation methods and tools to create awareness and support for schools, students and families to experiment using and creating with Biomaterials in their learning pathways.

1.1 Biodesign Learning: An Innovative Educational Approach

Biodesign learning integrates principles of biology with engineering and design, enabling students to create sustainable solutions. This educational approach is mainly rooted in interdisciplinary learning, where students are encouraged to explore the intersections between science, technology, engineering, art and mathematics (STEAM). Transferring knowledge between Biomaterials and Biodesign Research Institutes and Educational Institutions catalyzes innovation and value creation centered around sustainability to foster increased engagement particularly around younger generations. This involves creating educational programs that integrate biology, chemistry, enginering and design principles to equip sdents and professionals with the necessary knowledge and skills.

Considering the literature, Biodesign Learning (BDL) represents a new approach to education combining the principles of design thinking and bioscience to encourage innovation for the existing problems (Vygotsky,1978). To do that, Biodesign Learning aims to understand the problems by focusing on the biomimetic solutions inspired from nature and applying them for creative design processes via knowledge through experience for sustainable education (Benyus,1997). In addition, Biodesign learning mainly focuses on users' needs and expectations (Brown,2008) and aims to create a correlation between nature and design thinking for innovative solutions to the possible problems (Chappell, et.al.,2023). In this respect, Gopnik et al. (1999) demonstrates how Biodesign principles can create learning environments and encourage students to focus on real-world problems through biological point of views.

Biodesign Learning not only creates a new way of understanding for students, but also reveals benefits for improving students' creativity (Asghar, et al.,2012). Although Biodesign Learning is crucial for developing an environmental point of view for the existing problems, there are some obstacles which need to be considered. There is an urgent need for educators who are both capable in

biology as well as design principles and able to implement those changes into education (Myers et al.,2014). To fill this vital gap and beat these obstacles, BDL practices must be adapted to traditional educational settings urgently.

In this context, the importance and components of Biodesign Education can mainly be divided into subcategories, such as “Enhanced Problem-Solving and Collaborative Skills, Sustainability Awareness, and Interdisciplinary Learning”. BDE is crucial for integrating biological insights and design processes to encourage students to tackle everyday problems. This approach helps to enhance students’ ability to think wider and solve problems innovatively. Developing collaborative skills for better results also help students to learn how to work effectively in teams. This integration improves students’ understanding among various fields and applies them to real-world challenges (Pieters, et.al.,2019).

Educational innovations in Biodesign are crucial to transform the way students engage with biological and design principles. Improving sustainability awareness helps to focus on ‘Biomimicry’ and sustainable design which allow students to develop environmentally friendly design solutions (Benyus, 2002). Design thinking educators can create dynamic and interdisciplinary learning experiences by integrating biomimicry into their creative problemsolving processes.

Biodesign Education presents a forward-thinking approach to learn from the interaction of biological insights and design thinking to develop problem-solving skills through
interdisciplinary learning and awareness for sustainability. In this respect, integrating Biodesign into Science, Technology, Engineering, Arts, and Mathematics (STEAM) to combine biology with design thinking to create interdisciplinary learning experiences is inevitable to tackle with the obstacles in Biodesign Education (Bergmann & Sams, 2012). Developing online platforms as well as virtual labs to facilitate collaboration among students and educators are also crucial for enabling students to work together on innovative solutions (Välk et al., 2022). In this case, finding well-trained educators to deliver Biodesign effectively and integrating the changes to the current curriculum are the main problems (Biomimicry Institute, 2021) as implementing innovations requires significant resources (Ferruzca et al., 2022). Consequently, scaling Biodesign education to a wider range of educational institutions is inevitable for sustainable solutions.

1.2 BiomaterialKIT approach

The BiomaterialKIT – is a practical and pedagogical experiment for more sustainable consumption, fostering collaboration between universities, K-12 to K-16 schools and communities through training modules, workshops and hands-on projects that emphasize Biodesign practices. It aims to explore different scholarly contexts and introduce:

- better behaviors in consumer decision-making;

- awareness of individual and collective responsibility in the environmental impact,
- training for innovation through better use of Biomaterials and their reintegration into the circular economic cycle, to enhance and slow down the climate change effects.

Co-creation, Co-design and Co-innovation

The project focused on Biomaterials and Biodesign education, aiming to engage young citizens and the broader community in a participatory process to co-create improved physical, social, and economic solutions. Through the use of Biomaterials, this project sought to foster greater consumer awareness and enrich community life. Co-creation, in this context, involved cultivating a participatory, open-minded, and collaborative culture, which formed the foundation of co-innovation. These co-innovation layers were crucial to the success of co-design and community practice approaches.

Integrating a profound co-design culture into education (Scornavacco et al., 2021) was central to this project, addressing critical issues for comprehensive community development towards sustainability. This grounded culture of co-creation (Adamson & Davis, 2017) and co-design (Antonini, 2021) inherently encompassed ethics, shared experiences, human relationships, and the ways in which individuals interacted within a creative environment. It involved processes, codes, symbols, behavioral patterns, language, and customs, ultimately reflecting the BiomaterialKIT project's values, visions, environments, beliefs, and habits.

Education, families, and public spaces were emphasized as essential mediating environments for co-creation, fostering the convergence of experiences that could drive transformative changes in sustainable consumption and behavior within the community, families, and schools in the short to medium term.

Cultural drivers

The BiomaterialKIT project engaged with the societal, cultural, and economic differences between Portugal and Turkey, particularly through the lenses of co-creation and participatory culture. By recognizing and addressing these differences, the project aimed to foster a more inclusive and collaborative environment. The project's focus on Biomaterials and Biodesign education served as a medium to bridge the diverse cultural contexts of both countries, promoting an exchange of ideas and practices that enriched the learning and development processes. The participatory approach was crucial in ensuring that the project's initiatives were relevant and beneficial to both Portuguese and Turkish communities.

The Biomaterialkit research project focuses on the development of four primary tangible products:

- the BiomaterialKIT Manual, a pedagogical resource designed to support secondary school educators in introducing Biomaterials and Biodesign projects into their curricula;
- the MobileLAB, a mobile unit equipped with tools and equipment necessary for the inclass preparation of Biomaterials;
- the Community Building Intervention,

which involves the participatory co-creation of an urban Biomaterials-based sculpture;

· the BiomaterialKIT manuals for Families, a comprehensive guide offering recipes and instructions for conducting Biomaterials experiments at home.

2. Methodology

The research promotes awareness and support for schools to use innovative methods and tools to experience Biomaterials in their learning pathways. Introducing new competencies to the youngsters.

The methodological approach settles on participatory action research (PAR), participatory design, and co-creation processes to generate a commitment to the young citizens are the main actors of change with a higher impact on their communities and the future.

2.1 Overall Biomaterialkit process framework for green skills development

Reskilling for green skills and the potential of bio-based solutions.
The research promotes awareness and support for schools to use innovative methods and tools to experience Biomaterials in their learning pathways. Introducing new competencies to the youngsters makes them the influencers of change in their families and friends and acts as a culture of change agents. The Biomaterialkit process flowchart delineates a systematic approach for the development and deployment of Biomaterials through a structured fourphase methodology, based on Divergence, Convergence and Action from the Design Thinking processes (Mateus et al, 2016) see Figure 1.

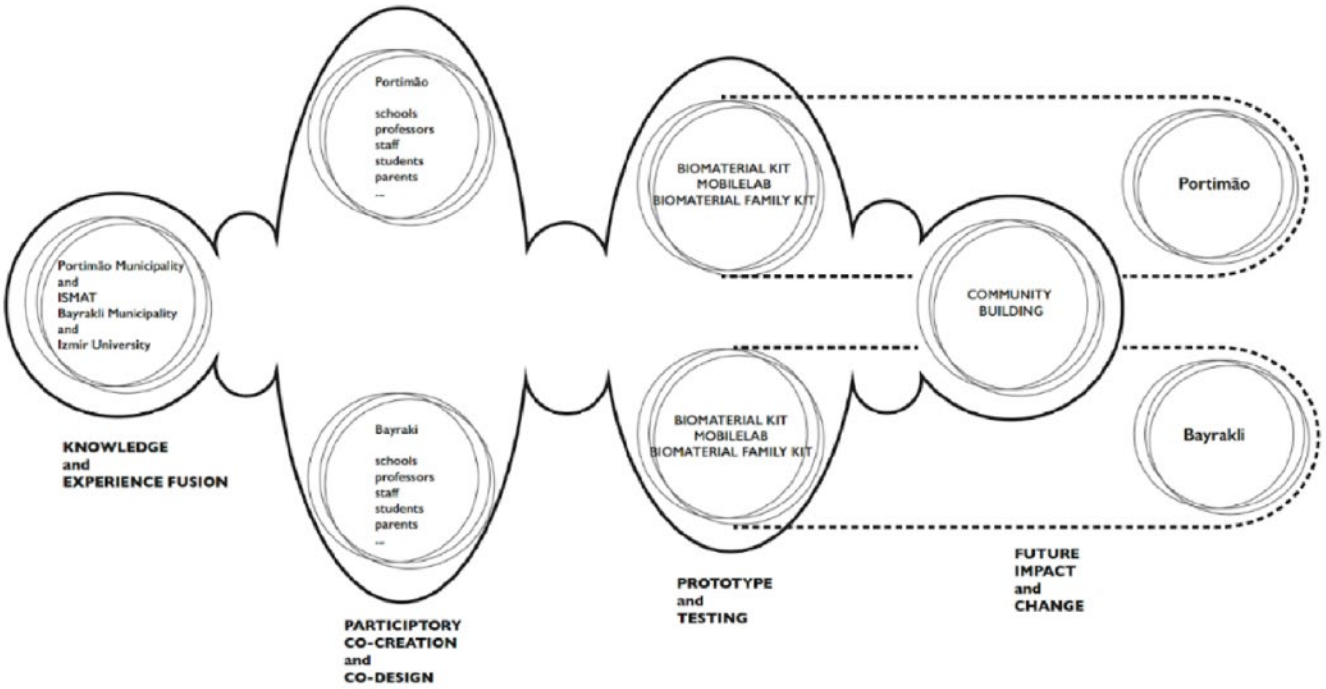


Figure 1. Knowledge flow chart of BiomaterialKIT framework.

Phase 1: Converge

The Knowledge and Experience Fusion framework, conceived by university researchers of the project, underpins the development of tools specifically designed for participatory processes within the BiomaterialKit initiative. These tools were designed to collect and facilitate insights from both the student and teaching communities regarding the development of the BiomaterialKit Manual and MobileLAB. Additionally, they were intended to coordinate community-building events aimed at promoting transformative change. Prior to the development of these tools, a sustainable awareness survey was administered to over 200 students to gauge their consumption habits and their understanding of sustainability and Biodesign. The findings from this survey were instrumental in informing the creation of targeted tools and activities for the subsequent bootcamp sessions, ensuring that the interventions were grounded in empirical data and aligned with the participants' needs and knowledge base.

Phase 2: Diverge - Converge

The participatory co-creation and co-design process encompassed a series of week-long boot camps held with secondary schools in Portimão (PT) and Bayrakli (TR). These multi-stakeholder sessions focused on the introduction of core concepts related to sustainable consumption through co-design methodologies and scenario development. The bootcamps began with an overview of these concepts, underscoring their relevance within sustainable frameworks (Diverge). Following this, students participated in group activities aimed at assessing their current understanding and assumptions about sustainable practices, and at developing actionable strategies for their practical implementation (Converge).

Phase 3: Diverge - Converge

Building upon the findings from the previous phase and the established framework for change, participants engaged in co-design activities to generate a range of potential solutions (Diverge) aimed at addressing the identified needs and innovation opportunities. This phase involved the development of design templates and content for the pedagogical school manual, the familybased recipes manual, and the school's forthcoming MobileLAB. Subsequently, stakeholders were responsible for prototyping the most promising ideas within their groups and presenting these prototypes to one another for evaluation (Converge). The most viable ideas were selected through a voting process involving students and teachers. These selected concepts were then utilized by the final design team, which comprised Biomaterialkit researchers, students from the Design degree at ISMAT, and Master's students from Izmir University.

Phase 4: Action

This phase aims to foster community awareness and drive impactful change among the project's target groups—students, teachers, families, and the broader community. In October 2024, all stakeholders will collaborate to co-create, co-design, and co-implement a communitybuilding sculpture and an urban public space in Portimão and Bayrakli. The sculpture will be constructed using Biomaterials produced in the Schools' MobileLAB and recipes from the families' home manuals. Each municipality has selected a public space for intervention, where a basic structure designed by the Biomaterials research team will be implemented, incorporating the Biomaterials created by the educational community and families. This initiative seeks to promote the project's values and objectives, highlighting it as a transformative community event aimed at encouraging better consumption behaviors and fostering more circular use of organic waste, which are foundational principles of the Biomaterialkit project.

In summary, the process methodology is designed to enhance the skills of the educational community—including students, teachers, staff, families, and friends—in developing green skills. This approach is grounded in an innovative adaptation of Design Thinking processes and methods, which are presented in detail subsequently.

2.2 Participatory Action Research (PAR) & Bootcamp Roadmap

Participatory Action Research (PAR) is a collaborative research approach that involves researchers and participants working together to identify a problem, collect and analyze data, and take action to address the problem (Chevalier & Buckles, 2019). PAR emphasizes the active involvement of community members by decentralizing the professionalized university-based knower in the research process (Fine & Torre, 2021), ensuring that their perspectives and experiences shape the research questions, methods, and outcomes. This approach is often used in social sciences, education, public health, and community development to empower participants, promote social change, and produce actionable knowledge. It also helps create an opportunity to create alternatives to education (Levin & Greenwood, 2008) by experimenting with pedagogy (Freire, 1970; Hooks, 1994).

Since the main aim of PAR is to transform society to be more democratic, equitable and just (Torre, Stoudt & Fox, 2012), the pilot study conducted for the BiomaterialKIT project encompasses over 200 K-12 to K16 students from educational institutions in two distinct cities: Izmir, Turkey, and Portimão, Portugal. This approach ensures that the target groups, embedded within their respective communities, have the potential to make substantial contributions to the project's objectives.

The project is designed to achieve six specific objectives:

- It aims to facilitate dialogue and the exchange of experiences between local stakeholders and between the two countries through the implementation of initiatives centered on Biomaterials and Biodesign.
- The project seeks to identify local natural resources to develop three deliverables for the Biomaterials KIT: a mobile school laboratory, a home toolkit experience manual for families, and a small-scale Biodesign project for the community.
- It will enhance educational skills and competencies by co-creating learning scenarios and experience manuals.
- The project will provide training for teachers, students, families, and the community on Biomaterials techniques and tools, promoting sustainable consumption practices.
- It aims to bridge the gap between schools and homes, fostering a deeper understanding of their roles in altering consumer behavior patterns, with an emphasis on the reuse of natural materials.
- The project intends to increase awareness and visibility of Biomaterials and Biodesign through community interventions and develop an action plan to integrate the Biomaterials KIT approach into the K12-K16 educational system.

Roadmap for Bootcamps

The roadmap for implementing Participatory Action Research (PAR) in the BiomaterialKIT project commences with the establishment of the project's objectives, which focus on advancing secondary education through the integration of cutting-edge knowledge in Biomaterials and Biodesign.

This roadmap spans a five-day period, with each day dedicated to specific thematic stages designed to promote sustainable practices, foster innovative learning, and facilitate hands-on experimentation among students. Each day is connected to a key research question:

- Day 1: Focuses on sustainable consumption habits, aiming to encourage students to recognize and adopt eco-friendly practices. Research question: "How to be Conscious?"
- Day 2: Examines the impact of ideas on behavioral changes. Research question: "How to Change?"
- Day 3: Introduces innovative learning scenarios to stimulate understanding and creativity. Research question: "How to Learn?"
- Day 4: Involves students in the development of Biomaterials manuals, applying theoretical knowledge to practical tasks. Research question: "How to Do?"

· Day 5: Centers on the conceptualization of a MobileLAB, where students experiment with and co-create tangible outputs. Research question: “How to Experiment?”

According to Bradley & et al (2023), the Design Thinking (DT) process must account for two distinct dimensions (see Figure 2):

· Horizontal Axis - Macro View: This dimension outlines the major sequential stages of the process that are anticipated to lead to the desired final outcome. It emphasizes the continuous and active involvement of students and all stakeholders throughout each phase.

· Vertical Axis - Micro View: This dimension details the various layers within each stage of the process, from Divergence to Convergence, to achieve consensus within each phase.

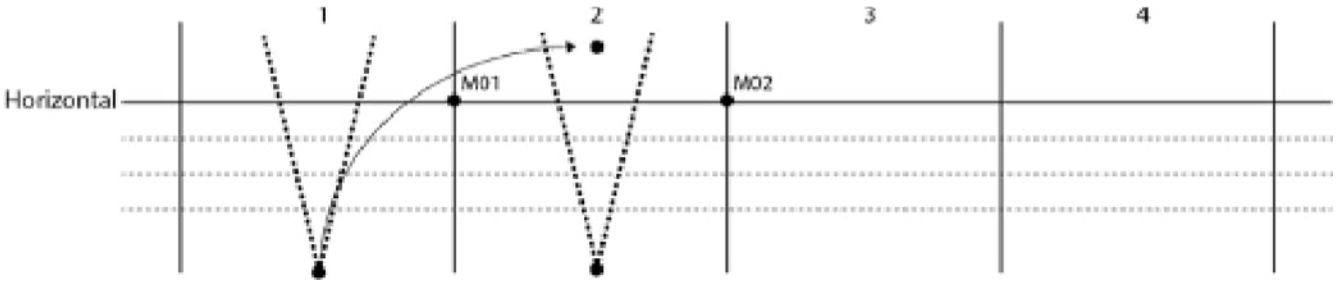


Figure 2. DT Process Macro & Micro Views, Bradley & et al (2023)

Based on the model outlined by Mateus (2016), the BiomaterialKIT program roadmap utilizes a variety of interactive and collaborative tools grounded in Design Thinking (DT) principles. These tools include mapping, ideation, co-creation and three-dimensional modeling, aimed at immersing students in experiential learning. The program incorporates dynamic group exercises, sensory experiences, and hands-on construction tasks, all designed to integrate academic knowledge with creative, real-world applications. The roadmap culminates in cross-fertilization sessions, during which groups consolidate and refine their ideas, present their outcomes, and link them to subsequent exercises to support continuous learning (see figure 3).

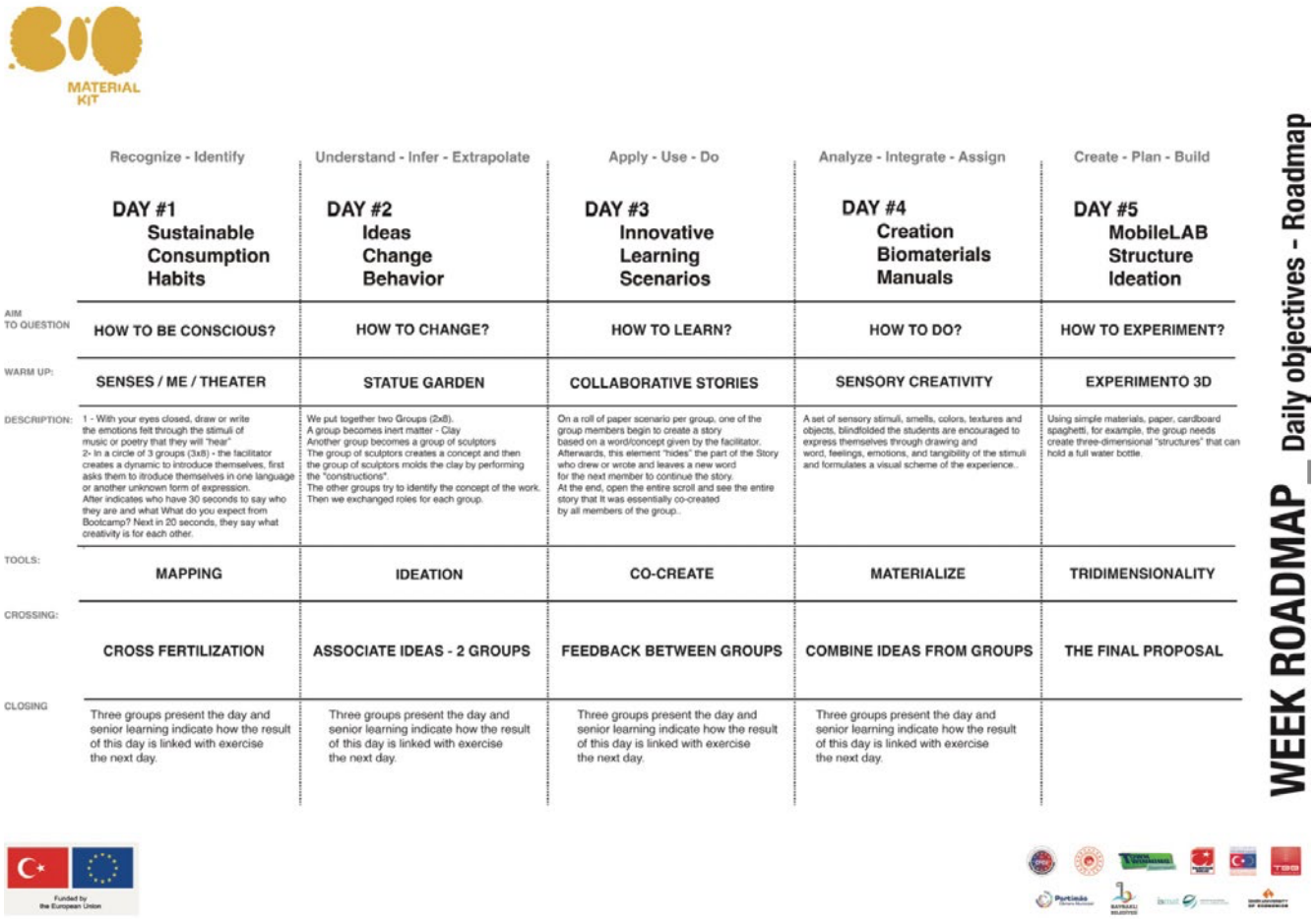


Figure 3. Road Map, the authors (2024)

Within the framework of the Roadmap, the Bootcamp workshop series employs four methodological tool canvases (see figure 4), developed in collaboration with universities and K12 to K16 students from Portimão and Bayrakli. The primary aim is to foster sustainable consumption behaviors among students through interactive and structured activities grounded in co-creation and co-design approaches.

The workshop begins with an introductory presentation that provides an overview of sustainable consumption and presents results from a prior survey. Following this introduction, the sequence of tools initiates group dynamics. Participants are organized into sub-groups of up to eight individuals each. Participants engage with the canvases to examine their knowledge, perceptions, and actions related to sustainability.

Inspirational letters, prepared by the research team, were placed on each work table. These letters presented content in a concise and highly visual manner, addressing the key issues that motivated each stage of the Design Thinking (DT) process. The content was curated to include best pedagogical practices, relevant case studies, exemplary consumption practices, and information on sustainable and circular products (see figure 5).

The workshop is structured around four comprehensive canvases that facilitate selfassessment, brainstorming, and scenario development:

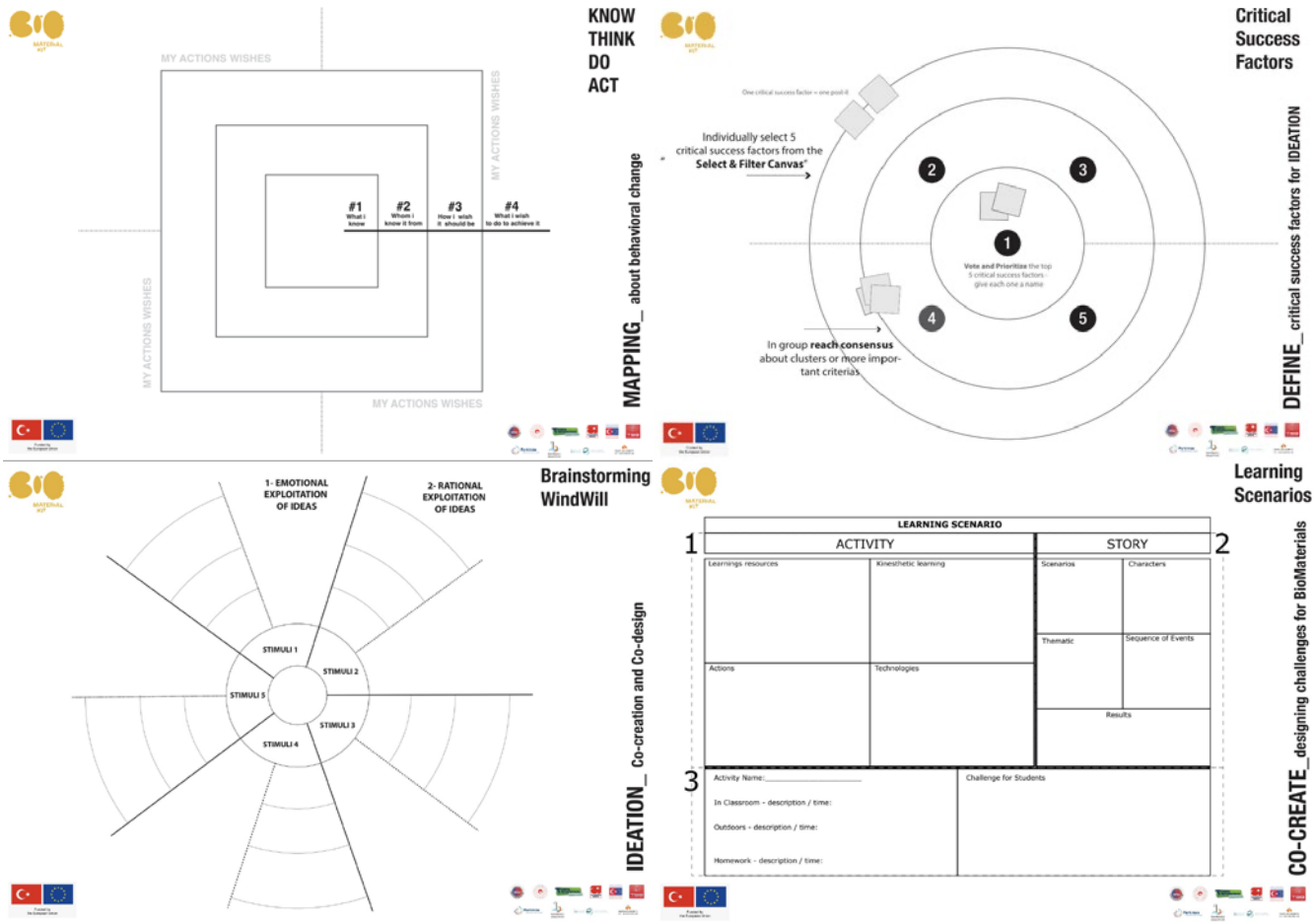
· Tool 01 - "I Know, I Think, I Do, I Act" canvas - encourages students to reflect on their understanding and practices concerning sustainability. Participants document their existing knowledge, identify their sources, describe their current actions, envision ideal scenarios, and brainstorm strategies to achieve these ideals.

· Tool 02 - "Key Success Factors for 'Act'" canvas - extends the "Act" component of the first canvas. In this phase, students individually identify critical success factors necessary for achieving their sustainability goals and subsequently categorize these factors into thematic groups during a collaborative session. The group then prioritizes the top five critical success factors through a consensus-building process.

· Tool 03 - "Brainstorming Windmill" canvas - focuses on collaborative ideation. Students individually propose ideas to achieve the critical success factors identified in the second canvas. The group then selects and refines the best ideas into actionable steps through collective brainstorming.

· Tool 04 - "Learning Scenario I" canvas - involves creating a detailed learning scenario using the top ideas from the brainstorming session. Participants develop a narrative that includes characters, themes, and a sequence of events. They outline expected learning outcomes and describe activities for classroom, outdoor, and home settings, anticipating potential challenges and proposing solutions.

Figure 4. Methodological Canvases for Mapping tools (upper left), Definition (upper right), Brainstorming



Windmill (lower left) and Learning Scenario, the Authors (2024)

Figure 5. Inspirational Cards, Left side Bootcamp Portimão, Right side Bootcamp Izmir (2024)



2.3 Creativity: Bootcamp Co-design process

As previously mentioned, the co-design aspect aims to collaboratively develop three tangible deliverables for the BiomaterialKIT project: a pedagogical manual, a home manual for families, and a MobileLAB to equip schools. The creative process commenced in alignment with the Design Thinking (DT) approach described earlier, building on the results from prior stages, specifically addressing what needs to be changed, how it should be changed, and how students expressed a desire to learn about and utilize Biomaterials. This activity builds on the concept of design-build-test, a common paradigm for students to design an experiment (Pham et. al. 2017). It is important to note that the project design incorporated preparatory activities, wherein the project research teams visited schools in advance to introduce the project, discuss concepts of sustainability, circularity, and Biodesign, and conduct Biomaterials experiments.

Initially, students were tasked with divergent thinking, where each member of the subgroup sketched individual ideas to address the questions, problems, and innovation opportunities identified earlier. Following this individual phase, students presented their ideas to one another and engaged in a dialogue about the ideas, discussing their complementarities and evaluating their creative potential. Through this discussion, each group starts to converge by identifying two combined ideas to explore further as a team. These ideas were then prototyped and prepared for presentation to the larger group at the end of the session

The constraints and objectives for each creative challenge were outlined, with particular emphasis on the MobileLAB. This modular educational laboratory kit is designed to facilitate biomaterial explorations using basic lab tools and equipment. It is intended to be paired with food and domestic waste, as well as low-cost laboratory chemicals, to provide a comprehensive and accessible learning experience.

To address the challenges involved in co-designing the BiomaterialKIT manuals for both school and home environments, and to deepen students' understanding of the context, setting, and pedagogical models associated with Biomaterials and Biodesign, the co-design session began with a demonstration of Biomaterials. This interactive session enabled both students and teachers to engage directly with the process. A series of demonstrations was developed to facilitate creative learning activities, aimed at increasing student engagement and promoting independent, student-driven projects (see figure 6).

Co-design is a collaborative design thinking process that transcends one-directional

feedback, fostering active participation from all stakeholder groups to achieve mutual understanding and shared creativity (Eckhardt, 2021). In the BiomaterialKIT Bootcamp, the co-design process was focused on the students rather than the project itself. The research team acted primarily as facilitators, allowing shared creativity to develop organically among interdisciplinary student groups from diverse schools, age ranges, and areas of expertise. This approach was designed to enhance the creative experience and complementarity among participants, yielding outstanding results that are detailed in the following section.

Figure 6. Biomaterial explorations with paper waste (left & middle) and domestic waste (right).

Figure 7. MobileLAB Ideas from Bootcamp (left) and Biomaterials demonstration





3. Findings & Discussion

The BiomaterialKIT aligns with the goals of the European Union Green Deal, which seeks to make Europe the first climate-neutral continent by 2050. By educating and equipping the younger generation with the skills and knowledge needed for sustainable living, the BiomaterialKIT contributes to the broader objectives of the Green Deal. It empowers individuals and communities to participate actively in the green transition, thereby accelerating the adoption of sustainable solutions and fostering a more resilient and environmentally conscious society.

3.1 Bootcamp outcomes:

The training activities to introduce the pilot program for K-12 to K-16 students reached over 200 students, 50 teachers, more than 600 parents, NGOs, local associations, and municipality representatives. These training activities, along with the co-creation process, led to outcomes that ensure K-12 to K-16 students have the necessary information and awareness for sustainable development and lifestyles in harmony with nature. Through detailed coaching led by professional designers, academics, and school professors, students were introduced to the bio-design thinking process. This initiative also aimed to develop a framework for similar projects at both national and international levels.

The co-creation process further empowered student groups to refine their ideas into the most promising strategies. During this phase, students developed detailed learning scenarios based on these strategies, identifying both opportunities and challenges in achieving sustainable consumption objectives. These learning scenarios were subsequently utilized to develop the MobileLAB (see figure 8) and the BiomaterialKIT pedagogical exploration at the secondary school level. Incorporating the students' co-designed final ideas, these scenarios were transformed into Biomaterial Recipe Cards (see Figure 9).



Figure 8. Bootcamp ideas for the MobileLAN (left) Final design MobileLAB (right)



Figure 9. Bootcamp Ideas for the School manual (left) and the final Biomaterials Cards (right)

3.2 Impact & Opportunities:

The impact of the project was based on the knowledge transferred from students to their wider circles and the integration of bio-based solutions to everyday life problems within educational curricula. This approach ensured that individuals had the relevant information and awareness for sustainable development and lifestyles in harmony with nature. The primary assumption was that visibility of these impacts, through learning about and understanding the use of Biomaterials and the power of bio-design as a powerful tool, would last a lifetime and provide students with skills they could leverage for personal use and future careers. The impact also aimed to enhance policy coherence for sustainable development.

The initial evaluation conducted with the participating school teachers was highly positive. In June 2024, students independently operated a biomaterial lab during their school's open days for the community. Additionally, the main topics learned from the research projects were applied by students at Bemposta School in Portimão to their real-life project, OUSAR, which focused on sustainability and innovative green development in urban areas.

We assume that through this experience, K-12 to K-16 students would continue to be motivated by the BiomaterialKIT and MobileLAB experiences, eventually joining societies, communities, and professional careers worldwide that seek equitable solutions through environmental consciousness. It is expected that the impact of the outcomes would have a lasting imprint on young people, helping them tackle social and environmental issues. Our broader aim was to create an international opportunity and expand the beneficiaries of the project beyond designers and professionals from two different countries, turning it into a compelling encounter and cross-cultural exchange, which was achieved.

4. Conclusion

The BiomaterialKIT project posited that implementing Biomaterials and the BiomaterialKIT would significantly reduce waste generation through prevention, reduction, recycling, and reuse, adhering to the principles of bio-design. The outcomes aimed to achieve environmentally sound management of knowledge regarding Biomaterials and their life cycles, in line with BiomaterialKIT's methodological frameworks, thereby contributing significantly to human health and environmental sustainability.

Additionally, the project sought to foster global partnerships for sustainable development by engaging multiple actors to mobilize and share knowledge, expertise, technology, and financial resources in support of sustainable development goals in both countries. The outcomes encouraged and promoted effective public and societal partnerships, leveraging the experiences and resource strategies of stakeholders.

The co-creation culture encountered differing contexts in Portugal and Turkey. In Portugal, the project benefited from a society with a long-standing tradition of community engagement and a well-established educational framework that supports participatory learning. This context facilitated smoother integration of co-creation practices within educational institutions and public spaces. Conversely, in Turkey, the project navigated a dynamic socio-cultural landscape characterized by rapid economic development and varying degrees of openness to participatory methodologies. The initiatives in Turkey focused on adapting co-creation principles to resonate with local customs and societal norms, ensuring effective implementation of the participatory culture in diverse educational and communal settings.

Despite these challenges, the BiomaterialKIT project successfully cultivated a shared understanding of sustainability and innovation across both countries, highlighting the transformative potential of co-creation and participatory culture in addressing global educational and societal challenges.

Future research should focus on further developing the BiomaterialKIT Education Model to meet the demands of the EU. Establishing contact with other research partners developing projects in this area is essential for structuring a vision that aligns with the new guidelines for the educational system and building a new proposal that can extend this pilot to a broader audience. This expansion is vital for enhancing the impact and reach of the project, ultimately contributing to more sustainable and innovative educational practices globally.

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“THE ‘MARAÑA’ AS A DYSPHORIC NOTION FOR STAYING WITH THE TROUBLES OF REVOLTS”.

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ABSTRACT | Drawing on Donna Haraway’s ‘Staying with the Trouble: Making Kin in the Chthulucene’ (2020), Silvia Rivera Cusicanqui’s ‘Ch’ixinakax utxiwa: A Reflection on Practices and Discourses of Decolonization’ (2010), and Paul B. Preciado’s ‘Dysphoria Mundi’ (2022), this paper aims to develop the notion of the ‘Maraña’ as both a theoretical-methodological and political tool. Through design research, this concept helps to address the complexities of a world that has entered a state of global tumult. The ‘Maraña’ is understood as a way to view socioecological phenomena as dense entanglements of forms, materialities, and intersubjective expressions that cannot be approached fragmentarily without losing their vitality and potential for becoming. Given its inherently intertwined nature, it is not apparent where each enmeshed component begins and ends. The ‘Maraña’ challenges the classic scientific rationality of modern epistemology, which tends to reduce phenomena to the mere sum of their parts, objectifying and sanitizing each phenomenon, thereby creating the illusion of understanding that would allow for control and prediction of its future. Following the etymologist Yakov Malkiel (1948) and his work on the concept, the word ‘Maraña’ has a polysemic and evocative character that allows for situated interpretations according to each object and context to which it may be referred. Consistent with its own logic, the word is tangled. It evokes everything from weeds and brush in Botany, a tangled mass of chords in music, to a difficult issue to resolve, thus precluding any univocal meaning. This paper aims to propose a critical and transdisciplinary elaboration of the notion of the ‘Maraña’, outlining its epistemological foundations and its theoretical-methodological potentials for design research, exemplified in relation to certain aspects and moments of the 2019-2020 revolt in Chile.

KEYWORDS | MARAÑA, DYSPHORIA, REVOLTS, CRITICAL DESIGN RESEARCH

1. Introduction

On Friday, October 18, 2019, a cycle of protests began in Chile, spreading across the country until mid-March 2020, when Covid-19 containment measures were implemented (Aguilera & Espinoza, 2022; Fernández Droguett, 2022). This cycle of protest, referred to as the social outbreak or uprising (Cuevas Valenzuela & Budrovich Sáez, 2020), commenced after two weeks of high school students' demonstrations in the capital's metro stations against fare increases. Within days, these protests extended throughout Chile, marking the largest demonstrations since the return to democracy in 1990 (Aguilera & Espinoza, 2022). Beyond the various labels for this cycle, what is significant is that it reflects

"a crisis of the commitments and organizational principles underpinning the regime of 'neoliberal capitalist democracy' of the post-dictatorship era, as well as the discourses, social grammars, practices, and institutions that sustained them. Indeed, during the events that began in October 2019, outside the party system and democratic institutions, society experienced an acute process of re-politicization in a series of unconventional formats"

(CUEVAS VALENZUELA & BUDROVICH SÁEZ, 2020, P. 178).

While the uprising encompasses multiple dimensions, including the protagonism of young people (GANTER SOLÍS & ZARZURI CORTÉS, 2020; Infante Aravena & Cárdenas Castro, 2022; Paredes & Valenzuela, 2021; Rivera-Aguilera et al., 2021), the management and distortions of the phenomenon's communications (Basulto Gallegos et al., 2023; Herrera et al., 2022; Riffo-Pavón et al., 2021), and the hypotheses on the reasons behind the revolt (Aguilera & Espinoza, 2022; Akram, 2021; Artaza, 2019; Matus, 2019; Morales Quiroga, 2020; Urzúa-Martínez & González Franzani, 2022), the occupation and appropriation of public space by mobilized citizens stands as a central aspect of the event. Various authors (Campos Medina & Bernasconi Ramírez, 2021; Fernández Droguett, 2022; Márquez, 2020; Orellana Águila, 2022; Paredes P., 2021; Pinochet Cobos, 2021) highlight that public space

became the principal stage of the revolt, not only through its intensive occupation over months via demonstrations in the streets and squares of different cities in Chile but also through the material and symbolic interventions that radically transformed the infrastructures and everyday imaginaries of public space. This transformation included graffiti, posters, murals, signs, and other visual interventions, which Campos Medina & Bernasconi Ramírez (2021) referred to as "graphic explosion."

"The writings of the uprising expressed the set of citizen demands, the variety of requests made by inhabitants to their authorities. They captured the progressive definition process of the demands, showed the commonality of needs, contributed to profiling the actors of the conflict, and formulating the antagonisms. They recorded the violence in its various forms and bore witness to the risks and dangers of the protest, but they did all this materially: there were mural writings, constant text replacement, overlapping layers, and collage, different messages coexisting on the same wall and dialoguing among themselves, in a variety of techniques and supports. All this accounts for the polyphony of writings, but it is also a material record of the protest and leads to thinking of the urban space as a kind of archive of the present"

(CAMPOS MEDINA & BERNASCONI RAMÍREZ, 2021, P. 117).

In a previous work, we conceptualized these forms of occupation and appropriation of public space as insurgent co-design (Fernández Droguett et al., 2023). Relatively spontaneously and emergently, the mobilized citizenry intervenes and transforms public space based on the needs of the uprising, ranging from political expression through various visual interventions to the destruction of streets and urban furniture to erect barricades and thus protect themselves from police repression (Fernández, 2021; Orellana Águila, 2022). It should be noted that these transformations of the neoliberal city (Pinochet Cobos, 2021) not only operate on the infrastructures and flows of the capitalist logic of the prevailing social order but also on material and symbolic layers that transcend the present and immediate past.

In this vein, Silvia Rivera Cusicanqui's notion of Ch'ixinakax utxiwa (2010) prompts bodies and collectives to consciously act against injustices, based on reflection on their own experiences and those of others to develop actions of resistance. Rivera Cusicanqui emphasizes that this is not just a theory but a living practice, involving a continuous process of struggle, self-affirmation, and self-criticism. In Ch'ixi practices, the incorporation of modern elements within traditional Andean ways does not show a process of hybridization but a complex and intertwined way of inhabiting that *enmaraña* the component identities, keeping them active and productive, allowing new cultural forms and practices to emerge that are simultaneously traditional and modern, political and transcendent. Resistance arises from collaboration and the ability to maintain and adapt practices that imbricate

collectives and worlds, in response to modern and neoliberal pressures and influences.

In accordance with this perspective, we consider that the notion of *maraña* allows us to approach the set of elements, relationships, and contexts that comprise the uprising as a complex and dynamic whole. As we will explain in more detail later, we understand *maraña* as a way of viewing social phenomena as an entanglement of forms, materialities, and intersubjective expressions that cannot be approached in a fragmented manner without losing their emergent configuration and the vitality they perform.

The present work aims to address some aspects of the occupation and appropriation of public space during the uprising and how these aspects transformed its morphology, aesthetics, uses, and meanings, constituting a *maraña* that should be analyzed by identifying its complexly articulated components. This approach aims to advance the understanding and account of the vitality and potency of the phenomenon. By approaching from a vision situated within the *maraña*, we align ourselves with a series of conceptual, epistemological, empirical, and political efforts that seek to move away from positivist pretensions of understanding social phenomena as merely the sum of variables susceptible to being addressed in fragmentary and reductionist ways. These positivist approaches not only reduce the comprehension of the uprising but also, by transforming its isolated parts into "objects" of study, often omit or reduce its vitality and the potency of its *enmarañada* coexistence.

The research methodology is qualitative in nature (Duarte, 2023; Sisto, 2008; Vasilachis, 2006), as it seeks to understand phenomena by integrating their subjective, intersubjective, relational, material, aesthetic, symbolic, contextual, and historical dimensions. Specifically, a photoethnography (Hermansen & Fernández, 2018, 2020) was conducted on the protests of the uprising between October 2019 and March 2020, in the area of Plaza Baquedano—renamed Plaza Dignidad—and Plaza Ñuñoa. During this period, participant observations and written and photographic records of the political uses of public space by protesters occupying these places were made.

2. Theoretical Perspectives: Analyzing how the theories of Haraway, Preciado, and Rivera Cusicanqui can inform and enrich resistance practices in the Maraña.

2.1 The Notion of Maraña

The etymological work of epistemologist Yakov Malkiel (1948) on the word *maraña* evidences its polysemic and suggestive nature, which invites situated interpretations corresponding to what it refers to or the context in which it is used. According to its own logic, the word is *enmarañada*. Its rich etymology is as diverse and promiscuously intricate as it is fertile in definitions and connotations. We stubbornly use it in Spanish because, as Yakov Malkiel (1948) described,

it is in this language where this difficult-to-translate word unfolds its richest range of meanings. It can denote a set of threads, hairs, or similar things tangled in such a way that they cannot be separated; in botany, it refers to a "weed, shrub, bush"; in music, to a "tangled mass of chords"; in logic, to a "difficult issue to resolve"; morally, to a "deception, trick or hoax" either human or demonic (Malkiel, 1948). Each *maraña* is unique, intertwining elements intricately that are incomprehensible to those not situated in the respective *enmarañamiento*. However, we can recognize that its different meanings and uses underlie a certain continuity. We will use the notion of *maraña* to indicate an entanglement of human and non-human entities, material and symbolic, that cannot be understood separately without stifling the vitality of the environment that intertwines them and whose metabolism exceeds (de la Cadena, 2015) the explanatory capacity of modern epistemology (Hermansen & Fernández, 2024; Hermansen & Guerra, 2023).

2.2 "Staying with the Trouble" to Coexist in the Maraña

In her theory of knowledge, Haraway develops the notion of situated knowledges in which she establishes the centrality of the gaze. However, following Borotto (2019), this notion of the gaze is not reduced to the mere processing of visual stimuli but is always laden with socio-historical significance that simultaneously constitutes both what is seen and who is seeing. For Borotto (2019), these processes of signification unfold through metaphors, using a language evocative of images, multiple and complex readings, distancing itself from the literal and reductionist language of classical science. As Borotto points out, this language

"pretending to offer a faithful description of the world, imprisons our perceptual capacity in rigid modes of visualization that induce us to think that the described world is the only possible one. It would be the normative effect of a language with claims of literalness. Against this, figurative language can bring to our visual field what has been arbitrarily excluded under the pretext of objectivity, rationality, and neutrality. Thus, the use of metaphors in Haraway becomes a subversive gesture"

(BOROTTO, 2019, P. 273).

For Caeymaex (2019), Haraway's (2016) writing deploys a technique and a pragmatics of meaning production where words and images train our sensitivity and invite us to conceive more-than-human modes of coexistence.

While a series of concepts have been proposed to address these imbrications – complexity, assemblages, hybridity, rhizome – we consider that these do not fully account for the qualities of coexistence in the current global upheaval, nor for the emerging modes of epistemic pain (Preciado, 2022) or correspondence (Ingold, 2017) between socio-environmental reality and the embodied ways of knowing and inhabiting it.

2.3 "Dysphoria Mundi" and Epistemic

Pain in the Maraña

Paul B. Preciado (2022) introduces the notion of "Dysphoria Mundi" to describe a global condition of profound discontent with the state of the world. This condition responds to the ecological crisis, structural inequalities, and the imposition of norms on bodies to restrict the free flow of identities and their potential for enjoyment. Preciado advocates for reconfiguring power relations and breaking with the normative systems that govern bodies and relationships, systems, and environments. They describes Dysphoria Mundi as "the resistance of a large part of the planet's living bodies to being subordinated within a petro-sex-racial knowledge and power regime; the resistance of the living planet to being commodified as capitalist merchandise" (Preciado, 2022, p. 22).

Preciado does not understand the body as an anatomical entity nor dysphoria as a psychiatric concept referring to a gender identity disorder. Instead, they conceives the body as a "somatotheque," a site of political action where technologies and power relations are instituted and dismantled. The body as a somatotheque is a battlefield where forms of identity, sexuality, and gender are negotiated and contested, containing the potential to dismantle racial, sexual, cultural, economic, and ecological inequalities and violences. The somatotheque, as a body *enmarañado* whitin the world, is a collective site from which to initiate and sustain the revolution against the petro-sex-racial order – of decarbonization, depatriarchalization, and decolonization. From this perspective, dysphoria is not a pathological alteration of the anatomical body with consequences on the sense of sexual identity, but a way of life in response to a new regime of knowledge-power through experimental life practices, which allow for understanding what Preciado calls "epistemic pain."

The "epistemic pain," as described by Preciado (2008) in "Testo Yonqui," is both personal and collective and arises from the experiments of hacking their somatotheque to resist the prevailing social order. Hacking their own body is not limited to its physical transformation but also implies a profound identity reconfiguration and a corporeal confrontation with the power structures that regulate and control bodies. Epistemic pain is, therefore, a constitutive part of the revolutionary process. It is the pain of dismantling and restructuring the frameworks of knowledge and the identity categories that have been internalized in bodies throughout life.

"It is necessary to understand dysphoria mundi as a general somatopolitical condition, the pain produced by the necropolitical management of subjectivity, while at the same time pointing to the potential (not the power) of the planet's living bodies (including the planet itself as a living body) to extract themselves from the capitalist, patriarchal, and colonial genealogy through practices of inadequacy, dissidence, and disidentification."

(PRECIADO, 2022, P. 27)

Recognizing ourselves as densely

enmarañados means experiencing epistemic pain while we try to hack ourselves to hack the categories and structures that the machines of capital, desire, and discourse production impose, describing them as sources of security and pleasure. Epistemic pain is inherent in the process of resistance and personal and social transformation, emerging from abandoning established certainties and identities to embrace new forms of relationship and existence.

In its constant reconfiguration, the Maraña demands a permanent adaptation of our coexistence, confronting us with renewed epistemic pains that derive from the struggles to reconfigure the frameworks of reference and life practices imposed by the neoliberal city. This painful confrontation is necessary to resist in a dysphoric and crisis-ridden world. Living enmarañados requires both an ethics of care and responsibility – the capacity to respond – shared by interconnected entities, as well as dysphoric policies and confrontational struggle. This implies constant intersubjective attention and consideration, along with the disposition for struggle and self-defense. By confronting and undermining oppressive embodied structures, the potential for building more just and equitable relationships opens up. The ethics of care, dysphoria as a will to resist, and responsibility in the Maraña are, inevitably, sources of epistemic pain, as they modify our bodies, demanding a constant revaluation of our actions, positions, and their affective and practical impacts on the interconnected fabric of dense coexistence.

2.4 “Ch’ixi” as Enmarañada

Coexistence

Following the reflections of Silvia Rivera Cusicanqui, we consider that both Latin America and marginalized territories by the Modern Capitalist World System (Bautista, 2015) have myriad histories of particular resistances. These need to be understood, shared, and incorporated to establish new ways of recognizing, transforming, and making worlds. When describing the notion of *Ch’ixinakax utxiwa*, Rivera Cusicanqui (2010) emphasizes that this is not merely a theory but a living practice that involves a constant process of struggle, self-organization, and self-critique, during which mobilized bodies and collectives consciously act against their colonization, exploitation, and marginalization.

We propose that the notion of Ch’ixi can be revisited as a situated manifestation of the *Maraña* in the Andean cultural context. In Ch’ixi practices, the imbrication of modern elements within traditional Andean modes should not be seen as a process of hybridization but as a form of coexistence that demonstrates the *Maraña* as an existential condition: complex, intertwined, and without a clear or final resolution among the entities and identities that compose it and give it vitality.

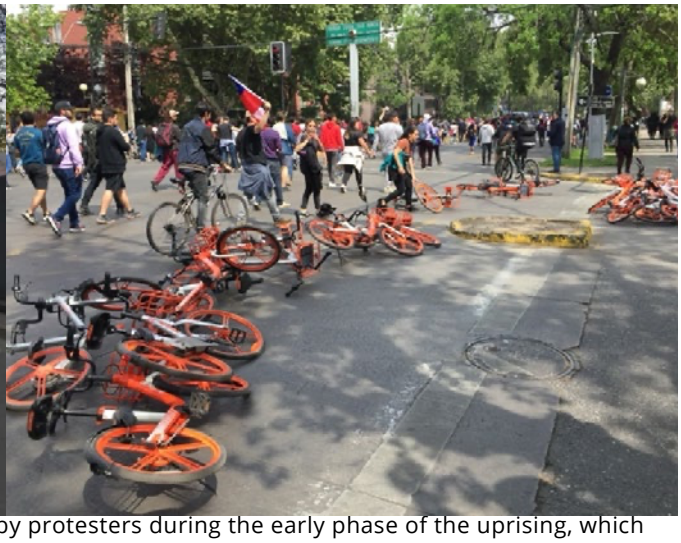
We embrace for the *Maraña* the quality of Ch’ixi that does not seek to homogenize differences but rather to keep their constitutive tensions active and productive, thus favoring the emergence of new modes and cultural practices that are simultaneously situated

and modern, political and transcendent. In Ch'ixi, the relationships between traditional and modern modes of coexistence, spiritual and economic, sustain their *enmarañada* vitality and suggest forms of resistance and adaptation. In the *Maraña* as in Ch'ixi, resistance arises from collaboration, friction, and the ability to apprehend (Butler, 2009) and adapt practices among subjects and worlds, in response to modern and neoliberal homogenizing pressures and influences. Bringing these concepts together offers an interpretative perspective that allows us to delve into understanding how collectives and environments can be seen as places of constant transformation. We believe this intersection is crucial for thinking about the decolonization of our ways of life, to recognize ourselves as bodies coexisting in *enmarañados* contexts.

3. ANALYSIS

On Friday, October 18, 2019, after two weeks of protests in metro stations by high school students against the fare hike, authorities decided to close most of the stations in the metropolitan network to avoid new demonstrations. However, this led to the protests shifting to public spaces, with increased intensity in the late afternoon outside the stations and then in emblematic places in the city. Thus, from 7:00 p.m. onwards, people began to gather in the main squares of the city to continue protesting. Over the days, the protests grew, and the mobilized citizenries became *enmarañada*, managing to resist police repression and settle in key urban areas. Just as had happened with the protests in the metro stations in the first weeks, the authorities criminalized the protest and deployed unprecedented repression since the return to democracy in 1990, resulting in the death of about 30 people and thousands of injured and detained. The protests continued until mid-March 2020, when they were interrupted by the lockdown measures to combat the Covid-19 pandemic.

As we pointed out in the introduction, the political occupation and appropriation of public space was a central axis of the uprising, which involved, as we can see in images 1 and 2, not only the occupation of squares and streets but also their blockade. Since the first day, the security forces developed a strong repression, consisting of the disproportionate use of water cannons and tear gas, as well as the shooting of tear gas bombs and rubber bullets. The protesters' street blockades began to be complemented with the use of urban furniture, such as fences and construction materials, as well as objects like shopping carts and rental bicycles. However, as the weeks went by and the repression increased, the street blockades became increasingly complex, systematic, and organized. This transformation, which involved a growing *enmarañamiento* of the protesters with the environments where they were located and their infrastructures, is evident in the comparison of photos 1 and 2, taken in the first days of the uprising, with photos 3 and 4, taken in December and January.

Images 1 and 2: These images show two barricades set up by protesters during the early phase of the uprising, which can be dated until November 2019.

Images 3 and 4: These images show two barricades constructed by protesters to defend the boundaries of the




occupied territory. By December 2019, the structures of these defenses reflect the emergence of an increasing level of organization and settlement in the areas occupied by the mobilized citizenry.

While during the first days of the uprising, citizen protests took place almost throughout the

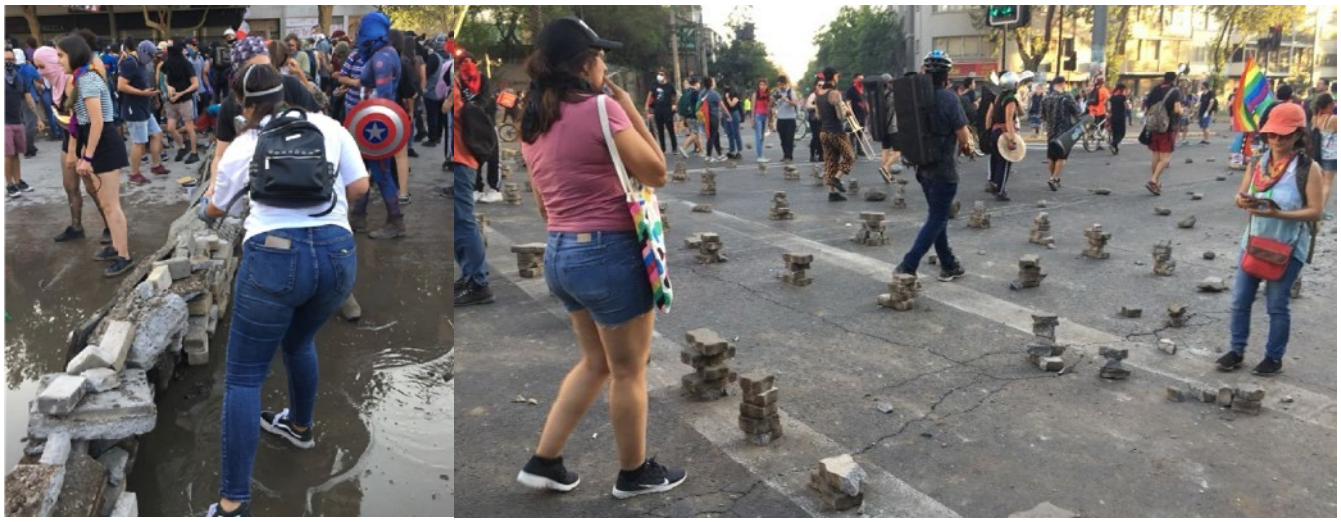
city, after a couple of weeks, they began to concentrate in strategic locations. Simultaneously, Plaza Italia, renamed by the mobilized citizenry as Plaza Dignidad, established itself as the symbolic center and main gathering place. This plaza, which has been a meeting point for citizens since the late 19th century, was occupied almost daily by the protests, with the largest and most violently repressed demonstrations occurring on Fridays. In this context, and as weeks passed, a growing organic citizen mobilization emerged, whose complexity is expressed in a spontaneous diversification of roles and specialization of respective tasks. One of the most emblematic groups was the *Primera Línea* (First Line), a sector of protesters who systematically confronted law enforcement to prevent their advance towards the center of the Plaza, where the majority of the demonstrators gathered peacefully. Along with throwing stones and other blunt objects, the *Primera Línea* erected barricades constructed with urban furniture, construction materials, and later also, in coordination with other mobilized sectors, began breaking sidewalks and pavements to obtain stones for use as projectiles and defensive barriers against repression.

As seen in images 5, 6, 7, and 8, individuals from various collectives participated in these activities collaboratively, constituting an emergent and certainly spontaneous organization – in the sense that throughout the uprising, there was no leadership from political parties or social organizations. This independence from organizations that have traditionally channeled citizens' political demands allowed for the emergence of original ethics and aesthetics of the uprising, whose modes of expression and action are possible only from a spontaneous and unprecedented entanglement of diverse subjectivities that coordinate and gather to protest. The uprising operated under a "self-convened" logic, whose organicity was undoubtedly greatly favored by the use of social media. Along with sustaining autonomous coordination, social media allowed for challenging the narratives that mass media tried to impose, in alliance with political and economic powers, to criminalize the citizen uprising. Images like these practically demonstrate the alliance between different sectors converging in Plaza Dignidad, discrediting the version that mass media attempted to impose, namely that there were violent groups acting independently of those protesting peacefully.



a quarry, and image 6 shows a line transporting the stones to be used as projectiles, in barricades, or for demarcating the territory.

Images 7 and 8: Show different but complementary uses of stones from the quarries. In image 7, stones are used to build a defensive wall against police attacks, while in image 8, they are stacked as boundary markers for a



cultural event.

Drawing on Rivera Cusicanqui's notion of Ch'ixi (2010), images 5, 6, 7, and 8 particularly

highlight the entanglement of aesthetics and discourses in political, practical, and affective alliances. We observe the coexistence of leftist discourses and pop graffiti, Mapuche emblems, and sexual diversity symbols, Tinku collectives with Captain America. By associating their agencies in a complementary manner, they entangle politically and affectively, exceeding the classical limits of the subject, thus challenging the traditional classifications used to comprehend and interpret this manifestation of civic discontent.

Images 9 and 10: We observe scenes of the constructive and destructive agency of the uprising. In image 9, we see one of the entrances to the Baquedano metro station





blocked by a barricade intended to hinder the repressive assaults of the police forces. In image 10, we observe the transformation and reinterpretation of the center of Plaza Dignidad through the entangled superimposition of expressions from the multiple and diverse identities and sentiments that gathered and interwove there.

The barricades erected at various points in the area serve as material evidence that these places have been transformed into borders of the occupied territory and scenes of intense confrontations. As we see in image 9, one of the most heated locations is the main exit of the Baquedano metro station, which faces directly towards the plaza. This station hosted the main demonstrations before October 18th, gaining particular importance due to the high level of repression towards the students, with several of them being detained and illegally confined within the station's premises. Later, although the station was closed, the police forces stationed inside would often emerge to throw tear gas and shoot rubber bullets at the demonstrators outside. These covert repression practices demanded the constant vigilance of the demonstrators, who would frequently throw stones inside and build barricades to try to block police actions, as seen in image 9.

The analysis of images 9 and 10 highlights the constructive and destructive dimensions of insurgent co-design actions, revealing an entangled continuum. The destruction of urban furniture to build barricades is combined with the creation of new forms of community

organization and resistance, evidencing the vitality and complexity of the phenomenon. While image 9 shows the destruction and disabling of one of the entrances to the Baquedano metro station through a barricade, image 10 presents a constructive intervention, transforming and reinterpreting the existing infrastructure through the entangled superimposition of the multiple and diverse identities and sentiments that converged and intertwined there. This original landscape of the uprising in Plaza Dignidad, filled with vitality, constitutes a milestone of our memory, of an experienced event that, as such, has the potential to be present over and over again.

4. CONCLUSIONS

The collective action in Plaza Dignidad was not just the result of individuals acting together, but of the convergence of identities, wills, and experiences that deeply intertwined, creating a robust and resilient social fabric that allows us to invoke the notion of Ch'ixi (Rivera Cusicanqui, 2010) as a precedent. This interconnection reinforces the idea of *enmarañamiento* as a cocreative process that is not only physical but also social, political, and affective. Through the resistance and reinvention of the places they cohabited, the demonstrators challenged official narratives and established powers, proposing new ways of understanding citizenship, politics, and community, essentially what we hold in common. As we have conceptualized in previous works, these entangled forms of occupation and appropriation of public space can be understood as insurgent co-design (Fernández Droguett et al., 2023), as they emerge from the same political manifestation practices, forming a complex and vital collective metabolism (Haraway, 2016), which reconfigures urban infrastructures, their uses, and meanings in a consistent and consonant manner with the course of the uprising, while embracing and not homogenizing the identities that constitute it.

This can be seen as an *enmarañamiento* between ethics, politics, power, and resistance, where each action in the Plaza redefined the balance of forces in the city and the country. Based on what has been observed, we consider that the notion of *Maraña* allows us to address the complexity of current social phenomena in a situated and pertinent manner, with a broad and dysphoric theoretical-methodological approach (Preciado, 2022) that approaches phenomena without simplifying, homogenizing, or stifling their vitality.

The social uprising in Chile represents a decolonizing gesture against the neoliberal city, demonstrating how the mobilized citizenry reappropriates urban infrastructures and transforms them into raw materials—stone and metal—to build and defend their own world. This transformation challenges the materialities and meanings imposed by colonialism and neoliberalism, turning them into devices of struggle and resistance. In turn, the citizenry, through mobilization, digests and reappropriates urban structures, contesting their original meanings and utilizing them

for their own purposes. This Ch'ixi process transforms the city through an insurgent and vital co-design of its space, where temporal and symbolic layers overlap and intertwine, resisting the logic of invisibility and erasure present since the disruption in the pre-Hispanic past, the imposition of the modern State, and currently, the logics and infrastructures of neoliberalism (Bautista, 2015).

The mutations of the Plaza Dignidad sector can be traced back to the early 20th century, showing how the plaza has been reconfigured as a space of capital and human resource flows, attempting to negate its character as a place of citizen gathering and political expression. The recurring appropriations of the place, such as football celebrations and political demonstrations, emerge as practices and knowledge available in the collective memory of this urban sector, challenging the transactional logic and capital multiplication that the neoliberal city seeks to impose.

The emergence of Plaza Dignidad, as a territory, is the result of self-organization. Its construction, configuration, and defense were emerging and collective practices of insurgent co-design (Fernández Droguett et al., 2023) through which various groups materialized, if only for a moment, another world, one that had previously only been imagined, transforming the city into original stone and tools of struggle. Barricades and other interventions not only serve as physical defenses but also organize and structure new practices of culture, health, and commerce in the occupied and re-signified public space.

These practices challenge and transgress, both materially and symbolically, the neoliberal urban planning of the city (Pinochet Cobos, 2021). These practices challenge the institutional logics with which cities have traditionally been designed and offer us 'new alternatives for a common future' (Pinochet Cobos, 2021, p. 2). These insurgent co-designs deploy practices of urban appropriation and transformation that have the potential to inform and inspire new ways of designing and constructing urban environments and public spaces that are more democratic, interpretable, transformable, and relevant to contemporary modes of inhabitation and the demands of modern citizenship.

Living *enmarañados* demands an ethic of care and shared responsibility, where the actions of some affect all. This ethic, combined with struggle and self-defense, allows for confronting and dismantling oppressive structures, opening the possibility of constructing more just, plural, and equitable relationships. Finally, we emphasize again the notion of *Maraña* as a useful tool to situate ourselves and understand the complexity of current social phenomena, allowing us to approach the uprising from a perspective that integrates ethical, political, and epistemic dimensions without reducing its vitality or homogenizing what it comprises.

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RESEARCH ON FASHION CLOTHING DESIGN STRATEGIES FOR THE YOUNG ELDERLY FROM AN INCLUSIVE PERSPECTIVE

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ABSTRACT |

As the global population ages, the consumption power and social activity participation of the young elderly have significantly increased. Inclusive design, a wellestablished design approach, is redefining many industries, including fashion. The young elderly are gradually becoming an indispensable consumer force in fashion design, necessitating a reevaluation of their composition and boundaries. This research employs methods such as literature review, case studies, and focus group interviews to focus on the redefinition and new characteristics of fashion design for the young elderly from an inclusive perspective. The study adopts an adaptive design paradigm to comprehensively optimize the economic and environmental benefits throughout the fashion design product lifecycle. It then analyzes the value and necessity of fashion design for the young elderly from three dimensions: user, function, and value. This research proposes fashion design principles (design relevance principle, social coherence principle), methods (inclusive design method, experience design method, etc.), and development processes based on inclusive design for the young elderly. Finally, these principles and methods are validated and optimized through design practice. This study aims to provide theoretical support and practical references for the fashion design industry in addressing the needs of the young elderly amid global population aging, further promoting high-quality development in the fashion design industry.

KEYWORDS | INCLUSIVE DESIGN, YOUNG ELDERLY, FASHION DESIGN, DESIGN METHODOLOGY, FASHION INDUSTRY

1. Introduction

Population is the cornerstone of social development. However, population aging has become a global trend(Bai, C et al., 2020). According to the "World Population Prospects 2024: Summary of Results" report released by the United Nations, by the end of the 2070s, the global population aged 65 and above is expected to reach 2.2 billion, surpassing the population under 18 years old(Wang, H et al., 2024). In the mid-19th century, France became the first country to enter an aging society, followed by several developed countries such as Sweden, the United Kingdom, the United States, and Japan. Mildly aging countries are mostly distributed in Asia and South America, moderately aging economies are mainly found in North America and other regions, and heavily aging countries are concentrated in Europe (Lutz W et al., 2008). Japan has become one of the most severely aging countries in the world (Coulmas F, 2007). Currently, the elderly population over 60 in China has exceeded 260 million, accounting for 18.7% of the total population (Zhang, M et al., 2024). China entered a deep aging phase in 2021, with the proportion of the population aged 65 and above rising to 15.4% in 2023. According to the latest data from the National Bureau of Statistics of China, by the end of 2023, the population aged over 60 had reached 297 million, accounting for 21.1% of the total population, and it is predicted to grow to 500 million by 2050. The increasing trend of population aging in China is gradually putting pressure on the social pension system(Chang, Z. 2024).

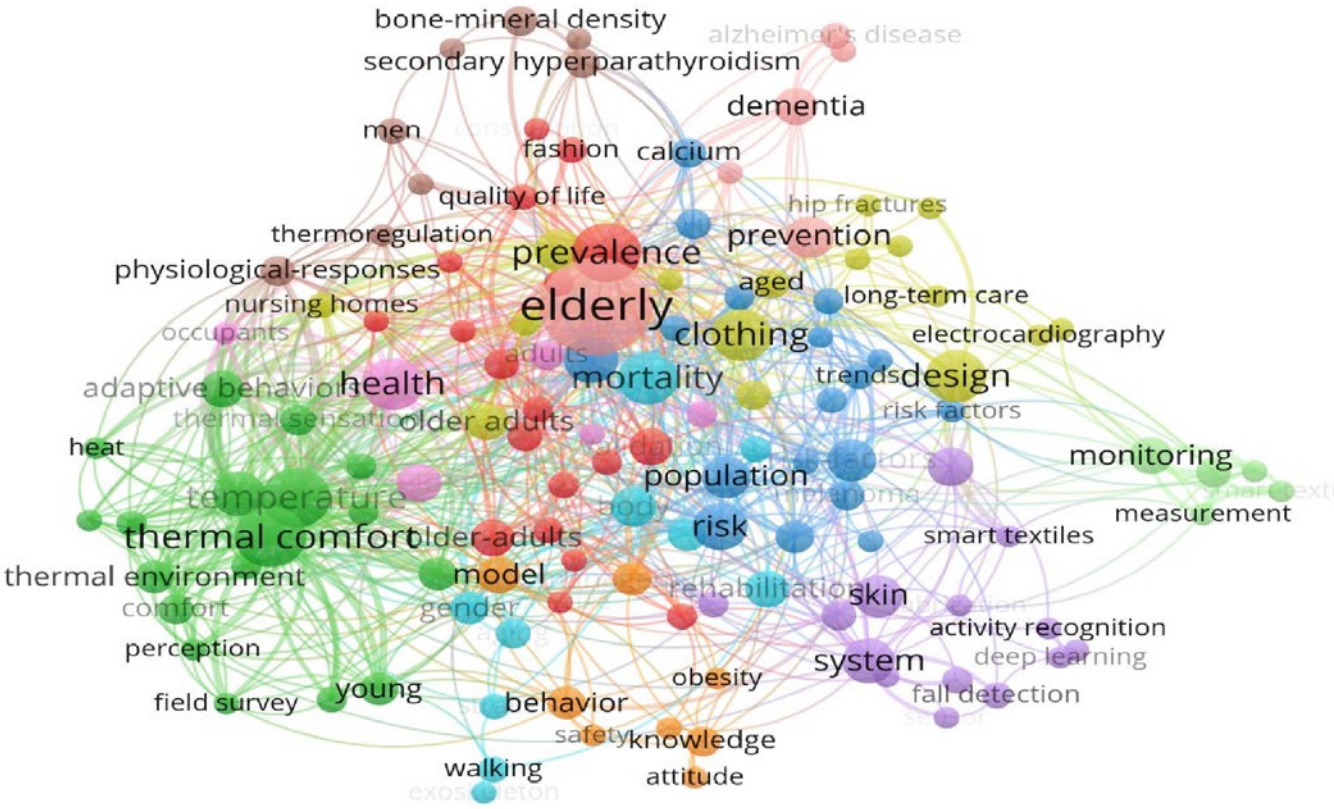
As the elderly population continues to expand and the quality of life and life expectancy of the elderly improves, the global aging industry has vast market potential and promising development prospects, becoming a new growth point for economic development. Karin Schmidt-Ruhland proposed in 2011 that with the changing population structure, the demand for products and assistive tools from the growing target group of the elderly is increasing. The changing demographics present significant challenges for the manufacturing and service industries, as traditional products do not meet the needs of the elderly, and many needs and requirements for this age group are not currently addressed (Schmidt-Ruhland K et al., 2011). Anna pointed out that the young elderly group seems to be gradually forgotten, with few consumer products available to

them (Sell A et al., 2017). Sandrine Dupont Rocher suggested in her 2016 study that the young elderly have specific characteristics, and research results targeting this subgroup should not be generalized to the entire elderly population (Dupont Rocher S et al., 2016). Christer Carlsson in his research highlighted that European policymakers often focus on the elderly population but fail to give targeted attention to the young elderly, an important and unique subgroup (Carlsson C et al., 2023).

As the trend of population aging intensifies, the young elderly are becoming an indispensable consumer force in the fashion market. This group not only has strong purchasing power but also shows a high demand for fashionable and personalized products, seeking not only material satisfaction but also self-expression and social needs. However, current market offerings often fail to meet their complex needs for fashion, comfort, and ease of use, indicating that traditional fashion design concepts and methods require innovation and improvement. Fashion is a term that is difficult to define; it appears to encompass everything yet is not all-encompassing, it is elusive yet not impossible to grasp. Fashion arises with the presence of humans, as it is inherently human(Sharma, A. 2024). Fashion is an external form of life, constantly seeking an appropriate form to express itself. The evolution of life is also a process of discarding old forms and creating new ones. Simmel's theory suggests that life and form are interconnected and mutually influential. He advocates respecting life and allowing it to continuously develop through changing forms (Zimmer, A. L. 2021).

Inclusive design, as an emerging design concept, emphasizes considering the needs of all potential users, especially those who may require special consideration due to age, ability, or other factors. Applied to elderly fashion design, inclusive design not only focuses on the functionality of products but also emphasizes the aesthetic and emotional value of clothing, ensuring that the elderly can enjoy fashion while feeling dignity and comfort. The British Design Council defines inclusive design as "a general design approach where designers ensure their products and services meet the needs of as many customers as possible, regardless of age or ability" (Clarkson P J et al., 2015). Currently, some scholars have conducted in-depth academic explorations on the lifestyles and health behaviors of the young elderly from disciplines such as sociology and psychology. However, there is a lack of in-depth research on fashion design for the young elderly. Using the Web of Science core database as the data source, I conducted a literature search using keyword combinations. By searching with keywords "elderly" and "fashion design" for all English literature included before July 20, 2024, I obtained a total of 371 results after manual sorting and screening. Knowledge mapping visualization analysis shows that keywords such as smart textiles, thermal comfort, physiological response, quality of life, and trend design are hot research directions in inclusive design for the elderly. This article will focus on researching fashion design strategies for the young elderly in China from an inclusive perspective.

Figure 1. Visualization Analysis of Fashion Knowledge for



Young Elderly Clothing

2. Current Status of Young Elderly Population in China Against the Background of Aging Population

2.1 Definition and Current Status of Young Elderly Population

According to the universal standards set by the World Bank and UNESCO, the young elderly are defined as individuals aged 60-698 (Forman, D. E et al., 1992). In China, both aging policy formulation and related research typically adopt this age range to classify young elderly individuals. As the global trend of population aging intensifies, the living needs and market potential of the elderly population are increasing, particularly in the realm of fashion consumption(Schiaroli, V et al., 2024). However, the current market often overlooks the specific needs of this group, leading to a mismatch between supply and demand.

Currently, the majority of young elderly individuals in China were born in the 1950s and 1960s. They grew up during the early years of the People's Republic of China and, compared to other middle-aged and older elderly populations, are characterized by greater willingness and ability to work, more robust physical health, higher cultural levels, more complete family structures, and stronger economic capabilities. Research indicates that before 2035, China will experience

the fastest growth and highest fluctuation in its aging population, with a relatively low social dependency ratio and the youngest elderly population structure, representing the period of highest proportion of young elderly individuals. Strategic and tactical preparations to address an aging society should be completed during this period(Kulik, C. T et al., 2014).

2.2 Clothing Needs of Young Elderly Individuals

Against the backdrop of escalating global population aging, the consumption capacity and social activity engagement of the young elderly demographic have significantly increased (Engelhardt, H et al., 2010). The clothing industry, a critical sector within the global economy, not only plays a pivotal role in consumption and exports but also provides a substantial number of employment opportunities. As societal aging trends intensify, the young elderly group has emerged as a significant consumer force within the apparel market (Sharma, A. 2024). However, the clothing needs of this demographic have become increasingly complex and uncertain.

This consumer group not only possesses substantial purchasing power but also demonstrates a high demand for fashionable and personalized products, seeking not only material satisfaction but also self-expression and social interaction on a psychological level(Li, G et al., 2012). Health and comfort are crucial factors in their clothing choices, with fabric softness, breathability, moisture absorption, and overall wear comfort being particularly important. Furthermore, functionality and practicality cannot be overlooked, with features such as ease of dressing, multifunctional garments, and materials that are easy to clean and maintain being essential to meet their daily needs. At the same time, the young elderly's pursuit of fashion has made personalized design a market hotspot, necessitating that designers incorporate modern trends to create clothing that aligns with age characteristics while retaining a sense of style.

However, current apparel products for young elderly individuals in the Chinese market often fail to adequately address their complex needs for fashion, comfort, and usability. As times change, this demographic is increasingly rejecting age-defined constraints and pursuing personalized fashion tastes. Statistics show that in 2023, the "silver economy" market in China reached 5.4 trillion yuan, with an annual growth rate of 25.6%, significantly outpacing the growth rate of the younger consumer demographic. This indicates the enormous consumption potential of the elderly, who are becoming an important driving force for economic growth.

Despite the growing consumption capacity and willingness of the elderly, the fashion industry has not yet sufficiently addressed the needs of young elderly individuals. Traditional and singular aesthetic orientations such as fashion, elegance, youthfulness, or national styles with bright colors and patterns

are increasingly being discarded in favor of diverse and individualized aesthetic choices. More and more young elderly individuals are choosing clothing based on their personal preferences rather than conforming to the conventional notion of what "elderly people should wear."

2.3 Young elderly individuals have become a significant sub-segment within the apparel industry

Young elderly individuals, as the youngest and most active subgroup within the elderly population, have now entered the retired demographic under current Chinese policies. This group of young elderly individuals is characterized by a significant population size and is expected to have a high level of remaining life expectancy, health, and educational attainment. Most young elderly people, due to their stable economic foundation and substantial purchasing power, exhibit a clear demand for high-quality and comfortable fashion products. Concurrently, modern society's perception of the elderly is evolving, with more elderly individuals willing to explore and showcase personalized fashion choices. They express their personal life attitudes and styles through clothing, pursuing fashion that transcends age.

This stage is closely linked to the transitional needs between middle-aged and older elderly populations. Understanding their fashion preferences and guiding their behavioral habits is crucial for future middle-aged and older elderly cohorts.

In the current Chinese fashion apparel market, there are notable deficiencies in the design of fashion clothing for young elderly individuals. Most apparel for this demographic lacks innovation and modernity, often relying on outdated color schemes and conservative cuts that fail to meet the young elderly's desires for fashion and personalization. Such clothing frequently overlooks the dual needs for aesthetics and comfort, instead opting for monotonous and uninspired patterns and materials, resulting in designs that appear outdated and rigid. This outdated design approach not only fails to reflect the vitality and individual characteristics of young elderly people but also does not engage their purchasing interest, thereby diminishing the vitality and appeal of the elderly apparel market. This phenomenon highlights the insufficient understanding of elderly needs within the current fashion design industry, underscoring the importance of more in-depth market research and innovative design methods.

3. Incorporating Inclusive Design into the Fashion Apparel Industry

3.1 Empowering the Elderly Apparel Market through Inclusive Design

As young elderly individuals become significant consumers in the fashion market, traditional fashion design methods face challenges, as they often fail to fully consider the specific needs of this demographic. The particular needs of this group reflect the dual pursuit of personalization and functionality in apparel design for elderly

consumers, especially given their growing market influence (Park, J et al., 2014). However, traditional fashion design frequently overlooks these needs. Currently, the development level of China's fashion industry lags far behind the pace of aging, placing greater demands on elderly consumption patterns and social service systems. China is one of the fastest-aging countries, and the rapid pace of this transition has left society with insufficient time to adapt and understand the shift, leading to a lack of comprehensive understanding. Many enterprises in the silver economy still have a superficial grasp of elderly people and their living contexts, lacking in-depth research and exploration of their needs.

Inclusive design is a method that leverages and realizes human diversity, focusing not only on the usability and safety of products but also on the emotional and social needs of the elderly, enhancing their quality of life through design (Steinfeld, E., & Maisel, J. 2012). Inclusive design can improve elderly individuals' ability and willingness to consume and engage in social activities by providing products that are easier to use and suited to their physical conditions. Additionally, as healthy young elderly individuals seek personalized and high-quality living experiences, inclusive design should also emphasize product personalization to meet their diverse needs.

3.2 Inclusive Design Drives the Development of the Fashion Industry

The role of inclusive design in the fashion apparel industry is crucial. By comprehensively considering the needs of diverse user groups during the design process, this concept drives the fashion industry to better meet the varied demands of consumers, particularly the young elderly population. Inclusive design integrates functionality, aesthetics, and emotional value, making apparel both practical and comfortable while fulfilling consumers' desires for fashion and personalization. Additionally, this design approach stimulates designers' creativity and encourages the use of new materials and technologies, thereby advancing overall industry innovation and progress.

For the young elderly demographic, inclusive design effectively addresses their complex clothing preferences, allowing them to enjoy stylish apparel while experiencing comfort and dignity. This not only enhances the brand's market competitiveness and social responsibility but also increases consumer loyalty and satisfaction. The application of inclusive design further broadens market reach, attracting a wider range of consumer groups and contributing to economic growth (Persson, H et al., 2015). Moreover, it fosters social inclusivity and harmony, advancing societal progress as a whole.

3.3 Challenges Facing the Development of Fashion Apparel Industry for Young Elderly

Despite the significant potential of inclusive design in advancing the fashion apparel industry, the sector focused on young elderly individuals faces numerous challenges. Designers often lack a deep understanding and research into the needs of the young elderly demographic, resulting in products that fail to fully address their physiological and psychological requirements. The current apparel design education system and training mechanisms have not kept pace with evolving trends, leading to insufficient emphasis and promotion of inclusive design principles, and failing to adequately prepare designers to meet market demands.

Moreover, the diversity and individual needs within the young elderly population add complexity to design processes. Designers must balance functionality, comfort, and fashion while also considering the impact of different cultural backgrounds and lifestyles on apparel design. However, the fashion apparel products available for this demographic often suffer from design homogenization, lacking innovation and differentiation, and failing to effectively attract and meet the diverse needs of young elderly consumers. Additionally, apparel brands frequently overlook the aesthetic preferences and consumer psychology of the young elderly when conducting market promotion and marketing, leading to imprecise market positioning that affects sales performance and brand recognition.

Furthermore, the consumption habits and purchasing behaviors of the young elderly differ from other age groups, rendering traditional sales channels and models insufficient. There is a need to explore new marketing strategies and channels to enhance user experience and satisfaction. Addressing the development of the young elderly fashion apparel industry requires overcoming challenges related to design principles, education and training, market demands, product innovation, and marketing strategies, necessitating collaborative efforts from all stakeholders to achieve a more inclusive and sustainable growth.

4. Building System Elements for Fashion Apparel Design for Young Elderly from an Inclusive Perspective

4.1 Building Design Elements for Fashion Apparel Targeted at Young Elderly

Experts in the relevant field were invited to form a panel and participate in an open interview concerning product requirements. Prior to the interview, the Vosview knowledge graph evaluation results were presented to the expert panel as foundational material to enhance the comprehensiveness of the interview information. During the interview, the author attended in the roles of interview facilitator and recorder, and added discussions at the end of each segment. This method of participation helps facilitate communication and understanding between both parties and allows for a deeper insight

into the interviewees' situations and needs.When selecting interviewees, the author required that they possess a certain level of understanding and theoretical foundation in the study's field. Therefore, we chose 3 senior university professors specializing in fashion design, 3 senior fashion designers, and 3 experts in inclusive design theory, making a total of 9 interviewees. The open interview lasted for 80 minutes. Basic information about the interviewees is shown in Table 1. In this study, we summarized the basic information of the interviewees and conducted preliminary organization of the interview audio data.

Next, we applied grounded theory research methods to encode and quantitatively analyze the data, obtaining the specific results shown in Table 2. Through the analysis of the interview data, we can gain a deeper understanding of the interviewees' views and needs, and also uncover some valuable information and insights. The application of grounded theory research methods enabled us to abstract core views and themes from a large amount of data and establish relationships and connections between them. This provides strong support and assistance for subsequent data analysis and decision-making.To ensure the effectiveness of the requirement elements, keywords mentioned 6 times or more were retained (6-9 times as sub-core codes, 10 times or more as core codes), while those mentioned fewer times were deleted. The frequency of each requirement keyword as a proportion of the total frequency was recorded as the requirement importance score.

Table 1. Basic information on the Panel of Experts

	classifications	quorum	percentage
genders	male	5	55.6%
	female	4	44.4%
educational background	Bachelor's degree	1	11.1%
	Master's degree	3	33.3%
	Doctoral degree	5	55.6%
age	18–30	4	44.4%
	31–45	3	33.3%
	45–60	2	22.2%

Table 2. Research Methods for Rooted Theory Specific Results Information

Primary elements	Word frequency /time	Number	Secondary elements	Word frequency/ time	Error or not	Weighted percentage (%)
Diverse demand	92	A1	Functional design	12	Yes	18.15
		A2	Comfort Optimization	13	Yes	20.07
		A3	Fashion trend	11	Yes	17.74
		A4	Personalization	5	No	8.08
		A5	Cultural adaptation	4	No	6.45
		A6	Lifestyle Matching	3	No	4.84
		A7	Health Aids	7	Yes	11.29
		A8	Psychological needs fulfillment	4	No	6.45
		A9	Scene Adaptation	3	No	4.84
Market segmentation	87	B1	Target Audience Identification	8	Yes	9.20
		B2	Consumer Behavior Analysis	11	Yes	12.64
		B3	Demand Characteristics	13	Yes	14.94
		B4	Psychographic Segmentation	5	No	5.75
		B5	Purchasing Power Assessment	4	No	4.60
		B6	Market Positioning	12	Yes	13.79
		B7	Product Line Refinement	3	No	3.45
		B8	Brand Perception Analysis	9	Yes	10.34
		B9	Social Media Influence	7	Yes	8.05
		B10	Marketing Channels	12	Yes	13.79
		B11	Regional Culture	3	No	3.45
Design innovation	106	C1	Technological Innovation	10	Yes	9.28
		C2	Material Innovation	7	Yes	6.48
		C3	Sustainable Design	11	Yes	10.19
		C4	Functional Integration	13	Yes	12.04
		C5	User Experience Design	3	No	2.78
		C6	Smart Wearable Design	8	Yes	7.41
		C7	Cultivation of Innovative Design	2	No	1.85
		C8	Fashion Aesthetics	4	No	3.70
		C9	Optimization of Design	5	No	4.63
		C10	User-Centered Design	14	Yes	12.96
		C11	Customized Fashion Design	13	Yes	12.04
		C12	Garment Structure Design	8	Yes	7.41
		C13	Color Coordination	8	Yes	7.41

As seen in Table 2, we extracted a total of 20 core and sub-core codes related to fashion clothing design elements for younger seniors that were mentioned 6 times or more. We had 9 experts rate the selected codes, with a total possible score of 100 points (as shown in Table 3). After the expert panel completed their scoring, we used the information weight method in SPSS to analyze the scoring weights of the 9 experts (as shown in Table 4). By calculating the CV coefficient and the weight coefficient, we ultimately obtained the final comprehensive evaluation scores for the 20 word frequencies.

Table 3. Expert scoring and composite scores

No.	Expert1	Expert2	Exper3	Exper4	Exper5	Exper6	Exper7	Exper8	Exper9	score
A1	89	92	78	90	88	85	89	93	90	88.295
A2	92	89	88	84	80	89	93	94	91	88.658
A3	81	78	84	82	80	75	71	73	80	77.971
A7	86	70	89	72	71	75	78	88	86	78.804
B1	85	87	77	75	89	91	94	75	71	82.865
B2	80	91	78	83	80	81	77	73	79	81.061
B3	90	76	92	84	75	71	87	89	91	83.242
B6	88	92	84	86	93	95	84	80	90	88.189
B8	87	76	79	83	89	85	71	91	93	83.653
B9	78	81	70	73	72	75	89	84	80	78.069
B10	85	86	88	82	91	94	85	81	80	85.928
C1	90	93	88	95	93	96	89	90	86	91.264
C2	85	96	91	88	80	94	91	81	86	88.123
C3	85	82	85	91	94	86	82	80	85	85.673
C4	87	79	84	81	77	89	93	91	70	83.242
C6	87	82	89	77	93	85	81	80	90	84.819
C10	90	94	92	95	94	92	89	90	97	92.696
C11	89	91	77	89	90	93	78	90	85	86.963
C12	78	89	90	90	88	92	95	87	92	89.585
C13	85	88	83	93	94	91	89	93	87	89.569

Table 4. Calculation of the weighting of expert scoring information

	average	Standard	CV coefficient	Weights
Expert 1	85.85	3.99	4.65%	6.55%
Expert 2	85.6	7.185	8.39%	11.83%
Expert 3	84.3	6.079	7.21%	10.17%
Expert 4	84.65	6.862	8.11%	11.43%
Expert 5	85.85	7.734	9.01%	12.70%
Expert 6	86.7	7.623	8.79%	12.40%
Expert 7	85.25	7.283	8.54%	12.04%
Expert 8	85.15	6.808	7.99%	11.27%
Expert 9	85.45	7.03	8.23%	11.60%

4.2 Element Data Analysis

We obtained the final evaluation scores from nine experts on term frequency using the information content weighting method. As shown in Table 2, we selected and recorded a total of 20 core and secondary core terms, which are functional design, comfort optimization, fashion taste, health assistance function, target group identification, consumer behavior analysis, demand characteristic classification, market positioning, brand recognition analysis, social media influence, marketing channels, technological innovation, material innovation, sustainable design, functional integration, smart wearable design, user participation design, personalized pattern customization, clothing structure design, and color matching. We extracted the secondary element terms that met the inclusion criteria and integrated them. The experts then re-evaluated these secondary element terms, and the weighting of the evaluation results was calculated. The weighted ranking of the scores given by the nine experts was as follows: Expert 5, Expert 6, Expert 7, Expert 2, Expert 9, Expert 4, Expert 8, Expert 3, and Expert 1. Terms with a comprehensive evaluation score above 85.433 were classified as core high-frequency terms, while those below 85.433 were classified as secondary core high-frequency terms. There were 11 core high-frequency terms and 9 secondary core high-frequency terms. In the design of fashion apparel for the young elderly, we need to focus on the functionality and comfort of the clothing, creating a new fashion ecosystem that fosters a symbiotic relationship between consumers and designers. By analyzing the high-frequency terms under the primary elements of design innovation and demand diversity, we aim to develop more universal solutions for the advancement of fashion apparel design for the young elderly from an inclusive design perspective.

5. Transformation and Upgrading Pathways for the Young Elderly Fashion Apparel Industry from an Inclusive Perspective

5.1 Increasing the Diversity of Fashion Apparel Choices for the Young Elderly

The diversity of fashion apparel choices for the young elderly is fundamental to meeting their complex needs. First, functional design is the cornerstone of young elderly fashion apparel, and should fully consider the physiological changes and daily requirements of the elderly. Designers must take into account the physiological changes and health needs of the young elderly, creating clothing that is easy to wear and remove, and offers supportive and auxiliary functions. For instance, using easily operable fastenings such as zippers and Velcro increases the convenience of putting on and taking off clothing. Designing waist and back structures with supportive effects can reduce the fatigue experienced by the elderly when wearing these clothes. Utilizing breathable, moisture-wicking, and sweat-absorbing functional fabrics can enhance the comfort and practicality of the apparel. Additionally, designers can develop specialized clothing with rehabilitation and auxiliary functions to cater to specific health needs, such as those of arthritis patients or individuals with mobility issues.

Secondly, optimizing comfort is a crucial aspect of clothing design for the young elderly. By selecting soft, breathable, and moisture-absorbing natural fibers such as cotton, linen, and silk, the close-fitting comfort of the clothing is enhanced. Attention to fine tailoring and sewing techniques can reduce friction and pressure, improving the wearing experience and ensuring the clothing's comfort and adaptability for extended wear. Considering the body shape changes in the young elderly, designers should use moderately loose fits that provide greater room for movement and flexibility.

Additionally, fashion appeal and personalized design are key factors in enhancing the attractiveness of clothing for the young elderly. Designers should integrate modern fashion elements with the aesthetic preferences of the young elderly, offering a wide variety of styles to satisfy their desires for fashion and self-expression. By introducing popular color combinations, pattern designs, and decorative details, the fashion appeal of the clothing can be increased. Adopting a design style that combines classic and trendy elements can meet the aesthetic needs of the young elderly while also leading fashion trends. Moreover, designers can draw inspiration from traditional cultural elements and craftsmanship to create fashion apparel with cultural depth and artistic value, thereby fulfilling the cultural identity and aesthetic needs of the young elderly.

5.2 Precise Segmentation of the Fashion Apparel Market for the Young Elderly

In the process of precisely segmenting the fashion apparel market for the young elderly, adopting diversified market segmentation standards and inclusive design strategies is crucial. First, the market should be segmented based on the physiological and psychological characteristics of the young elderly. Designers need to consider their changes in body shape, deterioration in vision and hearing, and psychological needs, such as self-esteem and social requirements. It is also essential to differentiate between young elderly and older elderly individuals, providing targeted designs for different consumer groups. For example, designers can create slim-fit styles for those with well-maintained physiques, while designing easy-towear clothing for those with mobility issues.

Additionally, it is necessary to incorporate the young elderly's lifestyle and interests, such as travel, sports, gardening, or dancing, by developing fashion apparel suitable for different scenarios. This approach not only meets their practical needs but also enhances their sense of belonging, happiness, and social attributes. Regional and cultural backgrounds are also important dimensions for market segmentation. By integrating local cultural elements, designers can cater to the aesthetic preferences and functional needs of elderly individuals from different regions.

Accurate market positioning is central to effective marketing. Through market research and data analysis, the target customer group for young elderly fashion apparel can be clearly identified, including their age range, income level, and consumption habits. This allows for more precise decisions in product development, pricing, and marketing strategies. Differentiated competition strategies should be developed based on market segmentation results. For instance, innovative and stylish products can be introduced for elderly individuals who follow fashion trends, while focusing on comfort and functionality for those who prioritize practicality.

The diversification and inclusiveness of marketing channels play a crucial role in market segmentation. An integrated online and offline marketing channel system can leverage the experiential advantages of physical stores, combined with the extensive reach of e-commerce platforms and social media, to improve market penetration and brand influence. Providing customized services is also a key means of meeting the personalized needs of the young elderly. By collecting customer data and information through online platforms, one-on-one personalized design and production can be achieved, enhancing customer satisfaction and brand competitiveness. Community and group marketing are equally important. By organizing interest groups and fashion salons for the elderly, the interaction and connection between the brand and consumers can be strengthened. Social media platforms can be used to establish fashion communities for the elderly, where they can share dressing tips

and fashion information, further increasing brand awareness and influence.

Therefore, by precisely segmenting the fashion apparel market for the young elderly through diversified market segmentation standards and inclusive design strategies, it is possible not only to better meet the diverse needs of the young elderly but also to effectively promote the transformation and upgrading of the fashion apparel industry, achieving more inclusive and sustainable development.

5.3 Design Innovation Drives the Transformation and Upgrading of the Young Elderly Market

Design innovation plays a crucial role in driving the transformation and upgrading of the young elderly fashion apparel market. By comprehensively applying technological innovation, material innovation, sustainable design, user participation design, personalized pattern design, clothing structure design, and color matching, the transformation and upgrading of the industry from an inclusive perspective can be effectively achieved.

Technological innovation in young elderly fashion apparel design brings unprecedented opportunities to the market. The integration of smart wearable technologies, such as health monitoring and emergency call functions, not only enhances the intelligence and practicality of clothing but also improves the safety and convenience of elderly people's lives. Additionally, using digital tools like 3D printing and virtual reality for fashion design and fitting improves design efficiency and significantly enhances user experience. The application of digital tools provides designers with more flexible and efficient tools, making personalized and customized designs possible, thus better meeting the unique needs of the young elderly.

Material innovation fundamentally enhances the quality and environmental friendliness of young elderly fashion apparel. Prioritizing the use of environmentally friendly, biodegradable, or recyclable materials, such as organic cotton and recycled polyester fibers, reflects respect for the environment and addresses the health needs of the elderly. Developing functional fabrics with antibacterial, deodorant, thermal insulation, and breathability properties better meets the physiological needs of the elderly, enhancing their comfort and health protection. Designers should consider the entire lifecycle of fashion products, including production, use, and recycling, to ensure sustainability. Adopting low-carbon production processes reduces energy consumption and environmental pollution, promoting green production and reflecting the design's responsibility to the environment and society. The lifecycle design concept and material innovation help reduce environmental burdens and meet modern society's demands for green consumption, actively responding to sustainable development.

User participation design, personalized pattern design, clothing structure design, and color matching are essential in promoting

the adaptability and innovation of the young elderly fashion apparel market. Through surveys and interviews, designers can deeply understand the needs and preferences of the elderly, ensuring that the design closely aligns with actual user requirements. Involving the elderly in the design process, such as by hosting design workshops and online voting, ensures their opinions and suggestions are incorporated into the products. This approach not only enhances the practicality and market acceptance of the products but also increases the elderly's recognition and satisfaction with the products.

In terms of personalized pattern design and clothing structure design, designs should integrate the cultural background and lifestyle of the young elderly, introducing diversity and inclusivity by combining traditional ethnic patterns with modern artistic elements to meet the aesthetic preferences of different elderly individuals. Personalized pattern customization services allow the elderly to design unique clothing based on their preferences and stories. Clothing structure design should be based on ergonomic principles to ensure a good fit and comfort, especially optimizing for common body changes in the elderly, and focusing on ease of wear, such as using large openings and elastic bands to facilitate independent dressing.Color matching is equally important in young elderly fashion apparel design. Using color psychology principles to create positive atmospheres, and considering the visual characteristics of the elderly by employing high-contrast colors to improve visibility, enhances the overall appeal. Combining fashion elements with classic colors to create designs that cater to the elderly's aesthetic while leading fashion trends boosts the visual appeal of the clothing, enhancing the confidence and style of the elderly.

5.4 Building a Sustainable Ecosystem for the Inclusive Fashion Design Apparel Industry

Building a sustainable ecosystem for the inclusive fashion design apparel industry is key to the transformation and upgrading of the young elderly fashion apparel sector. Policy guidance and industrial planning play critical roles in this endeavor. The government should implement policies such as tax reductions and financial subsidies to support the young elderly fashion apparel industry, encouraging enterprises to increase R&D investments and promote industrial upgrading. Developing a scientifically sound industrial plan that clearly defines the development direction and goals of the young elderly fashion apparel industry can guide orderly enterprise development, preventing disorderly competition and resource wastage. These policy measures not only provide robust support for the industry but also create a favorable external environment for enterprise development.

Secondly, technological innovation and talent cultivation are essential drivers of sustainable industrial development. Building a technology innovation system that integrates enterprises, market orientation, and deep

collaboration among academia, research, and industry can facilitate the application of new technologies, materials, and processes in fashion design. Enhancing talent cultivation in fashion design and related fields, especially through specialized training for young elderly fashion apparel design, improves the professional skills and innovative capacities of the workforce. Coordinating the industrial chain and integrating resources are also crucial for boosting overall industry competitiveness. Strengthening collaboration and coordination among upstream and downstream enterprises to form a complete industrial chain system enhances industry competitiveness. Optimizing the supply chain reduces production costs, improves product quality, and increases response speed. Promoting the sharing of design, technical, and market resources helps build an open and cooperative industrial ecosystem. Encouraging enterprises to engage in technical exchanges, collaborative R&D, and market expansion activities can achieve mutual benefits and win-win outcomes.

Simultaneously, market demand and consumer guidance, sustainable development and environmental protection concepts, and cultural integration with inclusive design are equally important in building a sustainable ecosystem for the inclusive fashion design apparel industry. Conducting in-depth research on the consumption needs and habits of the young elderly helps understand their actual and potential needs, providing a basis for product design and market positioning. Media promotion and fashion events can guide the elderly to establish correct consumption concepts, enhancing their awareness and acceptance of fashion apparel. Moreover, transitioning the young elderly fashion apparel industry towards green production by adopting eco-friendly materials and energy-saving, emission-reducing production processes and equipment can minimize environmental impact. Building a circular economy system to promote the recycling and resource utilization of used clothing reduces resource consumption and waste generation. Combining traditional cultural elements with modern fashion design concepts creates culturally rich and contemporary young elderly fashion apparel, fulfilling the cultural needs of the elderly and promoting cultural heritage and development. Adhering to inclusive design principles by respecting the individual differences and diverse needs of the elderly ensures they feel warmth and care from fashion apparel through humane design and accessible wearing experiences.

6. Conclusion

The transformation and upgrading pathway of the young elderly fashion apparel industry, centered on the core concept of inclusive design, seamlessly integrates functionality, comfort, and personalization in fashion design. From the drive of technological innovation and the selection of environmentally friendly materials and processes to the deep practice of user participation in design personalization and cultural integration, these core strategies provide new insights and solutions for the sustainable development of the fashion industry. However, achieving this pathway requires the collective efforts of designers, enterprises, governments, and consumers. Through this inclusive design-driven sustainable transformation pathway, the young elderly fashion apparel industry will embrace a more innovative, eco-friendly, and sustainable future. Inclusive design is becoming the new engine of fashion design, injecting fresh vitality into the sustainable transformation of the fashion industry. Simultaneously, we must cautiously address the challenges posed by new technologies and design methods, such as social equity, cultural differences, and ethical considerations, to ensure that design practices align with ethical and social values.

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BEYOND BOUNDARIES: ENHANCING HUMAN EXPERIENCE THROUGH INCLUSIVE DESIGN

Sooshin Choi
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ABSTRACT | In our quest to enhance humanity, inclusive design stands out as a transformative force, breaking barriers and promoting diversity. This paper explores the profound impact of inclusive design, intertwining accessibility, empathy, and social equity to foster a richer human experience.

At its core, inclusive design goes beyond functionality, embracing the full spectrum of human diversity—from physical abilities to cultural backgrounds, socioeconomic status to cognitive differences. By acknowledging and accommodating this diversity, inclusive design ensures equitable access and celebrates the worth and dignity of every individual.

Through real-world examples and student projects, this paper showcases how inclusive design fosters belonging and empowerment. From a device improving ambulatory function and muscle performance to a haven for hyper-sensitive individuals at theme parks, each case study highlights the transformative power of inclusive design.

Inclusive design is a holistic approach, beginning with empathy and ending with empowerment. It requires a shift in mindset—from viewing diversity as a challenge to embracing it as a source of creativity and innovation. By co-creating with diverse stakeholders, designers can create solutions that are accessible, meaningful, and culturally resonant.

In our interconnected world, the importance of inclusive design is paramount. It is a moral imperative, a social responsibility, and a catalyst for positive change. By centering inclusivity in design practices, we can create equitable, accessible products and environments, and foster a more inclusive society. This paper calls for embracing inclusive design principles to move humanity beyond borders, creating a world where everyone can fully participate, contribute, and thrive.

KEYWORDS | DESIGN FOR HUMANITY, INCLUSIVE DESIGN, HOLISTIC DESIGN APPROACH, EMPOWERMENT BY DESIGN, SOCIAL EQUIT

1. Introduction

Inclusive design represents a shift in the design paradigm, moving from a one-size-fits-all approach to one that embraces human diversity in its many forms. This transformative design philosophy goes beyond creating accessible products; it seeks to enhance the overall human experience by fostering empathy, social equity, and a sense of belonging. This paper delves into the theoretical foundations of inclusive design, showcases real-world applications through case studies, and provides practical guidelines for educators to instill these principles in future designers.

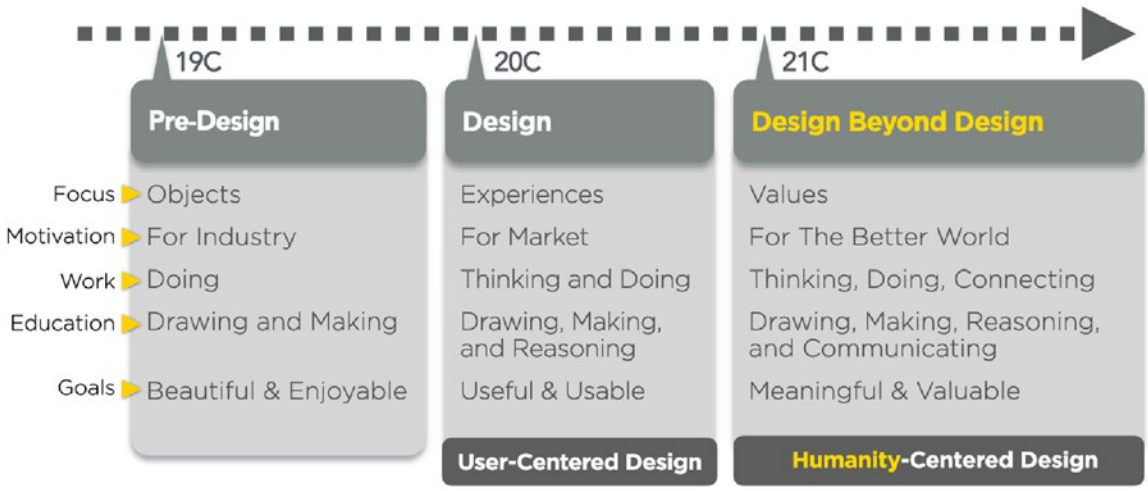
2. Historical Review of Inclusive Design

Emergent of inclusive design is a result of the evident need of equal opportunity, which had been overlooked in all industry and social sectors. As the focus is given to those who do not have access to products and environments. Also, with the development of assistive technology and growth of social awareness of DEI (diversity, equity, and inclusion, the importance of inclusive design has grown within the field of design.

Victor Papanek's vision of designing for all people, including those with disabilities and in developing countries, laid the foundation for inclusive design. His emphasis on ethical, usercentered, and socially responsible design practices in "Design for the Real World" has significantly influenced modern approaches to creating accessible and inclusive products and environments.[1]

It was a natural evolution from focus on object and product to people, not only as users, but holistic human being as the owner of the product and experiences.

[2] Sooshin Choi, Leveraging AI to Infuse Humanity in Industrial Design Education (WDO Education Forum Publication, 2023)



[1] Victor Papanek, Design for the Real World: Human Ecology and Social Change (New York: Pantheon Books, 1971)
Figure 1. Evolution of Industrial Design and Emanating of Humanity-Centered Design. By author.[2]

Inclusive design is one of the two major branches of socially responsible design, alongside sustainable design. Sustainable design has evolved from eco-friendly design, which focused on materials and the physicality of products and the environment, to sustainable design, which addresses products and businesses, and finally to circular design, which encompasses all aspects of products, the environment, and the economy. Similarly, inclusive design has progressed from barrier-free design, which focused on accessibility, to transgenerational design, which considered the elderly, user-centered design, which emphasized ergonomics, universal design, which aimed for the universality of design and the environment, and ultimately to inclusive design.

While sustainable design has been widely accepted and practiced across various fields such as design, business, economics, and environmental studies, inclusive design has seen limited application, primarily within design and architecture. One main reason for this disparity is that sustainable design has demonstrated its impact on the environment, particularly with the growing concern about global warming, as well as on business, thereby gaining national and global attention. It has even become a popular marketing rhetoric, sometimes used by businesses that do not fully practice sustainable design. In contrast, inclusive design has struggled to attract interest from a broad range of stakeholders. It is often perceived as prioritizing people's rights at the expense of business interests. Therefore, it is crucial to teach, practice, and promote inclusive design not only as a philanthropic approach but also

3. Shortfall and Opportunity of Inclusive Design

as a route to innovation and business success. Some design schools have sustainable design programs globally, while there is no design program specialized in inclusive design. Additionally, products in inclusive or universal design are often stereotyped as boring and mundane, making it challenging to capture market attention.

4. Theoretical Foundations of Inclusive Design

Inclusive design is built on several core principles that guide the creation of products, services, and environments that are usable and meaningful to a diverse range of people. These principles include:

4.1. Empathy

Empathy should be the first step in any design process as it helps to understand and share the feelings of others. While most design projects aim at the 'target users,' inclusive design looks at those who are often ignored and excluded in typical design approaches. In the context of design, empathy involves understanding the unique needs, challenges, and experiences of diverse user groups. Empathy-driven design seeks to create solutions that resonate with users on a deep emotional level, fostering a sense of connection and understanding.
Building empathy in design is crucial in any design process and achieved by:

- Contextual User Research: Conducting interviews, surveys, and observations to gain insights into the lived experiences of different user groups.
- Personas and Scenarios: Creating detailed profiles of potential users and their typical use cases to guide the design process.
- Empathy Mapping: Visualizing what users think, feel, see, and do to gain a deeper understanding of their needs and motivations.

4.2. Social Equity

Social equity in design involves recognizing and addressing the diverse socioeconomic and cultural backgrounds of users. Inclusive design promotes fairness and inclusion by ensuring that products and environments are accessible and meaningful to people from all walks of life. This principle emphasizes the importance of designing for marginalized and underserved communities, ensuring that everyone has the opportunity to participate fully in society.
Promotion of social equity can be achieved by:

- Inclusive Participation: Involving diverse stakeholders in the design process to ensure that multiple perspectives are considered.
- Culturally Responsive Design: Creating products and environments that respect and reflect the cultural values and practices

of different communities.

· Equitable Access: Ensuring that all individuals, regardless of their socioeconomic status, have access to the benefits of design.

4.3. Accessibility

Accessibility is a cornerstone of inclusive design, ensuring that products and environments are usable by individuals with varying physical, sensory, and cognitive abilities. Accessibility involves designing for a wide range of abilities, including mobility, vision, hearing, and cognitive function. This principle not only enhances usability for people with disabilities but also improves the overall user experience for everyone.

5. Real-world Examples of Inclusive Design

Successful inclusive design not only helps people who are otherwise excluded but also opens new opportunities for product innovation. There are numerous examples of designs focused on assisting neglected users becoming mainstream in the market. Two examples here demonstrate excellent design solutions that benefit everyone, regardless of their limitations, while achieving significant business success and impact.

5.1. Oxo Good Grips Potato Peeler

The OXO Good Grips Potato Peeler was initially designed to be usable by people with arthritis, but its ergonomic design proved beneficial for all users. Key features include a thick, soft handle for easy gripping and a sharp, swiveling blade for efficient peeling.

This product demonstrates how designing for users with specific needs can result in a product that's better for everyone. It embodies the principle of "universal design" - creating products that are accessible to as many people as possible without the need for adaptation.

Figure 2. Development of Oxo Good Grips potato peeler. Image courtesy Oxo.[2]



Impact of Good Grips product on business and innovation are:

1. Market success: The peeler's inclusive design led to widespread consumer appeal, driving significant sales and establishing OXO as a leader in kitchen tools.
2. Brand reputation: OXO became known for user-centered design, enhancing its brand value.
3. Industry influence: The success of the Good Grips line inspired other companies to adopt inclusive design principles.
4. Innovation driver: It showed that considering diverse user needs can lead to innovative solutions and market opportunities.
5. Shift in design thinking: The peeler's success helped popularize the idea that good design should be accessible to all, influencing design education and practice.

[3] https://www.oxo.com/blog/behind-the-scenes/behind-design-oxos-iconic-good-grips-handles

This example illustrates how inclusive design can lead to better products, business success, and positive social impact, encouraging a more inclusive approach to innovation across industries.

6. Successful Examples of Inclusive Design as Student Work

Most designers applying inclusive design focus on usability, but some expand the definition to include human dignity and product innovation. While the former approach is somewhat passive, solving existing problems, the latter is active, visualizing how designers can improve the quality of life and impact the market.

When products no longer work for them, it's not just the products that are deemed useless; often, the aged consumers themselves feel they have become useless. This leads to a profound and humiliating self-judgment.

6.1. IncludeHealth Access Strength fitness machine

The Access Strength machine, designed as a capstone project by Ryan Eder, a senior industrial design student in 2006, is designed to be universally accessible, allowing people with various abilities, including wheelchair users, to exercise using the same equipment as able-bodied individuals. Its key features include:

1. Adjustable components that accommodate users of different heights and abilities
2. A digital interface for easy program selection and tracking
3. Wheelchair-accessible design that doesn't require transfer

This design showcases inclusive innovation by:

1. Eliminating stigma: It allows people with disabilities to use the same equipment as others, promoting inclusion in fitness spaces.
2. Versatility: The machine serves a wide range of users without the need for specialized equipment for different abilities.
3. Digital integration: The use of technology enhances usability and allows for personalized workout experiences.

Figure 3. Inclusive fitness machine as a capstone project. Image courtesy of IncludeHealth[4]

[4] IncludeHealth Access Strength (source: www.prioritydesigns.com/content/include-health-access-strength)

[5] IncludeHealth Access Strength (source: www.prioritydesigns.com/content/include-health-access-



strength)

broader population.

The project was developed by the students as a capstone project. After earning lots of major design award, he was able to secure fund enough to establish a business to develop this student project into a reality. The images below show the product as a student project and the final product which took ten years in development.

This example underscores how designing for inclusivity from the outset can result in products that are not just accessible, but also technologically advanced and appealing to a wide market leading to new innovative product opportunities.

Figure 4. Fully developed IncludeHealth fitness machine. Image courtesy of IncludeHealth. [5]

6.2. Alle Bathroom Cleaning Tools



The Access Strength machine illustrates how inclusive design can lead to innovation that expand access to fitness, promote equality in public spaces, and potentially improved health for a

The challenge posed by the growing population of aging consumers involves more than just their disadvantages from aging and diminishing physical abilities. It also encompasses the gap between their desire to maintain dignity and their need for assistance. Additionally, many seniors live alone, separated from their families.

This leaves aging consumers with the challenge of maintaining cleanliness in their homes, particularly in the bathroom, without relying heavily on others. The bathroom, being a highly private space, adds another layer of reluctance for many to invite strangers for assistance. This can result in a feeling of helplessness and loss of dignity.

[6] Alle cleaning tools (source: https://www.rcjobe.com/alle)

Figure 5. Alle cleaning tools for senior users. Images courtesy of Cooper Jobe. [6]



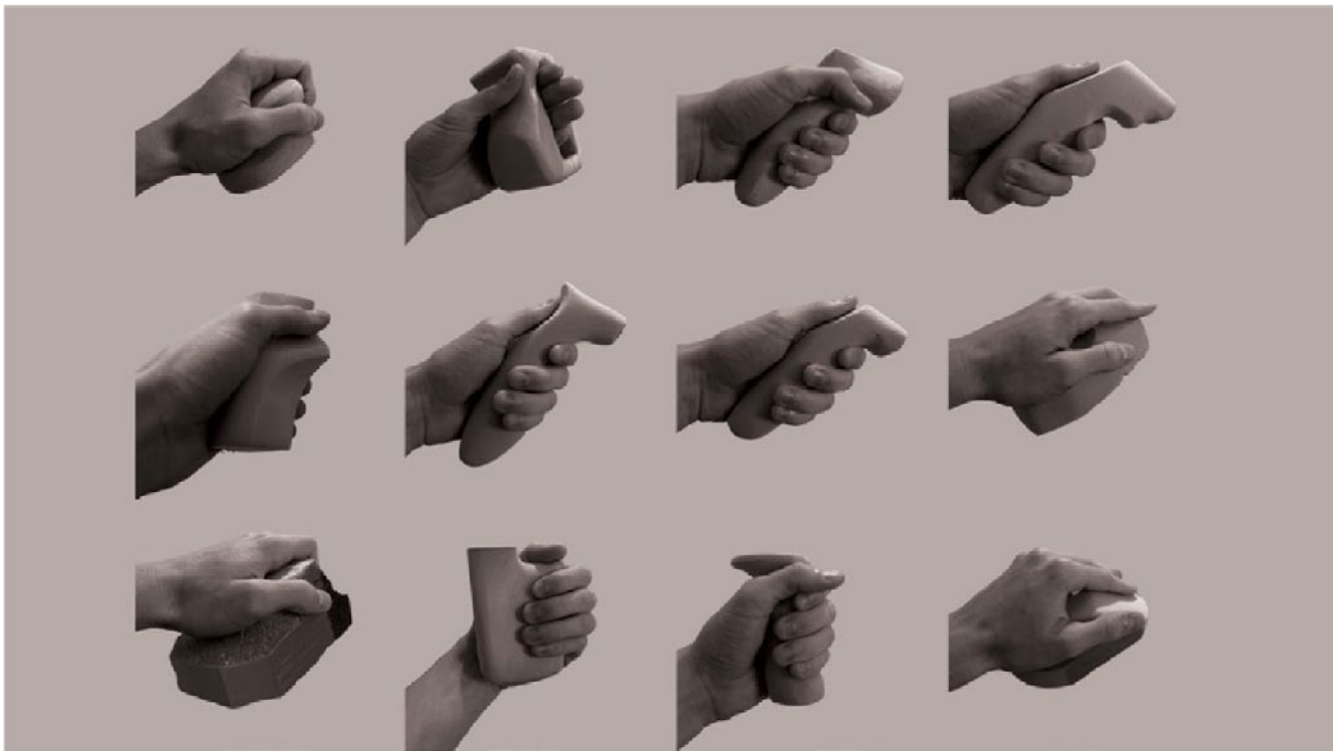
in 2023, is a series of bathroom cleaning tools specifically designed to address these issues, making the cleaning process more manageable and less strenuous for aging consumers. The development of Alle involved extensive consultation and concept validation stages. This ensured that the tools were not only ergonomic and easy to use but also genuinely met the needs of the target users. The name “Alle,” meaning “all” in German, signifies the inclusive intent behind the product. These tools are designed not just for aging consumers but for everyone, highlighting the universal design principle.

Alle, developed by Cooper Jobe, a senior industrial designer at Savannah College of Art and Design

This approach mirrors the success of OXO's Good Grips tools, which were initially designed for people with arthritis but became popular among all users due to their superior ergonomic design. This inclusive strategy not only helps aging individuals maintain their independence and dignity but also presents a compelling business opportunity by tapping into a broader market.

Figure 6. Concept validation of Alle cleaning tools. Images courtesy of Cooper Jobe.[7]

7. Practical Guidelines for Educators





Educators play a crucial role in fostering the principles of inclusive design among future

designers. This section provides practical guidelines for educators to help students develop more valuable designs that address the needs of marginalized groups.

7.1. Incorporating Inclusive Design Principles into Curricula

Ensuring that design education includes a strong emphasis on accessibility, empathy, and social equity is essential to preparing students for inclusive design practices. It has become more crucial than before as the focus on market success, technology, and even artificial intelligence redirects designers from developing designs for all. Educators can incorporate these principles into their curricula through various strategies including philosophical and practical aspects. The image below shows two pillars of an ideal industrial design curriculum that can prepare designers for the future.

The Future Literacy pillar of the curriculum covers practical aspects of design that will be useful for designers as professionals. It is important to ensure that students learn to handle the topics that are relevant for the future environments.

The Fundamentals of Design pillar of incorporates philosophical aspects of design that are the timeless virtue for designers. Without these values, they will become just design technicians.

Figure 7. Two pillars of Design Education. By author.[8]

[8] Sooshin Choi, Leveraging AI to Infuse Humanity in Industrial Design Education (WDO Education Forum Publication, 2023)

- Philosophical curricular courses:



Students to gain understanding of the virtue of designing for all in classes such as Design

Theory, Design for Society, and Design Colloquium.

· Practical curricular aspects: Students can learn applicable knowledge and experience of how to develop designs for all in classes such as Contextual Design Research, Ergonomics for Industrial Design, Design Studios.

7.2. Strategies for Incorporating Inclusive Design

· Course Content: Integrating topics related to inclusive design, such as accessibility, empathy, and social equity, into existing courses.

· Guest Lectures and Workshops: Inviting experts in inclusive design to give lectures and conduct workshops for students.

· Case Studies and Projects: Assigning case studies and projects that require students to apply inclusive design principles to real-world challenges.

7.3. Interdisciplinary Effort for Inclusive Design

In the "real-world' context, interdisciplinary effort is the key. So, encouraging students to work with peers from diverse disciplines and backgrounds helps them gain a more holistic understanding of user needs. Interdisciplinary collaboration fosters creativity and innovation by bringing together different perspectives and expertise.
Providing opportunities for students to engage in projects involving real users and real-world challenges is crucial for developing their ability to create inclusive designs. Real-world projects allow students to apply their knowledge and skills to practical problems, gaining valuable experience in the process.

Most design schools have partnerships with industry for collaborative projects. While these are primarily aimed at developing market-applicable concepts, schools can take the lead by introducing inclusive design as a motivation for innovation.

· Team Projects: Assigning group projects that require students from different disciplines to work together on a common design challenge.

· Collaborative Studios: Creating studio environments where students from various disciplines can collaborate and share ideas.

· Cross-Disciplinary Courses: Offering courses that bring together students from different disciplines to learn about and practice inclusive design.

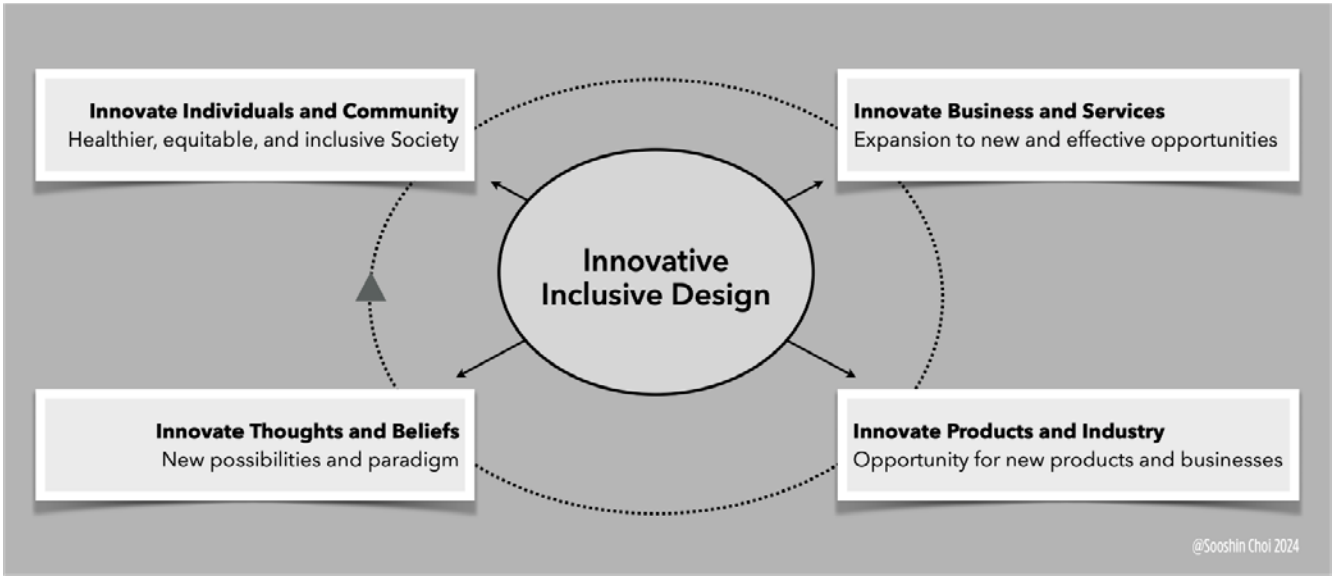
Conclusion

Inclusive design is a powerful tool for enhancing the human experience and

promoting social equity. By centering inclusivity in our design practices, we can create a world where everyone, regardless of their differences, can fully participate, contribute, and thrive.

Figure 8. The Impact of Innovation and Inclusion. By author.

This paper calls on designers, educators, and stakeholders to embrace the principles of inclusive design and harness its transformative potential to move humanity beyond boundaries. Through a commitment to inclusivity, we can cultivate a more empathetic, innovative, and equitable society.



Compared to sustainable design, which often appeals primarily to eco-conscious consumers willing to pay more for conservation efforts, inclusive design can attract a wider range of consumers and benefit individuals, communities, and industries alike.

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THE DEVELOPMENT AND LOGIC OF DIGITAL FASHION FROM THE PERSPECTIVE OF THE DESIGN

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ABSTRACT | As society and the economy transition to different organizational paradigms deeply influenced by digital technologies, the current education system, scientific research, and talent cultivation face elevated demands. Digital fashion, as a frontrunner in this transformative development, is continually pushing the boundaries of traditional fashion, redefining numerous aspects of the industry. In this process, design as a comprehensive and forward-looking discipline, plays a crucial role in understanding and shaping the development of digital fashion. This study addresses the critical issue of the unclear path for the transformation and upgrading of traditional fashion to digital fashion from the perspective of the design discipline. Utilizing theoretical research and case study methods, this research delves deeply into various aspects of the development status, forms of expression, and practical applications of digital fashion in luxury fashion companies and brands. In addition, this study summarizes specific practical approaches in five dimensions: social and spatial integration, deep technological integration, new paradigms of human-machine co-creation, virtual and real fusion, and transaction and circulation. The research demonstrates that the continuous convergence and integration of the design discipline not only drives innovation of digital fashion but also serves as a crucial link bridging technology and creativity, virtual and reality, commerce and art. The findings provide theoretical and methodological references for research on digital fashion from the perspective of design discipline, contributing to the positive development of a design-driven innovative fashion industry.

KEYWORDS | DESIGN SCIENCE, DIGITAL FASHION, FASHION DESIGN, DIGITAL TECHNOLOGY, DIGITAL DESIGN

1. Introduction

Nowadays, digital technology is everywhere. The constantly improving digital technology makes it possible for the process of digitalization in various industries. Digitalization refers to "the transformation of the socioeconomic environment through processes of digital artifact adoption, application and utilization" (Gradillas & Thomas, 2023). The transformation is happening in the fashion industry. The digitalization of the fashion industry also leads to a trend of digital fashion. Digital fashion refers to the application with the use of digital technologies in the fashion industry (Muhammad Sayem et al., 2023). Digital fashion involves digital human and metaverse, digital design and e-prototyping, digital apparel and smart e-technology and digital business and promotion (Sayem, 2022). The digital transformation in fashion has not only affected the creative processes of fashion designers and the production and sales of fashion products but also reshaped the media through which fashion symbols such as trends, styles, and aesthetics are expressed and disseminated (Cantamessa et al., 2020).

Research on the topic of digital fashion has been conducted through the perspectives of different disciplines. Baek et al. did a systematic review of the research on digital fashion. The result shows that the six research topics most closely related to digital fashion are design, virtual, printing, supply, body, and consumer (Baek et al., 2022). Although the topic of design seems to be a common interest of researchers, it is primarily limited to manufacturing and production (Baek et al., 2022). It's clear that design nowadays, both as an academic discipline and a professional practice, encompasses more than just products and the means of manufacturing and production (Cross, 2018). It includes the design of symbols and signs, material objects, actions and services, as well as systems and environments (Buchanan, 1992). Holding this view, the design of digital fashion should expand to a broader field beyond the manufacturing and production of fashion products.

This paper analyzes the essence and forms of fashion design. By organizing relevant digital technologies and applications, we discuss

how digital fashion functions as the bridge between reality fashion and virtual fashion. To present the development and logic of digital fashion, we use the "four orders of design" as the theoretical framework to conduct a case study of luxury fashion companies Louis Vuitton-Moët-Hennessy (LVMH) and Kering, along with their two most prominent luxury fashion brands: Louis Vuitton (LV) and Gucci. We examine the digital technologies and applications utilized by these two companies and their brands in the design of graphics, objects, activities, and systems in recent years. Through the case study, we identify the status quo and logic of the digitalization of luxury fashion brands and summarize the challenges and limitations of digital fashion today. Finally, from the five dimensions which are social and spatial integration, deep technological integration, new paradigms of human-machine cocreation, virtual and real fusion, and transaction and circulation, we provide potential pathways for the digitalization of fashion and predict the possible future development of digital fashion from the perspective of the design discipline.

2. The Perspective of the Design

2.1 The expanding scope of design discipline

As Cross said, "Design is developing strongly as an academic discipline, as well as a professional practice"(Cross, 2018). During the development of design as a discipline, it faces increasingly complex and wicked problems, a growing intersection of diverse elements, and an expanding range of applications. In this context, the meaning and scope of design as the fundamental question has once become a central topic in the design discipline. The foundational issue is crucial for understanding and advancing the direction of the design discipline. John Walker notes that design has multiple meanings, which can refer to the process, the outcome of that process, the final product, and the overall pattern of a product (Smal & Lavelle, 2011). Herbert Simon once stated that everyone who devises courses of action aimed at changing existing situations into preferred ones is engaged in design (Simon, 1988). Richard Buchanan views design as the capability inherent in human beings to serve personal or collective purposes through the conception, planning, and creation of artifacts (Buchanan, 1992). These varied interpretations of design by different scholars highlight the expanding scope of design.

As a professional practice, the objects that can be designed have continuously expanded. The scope of design has extended beyond traditional artifacts such as graphics and products to include intangible entities such as relationships and environments (Buchanan, 1992). The theory of "Four Orders of Design" put forward by Richard Buchanan provides a framework for clarifying the potential objects and orders encompassed in design activities.

2.2 The theory of "four orders of design"

The theory of "four orders of design" divides design activities into four distinct yet interconnected domains: signs, things, actions, and thoughts (Buchanan, 1992). The first order of design focuses on the design of graphics, which contains the creation and interpretation of symbols and images. The goal of design on this level is to solve communication problems. The second order shifts towards the material objects and products. Here, designers must consider aspects such as functionality and form of artifacts. The demand for graphic design and industrial design comes after the First Industrial Revolution. With the digital transformation of various industries, the demand for design goes to the third order, which extends to interaction, service, and experience. The user experience becomes crucial. In the fourth order, designers need to consider systematically. The system of business, organization, and government is involved in design activities. Design in the order emphasizes the integration of the resources in complex systems, to demand different stakeholders. Strategies become the form of design output. This theory has been applied in design research across various fields, such as interior design (Buchanan, 2019), digital media stage (Liu & Chen, 2020), organizational management (Buchanan, 2015), hybrid collaborative work environments (Meluso et al., 2022), digital publishing (Nylén et al., 2014), design education (Duman & TiMur, 2020), and policy-making (GovLab, 2018).

3. Digital Fashion: from Reality to Virtual

3.1 Connotation of fashion

Fashion exists in various aspects of social life and is continually negotiated within society (Loschek, 2009). It can be treated as a material object, a lifestyle, an abstract idea, a belief system, a social phenomenon, or a cultural value that is adopted by a significant segment of society (Crane, 2000). On one hand, Fashion refers to the idea of what is popular or on trend in a particular time and place (Reddy-Best, 2020). This idea can refer not only to tangible material entities (e.g., clothes and accessories) but also to abstract ideological and cultural currents. It needs to be stressed that material entities themselves cannot simply equal fashion unless they have been embraced by a significant segment of society, i.e., embedded in a broader belief system (Smal & Lavelle, 2011). On the other hand, fashion can also be understood as a social process: a particular behavior or style is possessed and propelled by a small group of pioneers, and then sought after by the public for a period of time and situation (Reddy-Best, 2020). This process represents the inherent scarcity value and flux of fashion.

Georg Simmel remarked that fashion is rational and possesses objective characteristics (Clarke et al., 2003). Different academic disciplines take on different meanings of fashion and conduct research from different perspectives. In a systematic

sense, the object of fashion research can be divided into four aspects. The first one is the symbol system of fashion, trends, fads, and styles; the second one is clothing, accessories, appearance, and other material culture related to lifestyles; the third one is the commercial system for the production and sale of material goods; the last one is the sociocultural forces closely linked to modern and postmodern societies (Kawamura, 2005).

3.2 Design of Fashion

Fashion design refers to a practical activity (Smal & Lavelle, 2011). In lots of contexts, fashion design is merely connected to the creation of objects in trends such as clothing and accessories, i.e., fashion product design. However, that is only a segment of the broader fashion ecosystem. In a broader context, fashion is a complex social phenomenon that encompasses not only material culture but also the commercial systems involved in the production and sale of goods, as well as the symbolic systems and social cultures intertwined with it. Fashion and design are inherently interdisciplinary fields, and their intersection stems from their shared existence within a network of interconnected activities (Smal & Lavelle, 2011). From the broader perspective of the design discipline, the definition of fashion design should not only be limited to the creation and production of merchandise. The interaction between consumers and fashion brands, shopping experiences provided by fashion retailers, and the environment of the fashion shops and shows can all be included in the design of fashion. In addition, the visible or invisible systems such as fashion supply chains, fashion company structures, and strategies, can also be designed. The theory of "four orders of design" provides a broad perspective to scan the fashion industry beyond the motifs and styles of images and products. Thus the definition of a fashion designer can be expanded.

Traditionally, undergraduate fashion design education has focused on developing practical skills, including technical expertise, specialized knowledge, and industry-related competencies. However, with the rise of digital technologies in creative industries like art and fashion, educational institutions are now exploring new approaches to train the next generation of digital fashion designers(Smal & Lavelle, 2011). With the process of digitization, every segment of the fashion industry from the raw material, design, manufacturing, distribution, and retail is experiencing the process of digitalization. Digitalization may provide a new approach to the innovation and reform of the fashion industry and provide more chances and challenges for fashion designers.

3.3 Digitalization of fashion

Digitalization in different industries demands scientific research and response of educational systems within the design discipline. On the one hand, digitalization has expanded the objects of design from traditional tangible products to include virtual products and experiences (Ramaswamy

& Ozcan, 2018). On the other hand, it has profoundly influenced the design processes and design tools across different design activities (Marion & Fixson, 2021). Additionally, The relationship between digital technology and design education has become increasingly intertwined. Digital technology offers design education opportunities to transcend geographical boundaries, allowing students to access knowledge on a global scale. This not only broadens the scope of education but also provides various online resources and tools, enabling students to stay abreast of the latest trends in digital design technology. Moreover, digital education fosters innovation by utilizing virtual laboratories and collaborative platforms, where students can share ideas, collaborate to solve problems, and apply design thinking within a global network, collectively advancing the field of design discipline.

Similar to the impact of digital technology on design, digitalization is continuously merging with the fashion industry. Digital fashion represents the intersection of fashion and digital technology, primarily focusing on the aesthetics and collection of clothing, accessories, and other material culture in the digital world (Bertola & Teunissen, 2018, p. 4). By leveraging technological means, digital fashion transcends the limitations of color, material, and craftsmanship in the real world, enabling the design, exhibition, and sale of virtual fashion products. The transition from traditional fashion to digital fashion has revolutionized the fashion industry, allowing consumers to immersively experience interaction with fashion material and culture through digital media and platforms.

In the early 21st century, with the rise of e-commerce, the term "digital fashion" was first introduced to the fashion industry. Marketers used this term to refer to e-commerce platforms that sold fashion products (Baek et al., 2022). At that time, digital fashion products were referred to as portable hardware devices (Baek et al., 2022). However, with the advancement of digital technology, the definition of digital fashion products has expanded from wearable computing devices to virtual goods within blockchain and metaverse spaces. In recent years, fashion brands have ventured into the metaverse and begun experimenting with digital collectibles, gaming, artificial intelligence (AI), and extended reality (XR) (Noris et al., 2021). As a result, the definition of digital fashion has continually evolved and become more complex. Digital fashion now encompasses any concept combined with digital experimental technologies with fashion. This includes real or virtual clothing and accessories produced using technologies like body scanning and 3D printing, as well as digital media for showcasing and disseminating these products and services, such as virtual avatars and online fashion shows.(Baek et al., 2022) through a systematic literature review of digital fashion-related research, define digital fashion as "the virtual creation, production, and representation of one's identity via computergenerated design" (2022).

The digitalization of fashion signifies a comprehensive transformation, as depicted in Figure 1. Reality fashion serves as the foundation for the existence of digital fashion. The term "fashion" here is used in a broad academic context. It refers to both a type of material culture (such as clothing and textiles, jewelry and accessories, and consumer services) and a system of symbols (Kawamura, 2005). Fashion functions as a commercial system that produces and sells products (including brands, systems, and intermediary media) and also as a socio-cultural force closely linked to modernity and postmodernity (Rocamora & Smelik, 2015). Thus, objects and symbols together construct fashion and, through practices of production, consumption, distribution, and representation, connect countless individuals and collectives (Elliott, 2004).

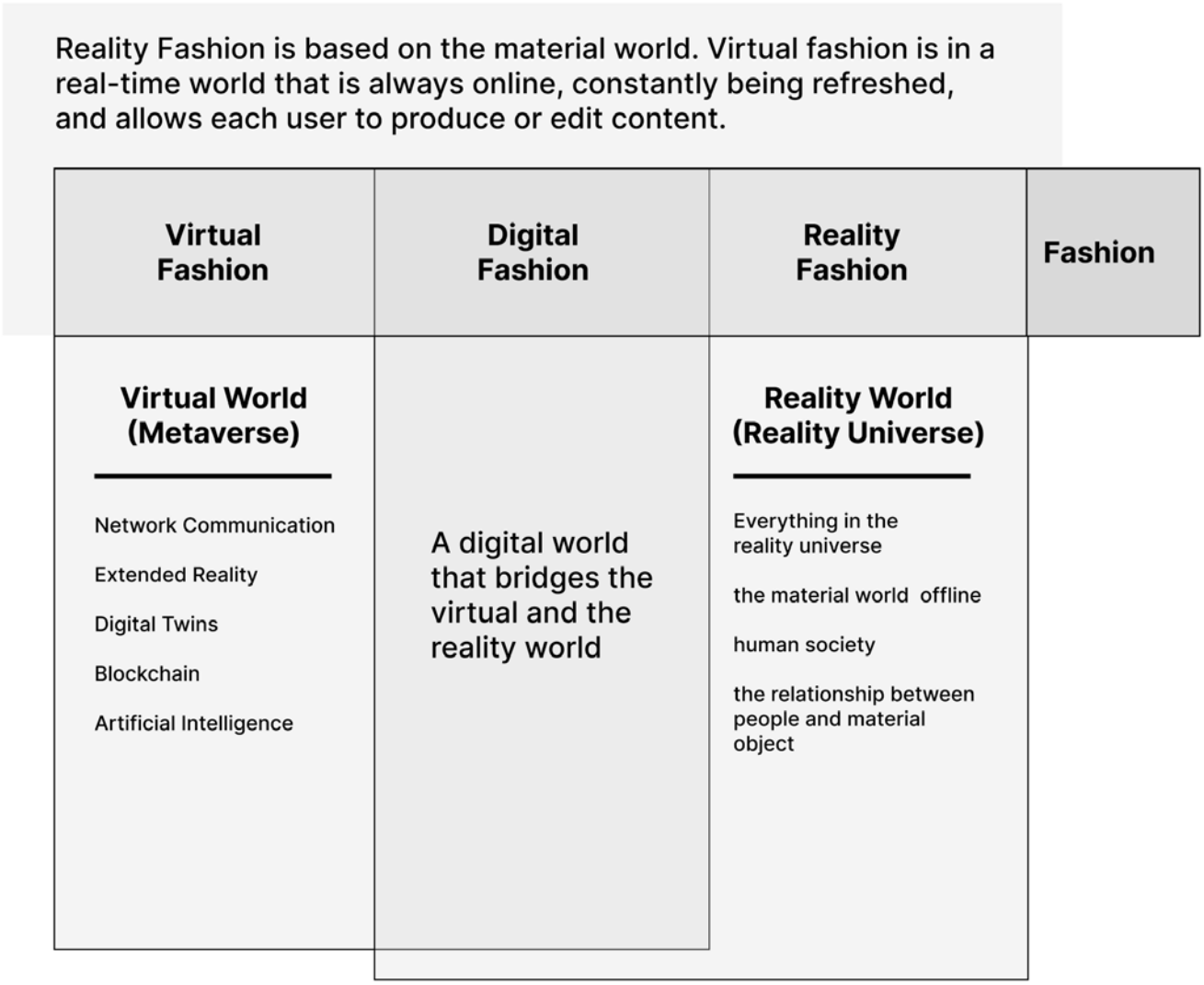


Figure1. Elements of development in digital fashion.

Since the onset of COVID-19, the development of digital fashion has led the traditional fashion industry to move beyond its reliance on physical materials. In this context, virtual fashion, based on digital technologies, has emerged (Fu & Liang, 2022). Virtual fashion represents an extension of reality fashion into the metaverse, a new hybrid form of internet application and social structure that integrates network communication, extended reality, digital twins, blockchain, artificial intelligence, and other emerging technologies (Huynh-The et al., 2022). The metaverse features a complete economic system, encompassing data, objects, content, and intellectual property, and functions as a perpetually online, continuously evolving real-time digital world (Lee et al., 2021). It allows users to create content and edit the world. Digital fashion blurs the lines between the real world and virtual spaces, with the metaverse providing a broader space for its development. Virtual and reality fashion are not separate entities but are interconnected, complementary, and enriched through digital technologies. Fashion consumers are now living in a fully digitalized dimension, where self-expression and identity exploration are not limited to various hardware and software applications. Instead, they are engaged in multimedia, crossmedia, and even virtual reality environments, showcasing and defining themselves in diverse ways. Through fashion media, individuals can express themselves and explore their identities beyond tangible material boundaries, pushing the pursuit of fashion beyond the constraints of the real world and into the expansive realm of digital fashion. In this digital environment, individuals are empowered to present diverse forms of self-expression, thereby opening up new avenues for constructing multiple self-identities. This evolution allows for a more profound exploration of identity and self-representation, transcending the limitations of the physical world and venturing into the boundless possibilities of digital fashion.

3.4 Digital technologies and applications in fashion

Digitalization is a key driver of transformation in the contemporary fashion industry, with the core of digital fashion development centered on the integration of various technological fields. Emerging digital technologies are reshaping traditional fashion design, production processes, and consumer behavior (Bertola & Teunissen, 2018). These shifts have profound implications for the overall ecosystem of the fashion industry.

In the fashion product design process, designers utilize computer-aided (CAD) modeling technologies and platforms (e.g., Rhino) and digital pattern-making software (e.g., CLO3D) to create digital prototypes. Users can enhance garment fit and size prediction by accurately scanning their bodies, thereby optimizing the design and development process of physical clothing. Parametric design techniques allow designers to maximize their creativity by constructing parametric structures. Moreover, virtual fitting, virtual bodies, and virtual fashion shows that use virtual bodies and apparel are also based on

CAD technology. The virtual concept in digital fashion goes beyond the realm of fashion products, introducing a new framework that includes digital platforms and virtual worlds based on real-time rendered simulations.

Additive manufacturing technology disrupts the traditional paradigms of fashion manufacturing and production. 3-Dimension (3D) printing enables designers to materialize complex forms of digital prototypes, facilitating rapid prototyping. Additionally, it offers sustainable production alternatives, allowing for material usage without waste, thus revolutionizing traditional supply chains. Digital accessories (e.g., Arduino) and wearable technology are also employed by designers to create products with fashion functionalities (e.g., smartwatches), or to design fashion pieces that respond to body movements in real-time.

Extended Reality (XR) technologies have transformed traditional tangible fashion into intangible fashion expressed through pixels and digital prints. XR technologies include Augmented Reality (AR) and Virtual Reality (VR). AR enables shoppers to interact with products in real-time within physical retail environments (e.g., digital Gucci shoes). VR aids fashion brands in developing virtual stores and virtual fashion shows, offering new venues for shaping digital fashion. It also allows consumers to develop their digital identities within digital environments like the Metaverse. XR provides consumers with new experiences in shopping, exhibitions, and identity formation.

Blockchain technology provides transparent and trustworthy data throughout the entire supply chain process in the fashion industry. For instance, blockchain technology can reveal the origin and quality of raw materials and ensure the authenticity and reliability of final retail products. Additionally, blockchain allows digital models to be sold as non-fungible tokens (NFT) and distributed to consumers in both virtual and real worlds.

AI and machine learning assist designers in quickly gathering design inspiration and realizing creative ideas. They empower brands to understand fashion trends and respond to consumer and market segment needs. Retailers can use real-time data provided by AI to observe changing trends and inventory performance, thus making informed business decisions. AI and machine learning significantly shorten the fashion creation and dissemination cycle.

Under the influence of emerging technologies, the interplay between visual arts, science and technology, digital information, and artificial intelligence has given rise to a new paradigm of digital fashion. Digital fashion is not merely the combination of art and technology. It represents a significant advancement in the cultural and creative industries, specifically within the fashion sector. This encompasses technological innovations and new models applied across various stages, from design and manufacturing to communication and distribution, thereby enhancing the industry's diversity. The incorporation of digital technologies does not simply alter traditional

fashion imagery but also profoundly transforms consumer perceptions. However, scholars have pointed out certain issues during the process of digitalization. For example, Smal & Lavelle states that "the over-reliance on historical elements in fashion has neglected the technological and global relevance of fashion in the twenty-first century."(2011) To address challenges, the framework from the design discipline can provide a theoretical foundation for exploring the structure and development paths of digital fashion, as shown in Figure 2.

Design Object		Tangible Fashion	Digital Fashion
Signs	Graphic	Brand logo Monogram Pattern Photograph Drawing	Digital brand logo and pattern Digital images Videos
Artifact	Product	Cloth Apparel Accessories	Smart wearables Embedded Electronics Virtual clothing and accessories Virtual avatar
	Tool	Traditional tools	2D/3D CAD AI for design & prototype
Action	Interaction	Offline Retail	Branded websites, applets Virtual platform
	Services	Maison service	Online retail (VR/AR shopping experience) Virtual try-on
	Experience	Offline Fashion Show Exhibition	Virtual fashion show/exhibition Digital and virtual games
Thought	Environment	Physical shops	Social Media Digital/Virtual fashion space Metaverse
	Business	Supply chain Offline Retail	Blockchain E-Commerce E-Promotion
	Strategy		AI for business

Figure2. Key elements of the four orders in the traditional and digital design spaces in the fashion industry.

4. Development and Logic of Digital Fashion

4.1 Research Design

We studied the current state and logic of digital fashion development by conducting a case study of two of the largest luxury fashion companies in the world: LVMH and Kering, along with their two most prominent luxury fashion brands: LV and Gucci. The case study method is effective in analyzing contemporary and unique phenomena that lack extensive theoretical grounding. Studying luxury fashion groups and brands allows us to better understand the practical logic behind digital fashion development, as these companies often leverage cutting-edge digital technologies to lead fashion trends. While fashion cannot be simply equated with clothing, the apparel and accessories industry is one of fashion's main drivers and a key stakeholder in the digital fashion landscape.

The theory of "four orders of design" provides an appropriate framework for our case study. Since these four orders are not isolated from one another, the logic of digital fashion development can be seen in the interactions between them. We organized and analyzed these companies' recent efforts in digital fashion from the perspectives of signs, things, actions, and thoughts, aiming to clarify the current state and underlying logic of digital fashion development.

4.2 Case study on graphic design

Before the rise of digital social platforms, luxury fashion groups primarily focused on promoting their brands through print and television advertisements. With the emergence of social media platforms like Facebook, Instagram, YouTube, and Redbook, luxury brands are no longer confined to the limitations of one-page magazine ads. Today, luxury brands and conglomerates are flocking to these platforms, leveraging a variety of digital media formats (e.g., pictures, videos, games) to reach an increasingly younger luxury audience.

For example, LVMH regularly posts images and videos of contemporary idols and celebrities wearing and showcasing their brands and products on social media. Meanwhile, Kering's brands have achieved high levels of engagement across all the platforms they utilize. Gucci, for instance, launched the online art initiative #GucciGram on social media, encouraging users to creatively reinterpret its iconic patterns like the "geraniums of Blooms" and the "graphic lines of Caleido." These classic brand patterns and products are shared and showcased through photography, painting, and collages on digital visual platforms. Social media platforms have allowed for consumerdriven content to enhance traditional fashion brand marketing, moving beyond the limitations of one-way advertisements.

In the digital era, brand symbols face new design demands. Logos and typography must adapt to various screen sizes on mobile phones, computers, and head-mounted displays to ensure brand recognition across apps, websites, and augmented or virtual reality environments. As a result, brand logos and patterns have gradually shifted from static designs to adaptive, dynamic, and interactive digital forms. For example, in LV's 2021 digital game "Louis: The Game," its iconic floral monogram appears as the protagonist's character element, as scene decorations, and even as a virtual joystick for player control. Moreover, luxury fashion brands are broadening the reach of their brand symbols through collaborations with the gaming industry. In the phenomenon-level game "League of Legends", Louis Vuitton introduced in-game skins featuring its logo, allowing players to express their personality and style through fashionable character customizations.

Beyond product logos and patterns, digital technology is redefining the symbolic forms of fashion brands. In 2022, LVMH introduced "Livi", a 3D-modeled digital figure, as its virtual brand ambassador. This technological advancement has enabled fashion brands to transition from traditional two-dimensional logos and patterns to more immersive, three-dimensional representations.

4.3 Case study on industrial design

Luxury fashion brands like LV and Gucci are renowned for their high-quality materials, exceptional tailoring, and exquisite designs. However, with the widespread adoption of digital technology, the design and production processes of fashion products have undergone a profound digital transformation. Today, designers can replace traditional hand-drawn sketches and manual cutting with digital tools, allowing them to conceptualize and create fashion items through software. AIdriven design tools further assist in generating novel styles. Beyond digital creation, 3D printing technology has revolutionized the manufacturing process of luxury fashion products. For instance, Gucci combined traditional craftsmanship with 3D printing to design its "Cub3D" sneakers, while LV introduced the "Cobra" sneakers using hybrid material 3D printing technology.

Digital technology not only influences the aesthetic of fashion products but also enhances their functionality. Gucci's smart rings and Louis Vuitton's smartwatches exemplify this trend. By integrating advanced sensors and miniaturized electronic devices into wearable fashion products, luxury brands capture physiological data and respond to users' interactions with their environment, achieving a fusion of digital functionality and fashion aesthetics.

Moreover, digital technology has expanded the definition of products from physical entities to virtual ones. On the one hand, by merging digital technology with physical products, luxury fashion brands are breaking down the barriers between the physical and virtual realms. Through digital twin technology, designers can create precise replicas of real fashion items, allowing consumers to preview, personalize, and virtually try on products in fully digital environments. Consumers can view how a product would look on them via 3D virtual models, aiding their purchase decisions. For example, Gucci uses AR technology in its mobile app and on social media platforms like Snapchat to offer virtual try-ons. Through a phone camera, users can "try on" Gucci's shoes, bags, and accessories, providing a new online shopping experience.

On the other hand, digital technology enables luxury brands to create entirely new forms of products. Virtual fashion can transcend physical limitations, offering novel visual experiences. These virtual fashion pieces can exist in games and on social platforms and can also be traded as NFTs on the blockchain, creating a new form of luxury. LV, for instance, launched the "VIA Treasure Trunk" series of digital collectibles in 2023. These NFTs feature iconic travel trunk designs and come with physical replicas. The high-priced NFTs cannot be resold or transferred, maintaining extreme rarity and exclusivity. By transforming virtual fashion products into unique digital assets, luxury brands enable consumers to own and showcase these items in virtual worlds. This virtual fashion trend not only expands the luxury market but also enhances the digital collectible value of brands.

Overall, in the second order of design, luxury fashion brands' digital transformation is characterized by leveraging advanced digital technologies to innovate the entire process, from design and production to sales, creating more novel, interactive, and personalized products and experiences.

4.4 Case study on experience design

Both Kering and LVMH are leveraging innovative digital tools to enhance brand interaction with consumers, optimize fashion experiences, and reshape customer relationships. A key step in LVMH's digital transformation was the launch of its multi-brand eCommerce site, "24 Sèvres", in 2017. This platform offers a wide range of online functions, including product availability checks, online fitting appointments, click-to-order, and in-store pickup services. In addition to a user-friendly interface, luxury brands prioritize providing a high-quality consumer experience. One standout feature of 24 Sèvres is the option for customers to have one-on-one video consultations with brand stylists. LVMH also uses social media platforms to enhance customer engagement.
On Facebook, for example, shoppers can interact with the "24 Sèvres Style Bot" to maximize the platform's shopping capabilities. Similarly, Gucci has strengthened social

engagement through campaigns like #GucciGram on social media, fostering a sense of belonging and brand loyalty among users.

With the development of digital technologies such as AR and XR, consumers can now view and interact with virtual fashion products in real or virtual environments through smart devices. These new interaction modes, enabled by head-mounted displays, introduce new demands for user interface design.
In early 2024, Gucci and Balenciaga, both under Kering, launched digital apps on the Apple Vision Pro platform. Through these apps, users can immerse themselves in documentaries, online fashion shows, and interactive styling experiences. VR and AR technologies offer consumers new interactive shopping experiences. AR technology makes personalized services like virtual try-ons and customizations possible. Gucci, for instance, began offering virtual try-on functionality in its app in 2019. This feature allows consumers to preview how clothing looks on them in a digital environment without needing physical products.

Moreover, the application of XR technology has expanded the boundaries of digital fashion displays and experiences. In 2021, Balenciaga partnered with Epic Games to launch the digital game "Afterworld: The Age of Tomorrow". Within the game's futuristic virtual world, Balenciaga showcased its 2021 Fall fashion collection. This gamification of luxury fashion brands attracted younger consumers through novel interactive experiences, providing a fresh way to present brand culture. By applying cutting-edge digital technologies, luxury fashion brands aim to enhance the shopping experience and optimize the display and interaction of digital fashion products. This allows consumers to enjoy interactive and service experiences on digital platforms that rival or even surpass those in physical stores, significantly boosting the immersion and interactivity of online shopping.

In the third order, luxury fashion brands' digital transformation focuses on enhancing user experiences and interactions through technological innovation. Digital technologies offer consumers more convenient, personalized, and immersive service experiences.

4.5 Case study on system design

Luxury brands are utilizing digital technology to create fashion spaces that blend virtual and physical experiences. On one hand, luxury brand offline stores integrate digital technologies to offer personalized and immersive fashion experiences for in-store customers. On the other hand, the design of environments is no longer confined to traditional physical spaces. By leveraging digital technology to build fashion spaces that are either parallel to physical ones, merge virtual and real environments, or are purely virtual, fashion brands can offer their users more diverse experiences across time and space. For example, GUCCI has experimented multiple times with creating virtual spaces

in the metaverse. In 2021, Gucci launched a two-week virtual exhibition called "Gucci Garden" on the Roblox platform, where players could discover and purchase digital Gucci collectibles, such as clothing and accessories. Following the success of "Gucci Garden," in 2022 Gucci introduced "Gucci Town" on Roblox, offering consumers a richer digital fashion experience, including creation, social interaction, customization, and themed games. That same year, Gucci partnered with the digital real estate platform The Sandbox to launch a metaverse hub called "Gucci Vault Land," making it the first fashion brand to own its assets on a metaverse platform. Such innovations not only bring brands closer to younger consumers but also provide fashion brands with a new path for creativity, transactions, and display within virtual spaces.

In addition, luxury fashion groups are driving innovation in supply chain management, brand marketing, and shopping experiences through digital strategies. Kering and LVMH have successfully streamlined the online luxury experience by launching fully functional e-commerce websites and tapping into the power of social media. This direct-to-consumer (DTC) approach allows luxury brands to extend their exclusive experiences from physical stores to digital platforms. In terms of supply chain management, Kering and LVMH have adopted RFID and NFC technologies at every stage of the supply chain, from fabric management and production to warehousing and sales. For instance, consumers can verify the authenticity of their LV purchases by scanning NFC tags. With the rise of blockchain technology and NFT markets, luxury fashion brands have begun engaging with virtual trading platforms. Both LV and Gucci have released several NFT products in recent years. Blockchain technology, with its decentralized, secure, and transparent nature, provides a reliable ownership and authentication database for digital fashion products, ensuring that the originality and ownership of each piece can be permanently recorded and verified.

The digital transformation of luxury fashion companies is also reflected in their holistic yet differentiated innovation strategies. Groups like LVMH have started implementing digital transformation plans across their entire organization. LVMH currently has over 75 brands, each with its own brand image, requiring differentiated digital strategies tailored to their individual characteristics. Since 2018, LVMH has been promoting the "La Maison des Startups" program, which fosters collaboration between startups in the luxury industry and its own brands, exploring the future of digital products and services in the luxury sector. This incubator model not only empowers startups to innovate but also provides LVMH brands with an open space for transformation.

5. Discussion: Challenges, Limitations, Projections and Pathways

5.1 Challenges and limitations of current digital fashion

Digital and virtual fashion presents exciting possibilities but also faces significant challenges. As fashion evolves at an increasingly rapid pace, trends emerge and disappear quickly. The attitudes of luxury fashion brands toward virtual fashion remain speculative. A noticeable fact is that many luxury fashion brands sparked a wave of virtual fashion during the pandemic. However, whether this trend will endure remains uncertain.

From a business perspective, transforming innovative designs into viable commercial products in the realm of digital fashion is challenging. This not only involves creating appealing virtual products and platforms through appropriate design but also exploring new business models suited to digital and virtual fashion. The glamorous future fashion world portrayed by the media is an illusion, representing only one facet of the business. The relationship between decision-making and the impact of luxury fashion brands in virtual spaces like the metaverse remains unclear (Granqvist, n.d.). Key challenges include ensuring the longevity and sustainability of virtual products, maintaining user engagement, and fostering content creation within virtual spaces. Furthermore, the conflict between blockchain-enabled supply chain transparency and the commercial confidentiality of fashion brands is yet to be resolved.

From the perspective of technological development, integrating virtual and real-world design requires substantial resources and technical investment. This may lead to a division of innovation forces within the fashion industry (Strähle & Grünewald, 2017). Additionally, fashion design education has shown a lag in adapting to the rapid growth of digital fashion. Traditional design curricula often fail to fully cover the skills and knowledge required for digital fashion, leaving young designers without the necessary digital competencies and facing the challenge of skill conversion (Chrimes & Boardman, 2023). To keep up with the times, they must learn new tools and technologies, such as 3D modeling and programming, which can result in a steep learning curve, potentially limiting their ability to innovate. For consumers, long-term participation in creating content within virtual environments is likely only if they find the digital components of the metaverse useful and user-friendly. Moreover, interoperability between different virtual environments remains an obstacle. While the exchange of tokenized collectibles in the metaverse is appealing, creating secure and efficient trading platforms for these assets to enable seamless transactions presents a challenge.

From the perspective of social acceptance and ethics, the widespread adoption of digital fashion still has a long way to go. This involves not only the safety and inclusivity of the technology but also how consumers reshape social interaction and personal identity in virtual environments. First, consumers are concerned about the privacy of personal data on digital platforms. For example, creating digital avatars often requires the collection and use of personal data, including facial images, sensory data, and behaviors (Jim et al., 2023). Access to such sensitive information may make users hesitant to enter the metaverse due to fears of personal privacy breaches. As virtual worlds evolve, the way brands collect, use, and apply consumer data remains a gray area, as seen with smart wearable devices. Second, from the standpoint of inclusivity, there are still no effective safeguards to prevent harmful avatar behavior, hate speech, or harassment in virtual spaces. Lastly, societal biases based on gender, race, and culture, which exist in the real world, continue to be present in digital environments. For instance, current avatar presets and digital clothing options are highly binary, limiting gender expression to male or female (Nabbosa & Kaar, 2020). As fashion brands transition into the metaverse, inclusive marketing will remain a critical issue.

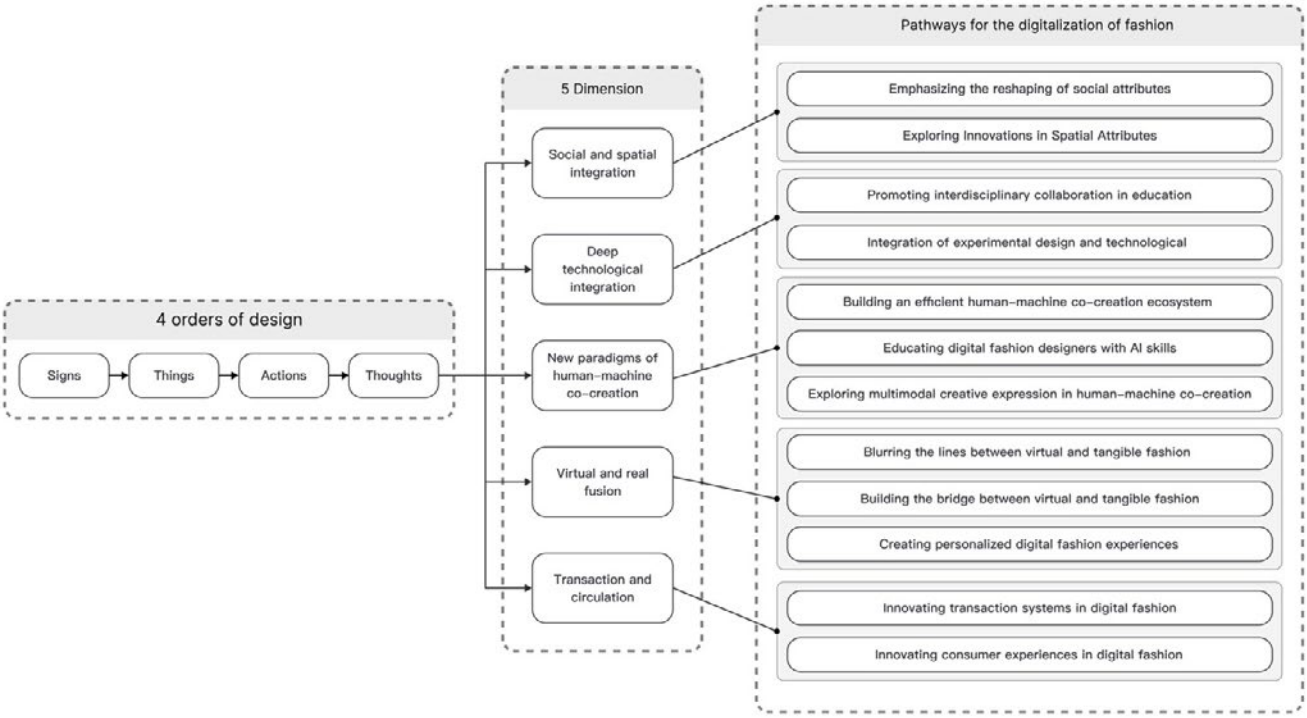
In fact, compared to other industries, the fashion industry has been criticized for its slow adoption of digital technologies. Fashion brands should be more proactive in addressing business and technological challenges. Beyond that, digital fashion still faces significant challenges concerning privacy, cultural diversity, rights balance, and gender issues, all of which touch on broader social and ethical concerns.

5.2 Projections of future digital fashion

With the development of the metaverse, future digital fashion experiences are becoming increasingly immersive, interactive, and personalized. For example, fashion brands will increasingly use NFTs as gateways for digital consumers to enter exclusive, club-like communities. Just as brand trust built on traditional social media platforms can influence brand loyalty, virtual communities in the metaverse will follow a similar pattern. By offering consumers personalized immersive experiences, exclusive privileges, and opportunities to participate in product development, brands can strengthen consumer trust and loyalty. Meanwhile, fashion marketing on social media is gradually shifting from broad-based strategies to building smaller, highly engaged niche communities within the metaverse. These communities will form around shared values, aesthetics, or unique experiences, enabling brands and users to co-create digital fashion. Consumers will no longer be passive buyers but active participants in fashion design and marketing.

Additionally, more fashion brands are adopting blockchain technology to ensure supply chain transparency by openly sharing information about material sources, production facilities,

and environmental impacts. Blockchain can be integrated with digital retail spaces in the metaverse, allowing consumers to explore the manufacturing process, supply chain transparency, and sustainability practices through virtual experiences. By scanning QR codes or NFC tags on products, consumers can access complete production information, thereby enhancing trust in the brand and verifying its environmental commitments. On the other hand, while competition exists between fashion brands, collaboration will become increasingly important for achieving supply chain transparency and fairness. The future of the digital fashion industry may see the emergence of standardized information-sharing systems across the sector. Brands will be able to open up their supply chains in a transparent manner while protecting trade secrets, ultimately improving the industry's sustainability and social responsibility through cooperation.



5.3 Pathways for the digitalization of fashion

Figure3. Five dimensions on digital fashion between "four orders of design" and pathways for the digitalization of fashion.

In the digital age, the rise of digital fashion is driven and constrained by various factors, including design concepts, technological advancements, and market demand. The inherent complexity and challenges in this field present the design discipline with significant opportunities for exploration and innovation. To strike a balance between opportunities and challenges in the transformation

and upgrading of digital fashion, it is essential to adopt a structured approach, applying architectural thinking for top-level planning and holistic layout within the design discipline. We deconstruct the development pathways of digital fashion from five dimensions: social and spatial integration, deep technological integration, new paradigms of human-machine co-creation, virtual and real fusion, and transaction and circulation, as shown in Figure 3. By exploring these dimensions, the aim is to accelerate the digitalization of fashion within the design discipline.

The first pathway is to shape the social and spatial attributes of digital fashion. Emphasizing the reshaping of social attributes. In the transformation and upgrading of digital fashion, reshaping its social attributes has become a key development strategy. This strategy focuses on leveraging the power of design to promote cultural integration and co-creation of values, reflecting and enhancing social diversity and inclusivity. Collaboration between designers and creators from diverse cultural backgrounds, along with the co-creation mechanisms offered by digital platforms, serve as bridges for cross-cultural understanding and communication. Moreover, incorporating sustainable design concepts, such as using eco-friendly materials, implementing recycling strategies, and developing innovative methods to reduce design waste, advocates for a more responsible and sustainable consumption model. Enhancing social engagement and user interaction through design strategies—such as design competitions on social media platforms and personalized services—heightens the appeal of digital fashion products and fosters a sense of belonging and loyalty among users. By reshaping the social attributes of digital fashion from a design perspective, students and designers can recognize that design is not only a form of visual and aesthetic expression but also a medium for social and cultural exchange. This can promote the formation of social values and the enhancement of cultural awareness. The integration of design thinking with social and cultural values plays a crucial role in shaping a more diverse, inclusive, and sustainable digital fashion ecosystem.

Exploring innovations in spatial attributes. Innovations in the spatial attributes of digital fashion are an inevitable trend in response to contemporary technological advancements and changing user needs. These innovations involve the integration of virtual and real worlds, the design innovation of digital exhibition spaces, and the application of intelligent spatial layouts, providing richer and more interactive fashion experiences. By using cutting-edge technologies such as augmented reality (AR) and virtual reality (VR) in design practices, designers can create immersive experience spaces that blur the boundaries between virtual and reality, greatly enriching the sensory experiences and interaction modes for users. Digital display platforms, such as virtual fitting rooms and 3D product displays, optimize the user experience using digital technologies, while also reducing the consumption of physical space and resources, embodying an environmentally friendly and

resourcesaving design philosophy.

The second pathway is to promote interdisciplinary integration of technologies in digital fashion. Promoting interdisciplinary collaboration in education. To foster deeper collaboration and knowledge sharing between the design discipline and fields such as computer science, materials science, and artificial intelligence, it is crucial to build and develop multidisciplinary collaboration platforms and update design education systems. This interdisciplinary cooperation not only broadens the technical horizons of design professionals but also introduces new technological possibilities and innovative thinking into design practices. Innovation in design education also plays a vital role. By integrating the latest technological advancements into design curricula, implementing project-based learning approaches, and offering specialized workshops and training, design education can more effectively cultivate students' abilities in cutting-edge technology application and innovative design thinking. Furthermore, encouraging lifelong learning and continuous professional development ensures that designers remain abreast of technological advancements, thereby reinforcing the central role of the design field in digital transformation.

Integration of experimental design and technology. To drive the cross-disciplinary integration of innovative technologies in digital fashion, it is essential to encourage experimental and exploratory design and to strengthen the dialogue between design and technology. This integration requires a willingness to experiment with new technologies and innovative methods, exploring the potential applications of advanced technologies such as virtual reality, augmented reality, and artificial intelligence in fashion design. Through experimental projects and prototype development, the boundaries of design can be expanded, and new possibilities for technological innovation in the fashion field can be explored. Additionally, establishing a continuous dialogue mechanism between design and technology is critical. Regularly organized seminars, workshops, exhibitions, and public forums provide a platform for designers and technology experts to share the latest research findings, technological advancements, and creative design ideas. This enhances cross-disciplinary understanding and cooperation.

The third pathway is to explore the human-machine co-creation potential in digital fashion. Building an efficient human-machine co-creation ecosystem. In the field of design, it is crucial to continually enhance the potential for human-machine co-creation in digital fashion. A key aspect of this process is optimizing collaborative design platforms. These platforms must provide intuitive tools that facilitate seamless interaction between designers and AI systems, enabling real-time feedback on creative ideas and exploration of AI-generated design solutions. To lower the technical barriers, these platforms should incorporate natural language processing and intuitive graphical user interfaces, allowing designers

to leverage AI capabilities without needing in-depth knowledge of the underlying technology. At the foundational technical level, enhancing the transparency and explainability of AI algorithms is another critical factor in promoting human-machine co-creation. Transparent algorithms enable designers to understand the data or design logic underlying AI-generated suggestions, fostering trust in the machine-generated process. This mutual understanding between human and machine promotes deep collaboration, allowing designers to more effectively guide AI systems and tailor outputs to meet project requirements.

An iterative design process also facilitates effective human-machine co-creation. In this process, designers and AI systems interact through continuous feedback and adjustment cycles, learning and adapting to each other. Designers can evaluate preliminary design solutions proposed by AI, providing specific feedback and new ideas, while AI systems adjust based on this feedback. This iterative process not only accelerates innovation but also enhances the quality and personalization of the final design outcomes.

Educating digital fashion designers with AI skills: as digital fashion undergoes transformation and upgrading, it is crucial to cultivate designers equipped with AI and digital skills, as this is key to unlocking the potential of human-machine co-creation. Design education should focus on a comprehensive curriculum that includes foundational AI, data analysis, machine learning, and human-computer interaction, empowering designers to collaborate effectively with advanced technologies. By adopting an interdisciplinary educational model that combines theoretical learning with practical projects, designers can learn to utilize AI technology in innovative ways. Additionally, specialized workshops and continuing education courses in digital fashion design can help practicing fashion designers update their skills. Enhancing AI proficiency not only strengthens designers' leadership in the co-creation process but also broadens their creative boundaries, making the design process more flexible and faster in iterations, ultimately driving innovation and personalization in digital fashion.

Exploring multimodal creative expression in human-machine co-creation: in the human-machine cocreation process of digital fashion, integrating various sensory dimensions (such as visual, auditory, and tactile) can enrich the interaction and creative process between designers and AI systems. Multimodal design approaches not only expand the boundaries of creativity but also enhance interaction between designers and machines, providing new sources of inspiration and methods of expression for innovative design. By developing AI systems capable of understanding and integrating various inputs—such as text, images, and sounds—designers can communicate with technology in a more intuitive and natural way, stimulating broader creative thinking and exploration. This cross-modal creative process not only fosters deeper understanding and cooperation between humans and machines

but also brings richer and more diverse perspectives to digital fashion design.
The fourth pathway is to surpass the boundaries between virtual and reality in digital fashion. Blurring the lines between virtual and tangible fashion: by integrating AR and VR technologies, along with the application of digital twin technology, the goal is to create immersive experiences that allow users to interact with virtual design elements in real-world settings. This effectively blurs the boundaries between virtual and reality. Digital twin technology offers a transformative approach to fashion design by accelerating the integration of innovative design and sustainability. Through digital twin technology, precise replicas of virtual fashion products can be created, enabling designers and users to preview, test, and modify designs in a fully digital environment. This approach not only enhances the flexibility and interactivity of design but also provides robust support for personalized customization and virtual fitting. The use of digital twin technology elevates the fusion of innovative design and sustainability to a new level. By constructing a fashion design space that parallels physical fashion spaces and merges virtual and real environments, this technology fosters the development of higher-order thinking in the public. It allows fashion design to be more seamlessly integrated into both real and virtual social lives. Digitalization empowers the general public further, making "artistic living" a possibility in everyday life. Through the fusion and application of art and technology, the design field can drive the innovative development of digital fashion, achieving seamless integration of virtual and reality in the fashion domain.
Building the bridge between virtual and tangible fashion: to surpass the boundaries between virtual and reality in digital fashion, continuous innovation in wearable technology is essential. By developing smart wearable fashion products integrated with advanced sensors and microelectronic devices, these products can capture users' physiological data and respond to their interactions with the environment. This results in a perfect blend of digital functionality and fashion aesthetics. Innovations in advanced technology not only enhance the practicality and interactivity of wearable fashion products but also offer highly personalized digital experiences for users. Through these smart wearable products, designers can seamlessly combine physical fashion with digital experiences, further blurring the lines between virtual and reality and promoting higher levels of innovation and personalization in digital fashion.

Creating personalized digital fashion experiences: the interdisciplinary co-creation process not only drives innovation in design and technology but also opens up new markets and user groups, providing broader development opportunities for the digital fashion field. In the process of digital fashion transformation and upgrading, promoting cross-disciplinary collaboration and co-creation, as well as enhancing user engagement and personalized customization, are critical paths to improving the digital fashion experience. Encouraging fashion designers to collaborate with game

developers, digital artists, and technology innovators from various fields helps explore new methods of integrating virtual and reality. By leveraging online platforms, social media, and virtual communities, brands can directly interact with users, gather feedback and personalized needs, and tailor designs and experiences more precisely to meet their pursuit of individuality and differentiation. Active user participation not only provides valuable data to guide product innovation and improvement but also strengthens the sense of belonging and loyalty among users, building a closer brand community. This fusion and creation of personalized digital fashion experiences require designers to possess an open-minded approach to innovation, interdisciplinary collaboration skills, and a deep understanding and respect for user needs and experiences. By putting people at the center, digital fashion can progress towards a more personalized, interactive, and experiential direction.

The fifth pathway is to Explore new models of trading and circulation in digital fashion. Innovating transaction systems in digital fashion: in the pursuit of new models for trading and circulating digital fashion, leveraging blockchain technology to ensure transparency and authenticity, as well as developing the digital fashion NFT (Non-Fungible Token) market, are crucial. Blockchain's decentralized, secure, and transparent nature provides a reliable database for the ownership and certification of digital fashion products, permanently recording and verifying the originality and ownership of each piece. Additionally, integrating digital-physical tools like NFC chips, dynamic QR codes, and blockchain technologies such as smart contracts establishes a new digital asset trading system. This system accurately records NFT transaction information and ownership transfers. Within this framework, the growth of the NFT market offers a unique platform for trading digital fashion products, aligning with the exclusivity and luxury associated with high-end fashion items, thereby attracting consumers and collectors alike. Digital fashion creations, often developed using 3D software and other digital tools, can be displayed within digital metaverses and augmented through virtual reality platforms, AR environments, games, or other digital experiences, providing immersive fashion experiences to users.

Through these multilayered interactions, blockchain and NFTs serve not only as tools for trading and circulation but also as a bridge connecting fashion with the digital world. This new model not only enhances the commercial value and marketability of digital fashion products but also provides designers and brands with innovative platforms for creation and marketing, driving innovation in the digital fashion industry.

Innovating consumer experiences in digital fashion: technological innovation plays a key role in enhancing consumer shopping experiences and optimizing the display and transaction processes of digital fashion products. Virtual try-on technology allows consumers to preview how clothing items

will look and fit on themselves without the need for physical goods, greatly enhancing shopping convenience and efficiency. Additionally, augmented reality (AR) technology expands the boundaries of digital fashion display and experience, allowing consumers to use smart devices like smartphones or AR glasses to view and interact with virtual fashion products in real-time within their physical environments. The integration of these innovative technologies not only improves user shopping experiences and reduces return rates due to size mismatches or style dissatisfaction but also provides designers with a dynamic platform to showcase their work in a more vivid and interactive manner. Through virtual try-on and AR technologies, the design field can explore new forms of design expression and communication, promoting the innovation and personalization of digital fashion products while also reducing logistics costs and environmental impact, aligning with sustainable development principles.

6. Conclusion

The digital transformation of fashion redefines the industry by merging virtual and physical realms, expanding the role of design from product creation to system innovation. Through the "Four Orders of Design," this paper has explored how luxury brands like Louis Vuitton and Gucci utilize digital technologies to reshape consumer experiences, enhance sustainability, and foster human-machine co-creation. The integration of virtual fashion with emerging technologies like AI, blockchain, and extended reality not only transforms the production process but also reimagines fashion as a dynamic platform for self-expression and social interaction. As digital fashion continues to evolve, the design discipline plays a critical role in driving innovation, offering new opportunities for creativity, personalization, and sustainability in the fashion industry.

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STRATEGIC FORESIGHT AND WORLDBUILDING WITH COMPANIES

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ABSTRACT | 'Tuulilulеima' is an artistic and futuristic protopian film developed using design fiction and art-based methods. Design fiction is a method based on narratives and worldbuilding that unravels unknown, yet possible, futures. Worldbuilding focuses on imaginary realms, cultures, and languages, usually used in literature, film, and gaming industries (Zaidi, 2019). This paper presents a research-through-design process of imagining possible futures aiming to better understand creative methods and the role of artistic expression, which can be further utilised as a means to facilitate companies' foresight and strategy work.

Tuulilulеima followed the core idea of design fiction by creating a physical prototype based on an envisioned future world. The filmmaking process, including costume design and cinematography, had a central role in creating the future world. As part of the speculative design, a futuristic wind chime was created to attract, measure, and deal with wind changes in the future. Tuulilulеima enabled companies to envision possible futures and various personas in future situations. This allowed them to join worldbuilding and apply this in their business strategising process for the future. The strategic foresight design process included the creation and utilisation of several foresight planning tools, such as a foresight matrix for three possible future scenarios (utopian, business as usual, and dystopian) and a canvas for future business model design.

KEYWORDS | STRATEGIC FORESIGHT, WORLDBUILDING, PROTOPIA,

1. Introduction

Tuulilulеima is an artistic and futuristic protopian film developed using design fiction and art-based methods. This paper presents a research-through-design process that imagines possible futures with the aim of understanding better creative ways and the role of artistic expression, which can be further utilised as a method to facilitate companies' foresight and strategy work. Art-based methods have been acknowledged to foster creativity and innovation in businesses (Nissley, 2010). Further, this paper discusses filmmaking—including fashion design, cinematography, and foresight tool development—that is part of the design fiction process. This paper questions whether design fiction can be used to facilitate future-oriented business design.

Tuulilulеima was iteratively developed by relying on intuition, artistic expression, and performative improvisation. It was part of the Empathy Business project (2023–24) funded by Business Finland and focused on researching empathy-driven and digital solutions in business prototyping and service development. The design fiction process included performative notes for a futuristic short film. The notes presented a protopia in which the changes in the main sea streams and wind patterns affected our living conditions and climate. The manuscript relied on embodied performances and reflections of future winds. The breaths of the wind were felt and expressed through the body and voice. Bodily improvisation was undertaken by following the instructions in the performative notes, but room was made for intuition and improvisation.

Futurists and speculative designers such as Kevin Kelly and Monica Bielskyte discuss the protopian future. Kelly (2011, 2022) discusses the importance of optimism when imagining our future. Our world has been designed by optimists with a strong belief in their solutions, such as inventing an airplane. He calls this optimistic future that we can imagine 'protopia'. This is based on trusting each other, gradually solving problems, and creating innovations that will push society forward. The future is not dystopian or

utopian; it is a future in which we are good ancestors and can trust future generations. Bielskyte (2023) highlights protopia as a continuous dialogue that is a process, not a destination—a space that will always iterate, question itself, adjust, and expand. Further, she presents protopian principles as being *'plurality—beyond binaries, community—beyond borders, a celebration of presence; regenerative action & life as technology, symbiotic spirituality, creativity & emergent subcultures and evolution of cultural values'.* Vize (2024, in press) focused on creative practice and, particularly, on utilising transformation design for the worldbuilding of plural futures.

Design fiction is a method based on narratives and *worldbuilding* that unravels unknown yet possible futures. Worldbuilding focuses on imaginary realms, cultures, and languages, usually used in literature, film, and gaming industries (Zaidi, 2019). Tuulilulеima followed the core idea of design fiction by creating a physical prototype based on an envisioned future world. In this future world, nature, particularly winds play an important role. A futuristic wind chime was created to attract, measure, and deal with wind changes in the future. Tuulilulеima was utilised to enable companies to envision the possible futures and personas in future situations where changes in climate conditions and available resources affect our daily lives. This allowed companies to join in the worldbuilding process and apply this in their future business strategising.

An important part of the process was a collaboration with several companies: Content Union, Zone ii Ltd, and Zone2 Pictures Ltd who also participated in the Empathy Business project. Content Union is a design consultancy. Zone ii Ltd is a location scouting company and Zone2 Pictures Ltd is a production company. We have been working with both worldbuilding as well as developing the foresight tools for planning future business models with these companies. Zone ii Ltd and Zone2 Pictures Ltd participated in the filmmaking process by providing cinematography and worldbuilding inputs. Content Union participated in workshops with the companies when testing the first tool and workshop formats. Throughout the development process, there have been several collaborative discussions and planning sessions.

First, the theoretical framework and its main aspects are presented. Thereafter, the research methods and data are discussed, after which the insights from two main parts of the research processes—design fiction by filmmaking and business design for the future—are presented. Then, the findings and conclusions are presented.

2. Theoretical framework

The design fiction process is outlined in this research paper, which deals with creating a representation of the future. Blythe (2014) discussed the uses of prototypes in the research-through-design process. He used design fiction to explore the value of

these prototypes. Blythe suggested that design fiction is used to create meaning. This is also applicable to this research case. Understanding different presentations of the future and discussing them is crucial for creating meaning and relating these meanings with one's business or design. Bosch (2012, p. 1) interviewed award-winning sci-fi writer Bruce Sterling in Slate online magazine regarding design fiction. Sterling made the following comments on design fiction: *'It's the deliberate use of diegetic prototypes to suspend disbelief about change. Diegetic means thinking very seriously about potential objects and services and trying to get people to concentrate on those rather than entire worlds, political trends, or geopolitical strategies. It tells worlds rather than stories'*. In Slate magazine, Blythe (2014), Bosch (2012), and Sterling bring up the role of crafting as an essential aspect of design fiction. Design fiction is a process whereby future representations are concretised as tangible. This process forces one to discuss the future on a rather concrete level, including the physical materials, logistics, and conditions involved therein.

Coulton et al. (2017) proposed that design fiction involves worldbuilding. They argued about the difference between storytelling and worldbuilding. Their preference of building worlds as design fiction can sculpt a plurality of different media forms as well as physical prototypes. They refer to worldbuilding as a process of constructing imaginary realms that can host several media forms and storytelling located within this realm. They make a reference to Bruce Sterling (in Slate magazine) and to Julian Bleecker and his work with the Near Future Laboratory[1] and his essay (2009). In his essay, Bleecker emphasised the role of design as thoughtful exploration, creative materialisation, material crafting, and imagining. Bleecker is pondering the role of design fiction as a combination of science facts and fiction and whether science fiction can have a purpose and be meaningful. Design fiction would be the combination of these two sides—facts and fiction. This combination will likely create a meaningful tool to investigate the future.

Kirby (2023, p. 1) proposes on-screen cinematic space *'whose properties are shaped by relationships between media forms and physical space'*. Kirby refers to the combination of media forms and physical space as a composite layered space. Worldbuilding can utilise such a cinematic space. In particular, the article at hand uses filmmaking and this kind of cinematic space as a platform for design fiction. Boillat (2018) discussed cinema in his book entitled 'Cinema as a Worldbuilding Machine in the Digital Era'. Cinema involves navigating various media enabled by new technologies as well as worldbuilding a multitude of worlds within the metaverse, virtual worlds, artificial worlds, and so on. Filmmaking and cinema are natural means of worldbuilding. Santos et al. (2024) define worldbuilding as a narrative device for describing a world with its geography, interactions, relations, and characters. One could think of the Netflix series 'Bridgerton' as an example of worldbuilding, where a version of London at the beginning of the

nineteenth century is described. In a similar manner, when creating a future scenario, worldbuilding needs to describe a logical story, which includes the plot, setting, characters, point of view(s), style, themes, and possible conflict (Coulton et. al 2017).

Certain philosophical studies recognise the flow of scapes, particularly mediascape. Appadurai (1996) discusses the five dimensions of global cultural flow: mediascapes, ethnoscapes, technoscapes, finanscapes, and ideoscapes. It is essential for these to be considered in worldbuilding, particularly in strategic foresight. Bello (2010) proposed the concept of 'Goodscapes' using theories from the social sciences and design that intersect among globalisation, things, and design processes. Bello placed significance on materiality and the flow of goods in the impact of various scapes, but also mentions future design which involves new physical and virtual environments acknowledging the social, cultural, political, and environmental changes in the society.

One cannot go on without mentioning Dunne and Raby's (2024) classical reading on future studies called 'Speculative Everything' with a new preface. In the book, they remind us about the futuristic nature of design, and that every design process has a certain amount of future thinking embedded in it. In a similar manner to Bleecker (2009), Dunne and Raby also highlighted the role of probabilities, imagining, and crafting concepts and actual designs. Further, in their preface, Dunne and Raby mention the building of parallel worlds rather than futures. This aligns well with the process of worldbuilding. The new preface also recognises Steven Shaviro's study on speculative fiction, speculative philosophy, and speculative finance. Shaviro's (2019) notion of speculative finances is interesting as it looks to the future by pricing potential future events. In our article, we also attempt to take steps in this direction; we attempt to outline future resources for entrepreneurs.

Garcia (2023) is engaged in extremely interesting work with fashion futuring that intertwines speculative design, foresight, and material culture and tweaks them towards sustainable futures. She discusses how designers and futurists are exchanging tools and techniques and, thus, becoming closer to each other. She addresses a critique of speculative design, addressing its elitist positioning as having little application in real life. She proposes that fashion futuring addresses creativity and agency. I see this as an activist action against elitism and pro-relevance. The same positioning is apparent when she places strategic foresight on fashion futuring. This offers tactics to involve decision-makers and gear their effort towards creating desirable futures. In this paper, fashion and costume design plays a central role in design fiction or speculation itself.

When creating design fiction and performing worldbuilding, we discuss different possible futures: dystopias, utopias, and protopias. In the introduction, we have already mentioned a few of the relationships among these concepts. This paper leans

towards protopia, which enables more plural opportunities. Protopia highlights the importance of optimism when imagining the future (Kelly, 2011, 2012) and progressive design movements that believe in human creativity, intuitivity, empathy, and solidarity in designing better futures (Boehnert et al., 2024). Barton (2022) discussed protopia in an exciting manner and proposed that protopian future thinking does not only involve framing futures in a new manner but also utilising technological innovation for proactive future prototyping that focuses on inclusivity, cultural values, and social ethics. Protopian scenarios are experimental platforms for asking complex questions regarding the future. Barton (2022) further reminds us that this is to resist modernist design that focuses only on one thing.

The theoretical framework combines filmmaking, design fiction, worldbuilding, and crafting meaning through creative action. This occurs through speculative design, costume design, fashion futuring, and cinematography. Together, these elements create a cinematic space that enables future prototyping and representing this to a larger audience. With new technologies, such as a virtual production stage, it will likely be possible to enact digitally crafted content and even use AI in prototyping.

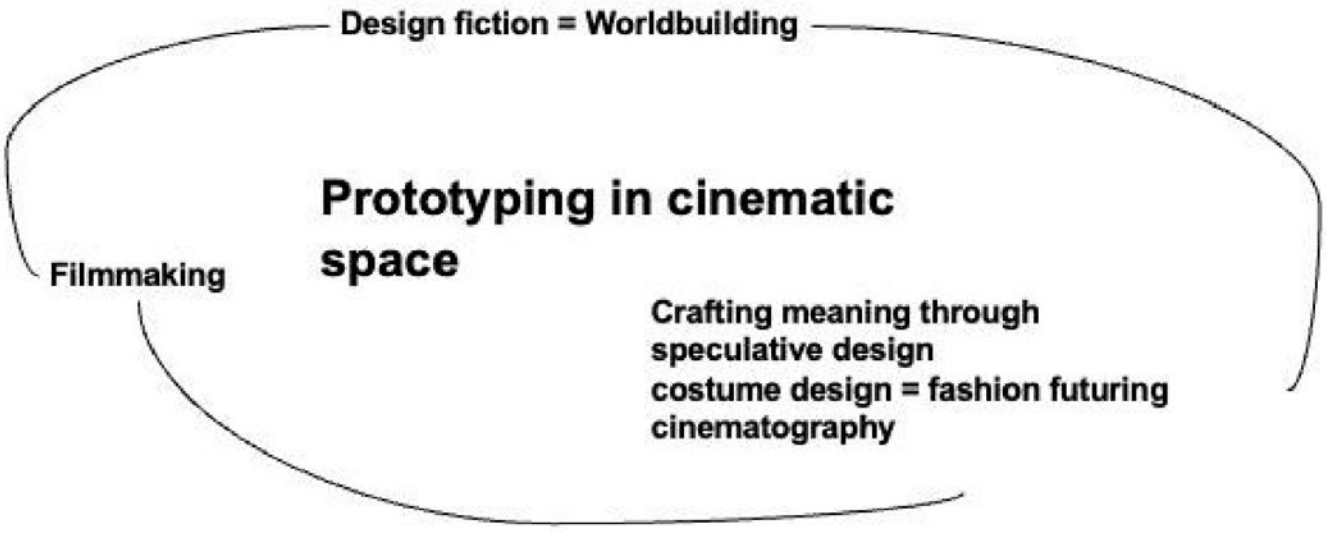


Figure 1 Theoretical framework

The focus of this paper is to consider strategic foresight and how companies can develop their future business. In the context of strategic foresight, methods, experiences gained through methodological implementation, and organisational practices have been discussed in the literature; however, there is limited research on use and motivation, z designers and artists a means to escape cultural traps and possible limitations they may face to explore what ought to be (Slaughter, 1997). It enables escaping realities of the past and the rules laid down by organisations

and those implied in their structures in terms of how processes are supposed to work, thereby emphasising histories and experiences and lessons learned instead of exploring prospective opportunities beyond these realms. Strategic foresight is defined by Slaughter (1997, p. 1) as *'the ability to create and maintain a high-quality, coherent, and functional forward view and to use the insights arising in organisationally useful ways'.*

Strategic foresight can assist designers to come to grip with active transcendence and thought experiments for their visions of the future. However, they can enact their ideas and create actual scenarios using their viewpoints by creating visual resemblances and examples of their visions by using photos, films, scenes, and sets. Designers and artists can build future visions and move into rich and more realistic spaces in which they avoid the 'flatland'. Slaughter (1997) refers to this as 'visions of the future that are 'impoverished, mined-out, polluted, stripped of (non-human) life and overwhelmed by increasingly powerful technologies'. Although his views may be dated, particularly as designers may envision futures with technologies far removed from flatlands and impoverished futures, Slaughter's understanding of how future scenarios may assist in viewing futures differently is relevant as his understanding enables active explorations and curation of methodological complexity to create high-quality insights of meta-level systems change that may be desirable for the future (Slaughter, 1997). As Iden et al. (2017, p. 88) explained, the aim of using strategic foresight and an assortment of good methods is to 'capture and perceive drivers of future change' and convert them into specific strategic responses. One of the challenges of strategic foresight remains the setting of clear objectives and identifying exactly what they seek to achieve (Iden et al., 2017).

3. Research methods

Research design is an iterative research strategy based on learning from the research process and findings (Thomas & Rothman 2013). As an outcome of the research design process, new theories, artefacts, and practices are produced (Barab & Squire, 2004). This strategy serves well in the research-through-design process in which the motivation lies in crafting tangible outcomes (Fryling, 1993). This case study is on an artistic and futuristic protopian film called Tuulilulеima includes styled costumes, speculative objects, an ethnographic documentary film entitled 'The Making of Tuulilulеima', and several business design tools. Research-through-design (Blythe, 2014) focuses on research in real life contexts by systematically working through a series of implementations (Wang & Hannafin, 2005) that are designed and evaluated. The design fiction process that includes both filmmaking and worldbuilding worked as a research context. Similarly, the workshops with companies enabled the business design process.

Blythe (2014) was critical of the limitations of the research-through-design process approach that is not necessarily replicable nor the outcomes always the same, which would

be the requirement for evidence. Of course, research-through-design and qualitative research are utilised more often in explanatory research to investigate phenomena rather than evidence. The background for this is a more general discussion regarding the differences between qualitative and quantitative research. Tracey (2019) summarised the qualitative research approach into three phases: a) collecting evidence; b) crafting analyses, and c) communicating evidence. She also emphasised the role of the researcher and self-reflexivity in comparison to quantitative studies.

The design processes were systematically documented through ethnographic observation, video, and photography as well as field notes. Ethnography as a method focuses on studying real-life settings in which the participants live in personalised, inductive, dialogic, and holistic ways. Biographical ethnographic writing allows for the viewpoint of the author as an active creator or producer of knowledge in social life (Coffey, 1999; Pink, 2015). This perspective is rather essential in the research-through-design process in which reflexive practice plays the central role. Further, several reflective discussions that were recorded, transcribed, and analysed were part of the process. This reflectivity enables learning that is focal to both the research design and research-through-design processes. (Currano & Steinert, 2012)

Further, the research process included an impact assessment of the process. The impact assessment was based on a literature review that particularly focused on both creative evaluation as well as methods of evaluation and reflection in design research. The assessment involved an examination of indicators in areas typical or feasible for a creative process such as engagement, DEI, trans and/or interdisciplinarity (Owen et al., 2022); novelty and creativity (Harvey & Kou, 2013); learning (Rindova et al., 2011); tangible outcomes (Farnese et al., 2019), and systematic reflection (2014). The impact evaluation was conducted in a rather straightforward manner. An impact evaluation form was created and this was filled in by the participating group. The impact evaluation was supported by a survey study (Basballe & Halskov, 2012). The companies participating in the development of the strategic foresight tool completed the survey to assess the workshop's effectiveness.

4. Design fiction through filmmaking

The design fiction process was initiated by creating a manuscript for a futuristic short film called Tuuliluleima. The manuscript was based on a narrative for different futuristic scenes that created a platform for body storming and performative enacting rather than dialogue. Body storming (Broadbent et al., 2023) or enacting (Coenraad, 2019) are familiar methods in design research. In performance art, such a manuscript is called 'the performance notes' (Zeami, 2008). The manuscript relied on futuristic thinking and imagining the future in 2035. The presented image of the future included changes in

inanimate factors such as the main sea streams and wind patterns that have affected our climate and living conditions. Desirable and viable futures require new ways of designing how people live on the planet based on the understanding of the entanglements between humans and the more-than-human in future transitions (Boehnert et al., 2024). Ecological literacy aims to help identify cultural and sociopolitical dynamics that cause or threaten to cause ecological harm and reveals future visions that both work for and against sustainable living on the planet (Boehnert et al., 2024).

Willis and Anderson (2013) discussed how worldbuilding can represent several ideas. It illustrates the process of imagining a unique world for a film set. This world itself can be the genesis for the resulting script. There can be several parameters and visualisations that describe the space as well as a new filmmaking workflow for this world design. This process moves on from the world to the story. Thus, worldbuilding refers to the construction of the visual world of a story prior to writing of the manuscript. Willis and Anderson (2013) refer to the movie Minority Report as an example of such a process. The manuscript worked as a starting point for the worldbuilding process that was initiated by the collaborative reading of the manuscript. The filming team consisted of a director and artist, researchers, and a cinematographer. The daily routine included collaborative discussions and planning, where the team was immersed in worldbuilding. The team needed to plan the logic of the future world. This included discussions of the materials, technology, infrastructure, and climate conditions that the future world would have. In addition, the team needed to think about the personas involved in the future scenario. What were their motivations, feelings, and competence levels to not only survive but also solve problems? The team needed to scout the filming locations and plan each scene as well as its filming. An important aspect of the routine was a daily screening of the materials being shot.

Figures 2 and 3 Images from the set





4.1 Costume design and styling

Fashion and costume are often used to transport actors and viewers alike into specific ephemeral scenarios, thereby enabling them to enact specific characters or be transported by such characters through given themes and enactments (Roubelat et al., 2015). The role of fashion and costume in this context was to function as the 'tool in rethinking fashion futures and testing the plausibility of diverse scenarios' (Burcikova, 2019, p. 328). The costume was reinterpreted to suit future scenarios in which the actors searched for an understanding and reimagining of the climate and living conditions in our speculative futures. The team sourced two fashion collections created by one of the authors called 'Water Wasted' and 'Whom Wore This?'. The Water Wasted collection adapted recycled materials such as the foil lining of water packs and their plastic spouts. The idea of material resourcefulness is well suited to the imagined future world. The other collection utilised a combination of vintage underwear and safety pins, which also conveys the idea of repurposing materials. These two collections provoked a sense of worldbuilding when discussing their materials and repurposing them.

When styling the costumes, design fiction and worldbuilding merged, as proposed by Coulton et al. (2017). The act of styling is a physical process of fitting the costumes in a manner that will suit the performers' bodies and can be utilised in different scenarios when moving around in them. In addition to embodiment, the costumes enable specific viewpoints and mindsets for the performers in a physical and psychological sense by recreating reality into fiction, and weaving materiality into culture (Garcia, 2023). This is called physical crafting through the utilisation of tools and materials. The styling is utilised to create meaning for the costume so it will fit the future world and its storyline. For example, duct tape was utilised to symbolise an interactive digital interface both in clothing and on the skin of the performers. Another example would be the vintage underwear that was repurposed to function as a protective layer over the ears and necks of the performers.

There is a substantial amount of value discussion embedded in costume design and styling. The repurposing and creative resourcing of materials support the more sustainable use of materials in the future world. This resonates well with Caravalho Garcia (2023) who highlights the same values with fashion futuring.

4.2 Speculative design for solving problems

In Tuulilulеima, there are two scenes in which two older women and a younger android—a humanoid robot—are first building a wind chime together and then use it to harvest energy at the wind station. These two scenes resulted from an active process of collaborative worldbuilding. In the manuscript, the performative notes provided an initial narrative for imagining the future world; however, as the design fiction process progressed and the logic for the protopia developed, it became apparent that there is a need for energy that needs to be solved. Here, the role of crafting in design fiction becomes focal as highlighted in Slate magazine by Blythe (2014), Bosch (2012), and Sterling (2012). The team utilised the resources available to build a prototype for both the wind chime and the testing station. The worldbuilding process helped to create these speculative designs.

It must be noted that the idea of protopia was significant during the worldbuilding process. This impacted the team to think about storylines and ideate for solutions. This also embedded a huge number of discussions on ethics and values.

4.3 Cinematography

Filmmaking and cinematography created a cinematic space for design fiction (Kirby, 2023). In our team, the cinematographer played an important role in creating a representation of the future world. He would see what is visible in the shot. He would also see how the performance would look through the lens. In certain scenes, he would be able to provide guidance and direction on how to improve or synchronise actions. For a cinematographer, one of the first decisions affecting the style of a film is the choice of lenses to use. For this work, the modern ultra-sharp lenses did not appear right. The choice of lenses in Tuulilulеima was vintage Nikkor primes from the 1970–80s, with a softer, even ‘spicy’, look. If shot at full aperture, the highlights break up into halos.

The cinematic space for design fiction was created through pre-production, production, and post-production. All these phases contributed to how the future world would be presented in the film. In pre-production, our director/artist created the performance notes. Here, the selected location played a role as wintery scenes replete with snow outline the narrative. In an ongoing production, the cinematographer would need to be able to use his experience to create a prototype and experiment with the team. As worldbuilding is an ongoing process, there is no exact storyboard that would help in planning the process. Moreover, the cinematographer’s ability to shoot supporting material would become handy in the post-production stage in terms of providing more information to the viewer. In post-production, the director/artist would use a variety of digital materials to support the envisioned future world.

The cinematic space where improvisatory performance and enactment take place enables the prototyping of the scenes. In

collaboration with a cinematographer or the director who sees through the lens and the performers, the action is prototyped and finalised. A few of the elements will be only added in the post-production stage. The final step for cinematographers is the colour grading of the film. This is usually done together with the director. Colour grading can be used to adjust mood, character, and period of time. This ensures that the look of the film facilitates the telling of the story in the selected world and not fight against it.

5. Business design for the future

An important part of the process was the goal of developing a tool for strategic foresight with companies. During the filming process, the team discussed the following question on various occasions—how can design fiction be applied in strategic foresight work with companies, particularly SMEs? This was also discussed in the Empathy Business project meetings with all the participating companies. Small and medium-sized companies are important to the European economy through job creation (Palmieri, 2007). It is important to develop tools that are forward-looking and enable companies make decisions that support their future business planning.

Figure 4 Workshop with company representatives

The business design process to develop strategic foresight tools took several phases. First, the project partners immersed themselves in the process of creating a 'three possible futures table' focusing on the Tuulilulelma world. This table discussed the political, economic, social,



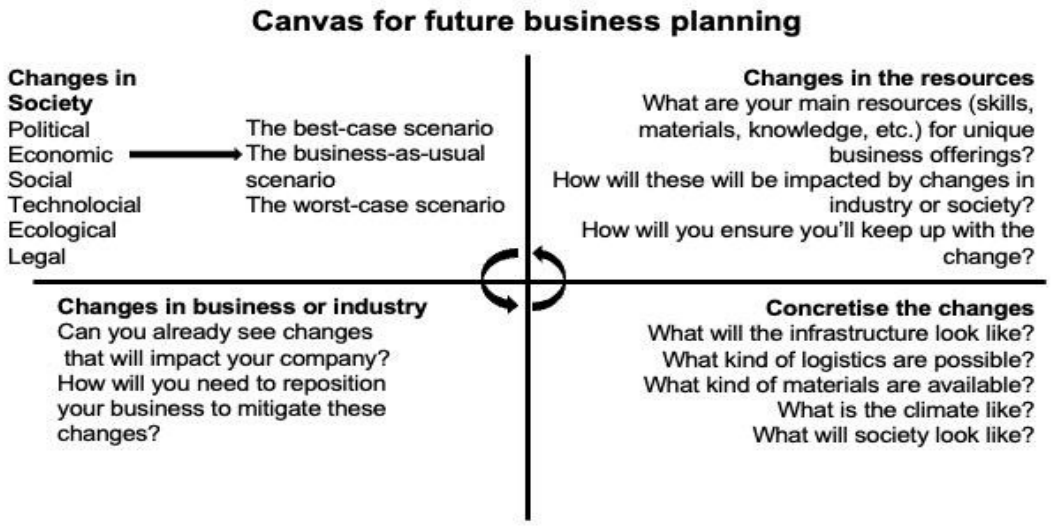
technological, ecological, and legal (PESTEL) aspects of the future from three distinct perspectives:

best possible, business-as-usual, and worst-case scenario perspective (Demneh, 2023). This was a rather analytical and systematic process of outlining the global flow for all these perspectives, which is in keeping with Apparurai's (1996) spirit. This table provided participating companies an understanding of possible futures and the factors impacting it.

After this, a canvas-based tool was developed to help companies study their own businesses and strategise how these would be impacted by global flows, trends, and factors in possible futures. The canvas-based tool focuses on future business planning and how the availability of resources, technologies, and infrastructure as well as the transformation of the business area would impact one's future business model. This is based on Schumpeter's (1934) theory that value is created from a unique combination of resources (Schumpeter & Swedberg, 2021). Further, Canvas as a business planning tool was introduced by Osterwarder and Pigneur (2010).

The third phase consisted of a workshop with companies to immerse them in strategic foresight work. In a collaborative workshop, the participants first saw the Tuulililuleima protopian film. Thereafter, they were introduced to the 'three possible futures table' and they could choose and discuss topics relevant to their business. In the last phase, they worked with a canvas-based tool and focused on their future business planning based on resources available in the future. At the end of the workshop, participants filled in the survey that asked about the relevance of the workshop and the utility of using 'three possible future table' and the 'canvas for the future business planning' (see Figure 5).

Figure 5 The second iteration of Canvas for future business planning



The outcomes of the business planning were interesting. The survey divided participants into half. One half of the participants experienced the benefits of seeing the protopian film and participated in a freer discussion whereas the other half believed that the more structured work, particularly with Canvas, was the most significant aspect of

the process. 'The three possible futures table' was experienced as too dense and having too much information to absorb in a short period. All the participants experienced the workshop as meaningful. Our project team experienced all the distinct phases of the process. The film immersed the participants into future thinking and worldbuilding. The 'three possible futures table' opened up a vast systemic perspective and concretised complexities related to foresight work. Finally, Canvas made participants focus and concretise the topics relevant to their companies. Yet, based on feedback, the next iteration of the workshop will focus on film and a more developed version of Canvas.

6. Findings

This research paper responded to the question of how design fiction could be used in future-oriented business design. This research paper responds to this question in several ways. First, the literature review explains how the crafting of concrete physical or digital designs prompts one to think about future resources, logistics, and infrastructure as well as respond to future needs and challenges with this design. Further, the literature suggests that worldbuilding is design fiction. In this paper, we discuss how filmmaking utilises worldbuilding as a design fiction process. We shared examples of how a protopian future scenario prompted the team to use costume design and styling for design fiction, create a speculative design to address a future problem, and prototype future actions in cinematic space. The overall process of design fiction addresses future challenges and resources that we may or may not have. This has a direct bearing on how to prepare a business design and utilise resources with unique offerings. Skills and capabilities are also part of the resources, and a large part of the future business design is to understand what kind of skillsets can deliver such unique offerings in the future.

The design fiction process helped to understand which kind of tools companies need to design their future business. 'The three possible futures table' offered a systematic view of global trends, flow, and complex systems that interact with each other. The canvas-based tool for future business planning focused on specific businesses and made the companies think of and concretise the trends that transform the business area and directly impact their resources.

This is a process in making so the project team will continue to test and iterate the process and the tools developed until the end of the year 2024. The insights from the first iterations already offer numerous development perspectives. In the next phase, we will test how to utilise a virtual production stage to enact or prototype in an immersive environment with rendered designs. We plan to iterate the future business design workshop with participating companies, and the tools will be further developed for this purpose.

6.1 Discussion and conclusion

In conclusion, we can respond that yes, design

fiction does help companies to concretise the changing future and its impacts on their business. As a novel contribution of this paper, we were able to create a cinematic space for future prototyping by utilising worldbuilding as design fiction and bring together several creative areas—such as costume design and fashion futuring, as well as speculative design and cinematography—to enable this. This created a platform for concretising the changes that will impact the future world. In particular, in resource-based business planning, it is crucial to understand which future resources could impact and how they will impact a business. To facilitate this, we created a canvas-based tool for business design.

There are not too many examples and methods available to prototype, concretise, and craft future scenarios; thus, the use of cinematic space offers new kinds of possibilities for this. Willis (2015) writes about cinematic humanities and the possibility of new kinds of ways of knowing expanding knowledge from written forms to thinking and making through critical visual work that integrates space, time, and the methods of design. We argue that future prototyping in cinematic space can also be utilised for strategic foresight and create new ways of knowing that would not be possible without the elements of creativity.

Bühring and Liedtka (2018) argued that the integration of foresight and design methods can impact strategic decision-making processes. They discuss the timelines or horizons related to product and service development; however, this is focused on short-term market needs. In this paper, we contributed, in particular, to means and methods for more long-term business design.

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A DESIGN-LED SYSTEM TOWARDS CIRCULARITY

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ABSTRACT | Over 400 million metric tons of plastics are produced each year and accordingly increasing plastic waste poses a significant threat to the environment and humanity. Conventional recycling initiatives face challenges due to the low value of recycled plastics and inefficiencies in centralized waste management systems.
To address this crisis, we propose a design-driven, value-oriented circular approach. This involves contextual creation and localized processing, allowing for adaptive distribution beyond the limitations of conventional recycling. Waste materials with little value in the recycling process are sourced locally and transformed into novel composites with unique physical properties and perceived qualities. Parametrically designed objects are then created from these composites, evoking value and emotional durability towards a more sustainable future. Case studies from Samoa and New Zealand demonstrate the transformative power of this circular system. In Samoa, plastic waste is repurposed into composite materials for handheld tools and souvenirs, reflecting the country's cultural heritage. In New Zealand, artifacts with Māori patterns are crafted from novel composites made of soft plastic waste and native plant leftovers. Our approach has also been integrated into design education, resulting in innovative sustainability solutions that transcend geographical, cultural, and technical boundaries.

KEYWORDS | DESIGN, SUSTAINABILITY, CIRCULAR ECONOMY, PLASTIC WASTE, LOCALIZED PROCESSING, DIGITAL CRAFT, TRANSFORMATIVE SYSTEM, VERNACULAR CONTEXT

1. Complex problems of plastic waste

Plastics are an essential ingredient of civilized society. With unparalleled versatility in color, shape, and detail combined with economical and efficient processing techniques, plastics have revolutionized modern life by enabling mass production and global distribution of functional yet affordable products. The unprecedented lightweight, resilient, and accessible material with prolonged shelf life has addictively attracted industries, consumers, and designers, and global production and consumption of plastics is expected to almost double in the next 25 years (Geyer et al, 2017). Strong desires for higher standard of life driven by economic growth around the world increase demands for products and services for convenience, efficiency, and access. Abundant varieties, established manufacturing, and global logistics make plastics the easy and sure material option for the opportunity. The unique, incomparable status that plastics occupy was confirmed again by the rapid response to the surge in need for sterile medical products, personal protective equipment, and hygienic packaging during the global pandemic (Ellis et al, 2014).

Despite the numerous benefits, plastics instigated our excessive reliance and habitual pursuit of low-cost, disposable materials that have consequently caused a global waste crisis, one of the most serious problems that afflict humankind. Since 1950, it is estimated that 8.3 billion metric tons of plastics have been produced and more than 5 billion metric tons of them have been accumulated in the environment. The numbers are expected to exceed 40 billion metric tons and 12 billion metric tons, respectively, by 2050 (Jambeck et al, 2015). Along with the fact that more than half of the plastic produced is intended for single use, mismanaged plastic waste entering waterways each year is projected to sharply increase its amount from 20 million metric tons, exacerbating the situation. Plastics make up 80% of debris that floats on or suspends in the ocean, which break down or degrade to microplastics and nanoplastics, causing a significant, accumulating threat to the marine ecosystem.

As the most common method of waste management, recycling has been in practice in many parts of the world. Sharing many aspects with mass manufacturing, the current recycling scheme adopts the concept of centralized collection and concentrated processing. Collected plastic waste from municipalities, regions, or even an entire country is transported to a small number of large-scale processing centers where the waste is separated, cleaned, and recycled using mechanical and thermal techniques in large quantities (UNEP, 2021). While the scheme has reduced the amount of plastic waste left in the natural environment throughout a few decades' execution, it inherits the major shortcomings that mass manufacturing has, such as capital-intensive infrastructure, large minimum trade quantity for each instance, long turnaround, and long-haul transportation.

In addition, the centralized, concentrated recycling scheme allows recycled plastics limited diversity in material properties and marginal room for application-specific qualities, often causing recycled plastics to demonstrate inferior performance at higher costs compared to new materials. Poor material and monetary value is widely regarded as the key reason for making recycled plastics a significantly less attractive option for adoption and consequently the centralized, concentrated recycling scheme unsustainable without subsidies. The recent findings that only 9% of plastic waste has been recycled and 90% of the amount has never been recycled again show complexity and limitations of the one-size-fits-all approach (UNEP, 2023).

As an alternative approach, chemical recycling has recently been pushed by the plastic industry, including major resin manufacturers. Despite massive investment, there are fundamental questions as to whether the energy-intensive or solvent-based processes provide environmental benefits over the conventional recycling techniques (Korley et al, 2021). While the approach is relatively nascent, recent closedowns of facilities and slowdowns in activities cast doubt on its future.

2. Upcycling over recycling

Upcycling was proposed as an alternative approach to address critical limitations associated with conventional recycling (McDonough & Braungart, 2002) and has gained attention as an essential principle of a circular economy or "cradle to cradle". Upcycling involves repurposing materials by upgrading its value and reshaping the way products are consumed, and therefore is considered a process capable of controlling the entire material lifecycle (McKinsey, 2016). Building on the conceptual foundation, upcycling focuses on reutilizing waste stream materials into products with higher quality or value as opposed to production of items with comparable or inferior quality through conventional recycling.

An emerging element of upcycling is additive manufacturing, often represented by 3D printing (Unruh, 2018). With an unprecedently high level of design freedom and production flexibility compared to conventional methods (Lipton & Kurman, 2013), the technology offers unique benefits towards sustainability,

including minimized material waste, reduced energy consumption, and small-scale, localized production (Anastasiadou & Vettese, 2019).

Recent approaches to upcycling incorporate lifecycle-based practices into additive manufacturing across design creation and optimization using digital tools, 3D printing of products with waste plastic, demonstration or distribution of products, extended use in target context, and upcycling of end-of-life products. In addition, unlike mass production, customization or personalization enabled by such approaches is a crucial element of product longevity through emotional durability or psychological attachment to products (Tateno & Kondoh, 2017). Examples include bespoke products from designer enterprises, such as The New Raw (n.d.), vanPlestick (n.d.), and Dirk van der Kooij (n.d.), which demonstrate contextual configurations and unconventional esthetic achieved by systematic design and production procedures. Philips' fishing net lamps (IF Design, 2022) show that such approaches are adopted by multinational corporations.

3. A design-driven, value-oriented approach

From the findings that the critical issues of the conventional recycling scheme are attributable to the aspects that originated from mass manufacturing, it was hypothesized that an approach that aims to increase the value of recycled materials could address the issues. We correspondingly formulated a design-driven, value-oriented approach for circularity that incorporates decentralized collection, localized processing, and distributed manufacturing. Beginning with exploratory analysis of context, history, and significance through engagement with stakeholders, our approach aimed to amplify the value of plastic waste by formulating materials and artifacts that demonstrate case-specific elements discovered from the analysis.

3.1 Analysis

Following a preliminary study on a specific case associated with plastic waste, details are identified through visits to the location and meetings with stakeholders, including members of the local community, industry, and government impacted by or relevant to the case. The findings are analyzed in relation to historic attempts made to address the issue and their results, explicit and implicit needs of the stakeholders, and social, economic, and cultural significance of the case (Koskinen et al, 2011). Outputs of this engagement-based analysis form the overall direction and guidelines for the subsequent activities. Concurrently, we collect plastic waste materials from the location and analyze them using standard physical and chemical analysis methods to identify their compositions, estimate their value, and explore potential processing conditions. This practice validates viability of decentralized material collection,

which can minimize carbon footprint from long-haul transportation.

3.2 Processing

Selected waste plastics from the analysis are processed at our lab through mechanical, thermal, chemical, and physical techniques. The materials are sorted, cleaned, separated, pulverized, and compressed into a few forms, including powder, granules, slabs, and sheets. We deliberately select easily reproducible processes using standard processing equipment for localized processing to address the limitations of the conventional recycling scheme.

3.3 Material development

A range of material formulations are prepared by blending waste materials and additives using a twin-screw extruder. Each formulation is a permutation of a ratio of the ingredients processed at a particular temperature profile and RPM (revolutions per minute) to augment material value. The formulations are evaluated against a set of criteria across mechanical (strength, elongation, and flexibility), environmental (durability against temperature, UV, and water immersion), visual and tactile (color, shine, and surface) manufacturing (3D printability, shrinkage, representation of horizontal, vertical, and diagonal lines, curves, angles, holes, and overhang) properties and qualities. Promising formulations are identified and used for design development.

3.4 Design development

Informed by the properties and qualities of the promising material formulations, we design artifacts with amplified perceived value and incorporate them into a scenario with a focus on circularity. Building on the material value, cultural, social, and communal attributes discovered in the analysis are interpreted into visual, tactile, geometrical, and configurational elements of the artifacts. According to the scenario, the scope of artifacts spans accessories, lifestyle products, crafts for cultural heritage, exhibits for display, lighting, public furniture, tools for education, sports gear, and outdoor installation. Criteria-based evaluation of the artifacts identifies promising design candidates for prototyping and leads to optimization of the material formulations. Open-source CAD applications and general-purpose 3D printers are used for design development to facilitate data transfer and distributed manufacturing.

3.5 Production

Full scale artifact prototypes are prepared using 3D printing with the optimized material formulations. Production of artifacts ensues from evaluation of the prototypes against perceived and material value in comparison with the estimated value of the waste plastics and the outputs generated by historic attempts, analyzed earlier. Desktop, large-scale, and robotic 3D printers are used to identify the most suitable production method

for scalable implementation.

3.6 Implementation

In relation to the scenario, artifacts are displayed, installed, or circulated in the target context through the established partnership with the stakeholders. For robust implementation of a circular system, we pursue subsequent pathways, including community-based entrepreneurial development, quantity production by local manufacturers, and adaptive introduction to other cases.

We have implemented the approach in various contexts and locations (Ok et al, 2024). While each case has distinct aspects, our approach in general consists of the multidisciplinary activities. We discuss details of three case studies of our implementation across design with traditional attributes for global equity, contemporary reimagination of cultural heritage, and transformative higher education (Yin, 2021).

4. Striving for global equity

The consequences of plastic pollution reach much further than inflicting harm on the natural wildlife and ecosystems. Harsh economic implications by plastic pollution inequitably affect countries that rely heavily on natural environments for their sustenance and income, and the Pacific Islands are particularly vulnerable to plastic pollution. While the Pacific Islands contribute less than 0.1% of global greenhouse gas emissions but bear the brunt of climate change impacts. Similarly, these countries contribute negligible amounts to plastic waste generation but receive a disproportionate share of it (APWC, 2023).

Samoa, an archipelago nation in the Pacific Ocean, earns approximately 25% of its GDP from tourism (World Bank, 2020). The country's reputation for pristine natural beauty and rich cultural heritage has been the cornerstone of its marketing strategy. Tourist attractions like "Swimming with Turtles" are built on the concept of harmonious coexistence and interaction with native species. However, the severe impact of plastic pollution on Samoa's natural habitat and the tourist experience is a significant concern. Plastic waste degrades the beauty of the beaches, threatens marine life, and negatively influences tourists' perceptions of the country. Moreover, the potential consequences for Samoa's economy are alarming, as tourism is the primary source of income (Tofilau, 2024).

From a comprehensive field study through meetings with tourism and government agencies in Samoa, we identified the types and quantities of plastic waste and its sources. Most plastic waste found in Samoa was foreign borne, primarily through imported products and foreign visitors. More than 60% of the plastic waste collected in Samoa originated from outside the country. The tourism sector contributes about 20% of all plastic waste, and tourists generate 40 times more plastic waste per person per day than a Samoan resident does (IUCN, 2021). The

situation is aggravated by lack of separated collection of recyclable materials combined with absence of local plastic recycling, leaving stockpiling of plastics for later overseas processing the only option for plastic waste management in Samoa (SPREP, 2023). In addition, more than 50% of plastic is never collected or landfilled, and a considerable amount of the leaked plastic might have gone astray in the natural environment (IUCN, 2024). A consensus among the local government and international organizations is that the underlying cause of the exacerbating environmental and economic problem includes low market value of plastic waste and insufficient trade volume for local processing (IUCN, 2021).

In addition, we gained a deeper understanding of Samoa's culture and lifestyle from conversations with arts and crafts communities and educational organizations. The Samoan communal way of life (fa'a Samoa) is found throughout Samoa. The whole community shares responsibility of living, educating, and helping together as one big extended family, and it is most evident during times of family occasions and traditional events. Mea alofa is the term that expresses the gift giving culture in Samoa. Gifts are prepared and presented at any large gatherings even to greet visitors. The culture is associated with rich and longstanding craft traditions in Samoa that spans everyday items, implements, decorative artifacts, and symbolic structures. For example, the asi is a simple handmade tool used to scrape the outer skin off the taro root, the staple of Samoa. The material has changed from coconut shells to the end of a metal can, most commonly mackerel cans, in favor of availability and durability.

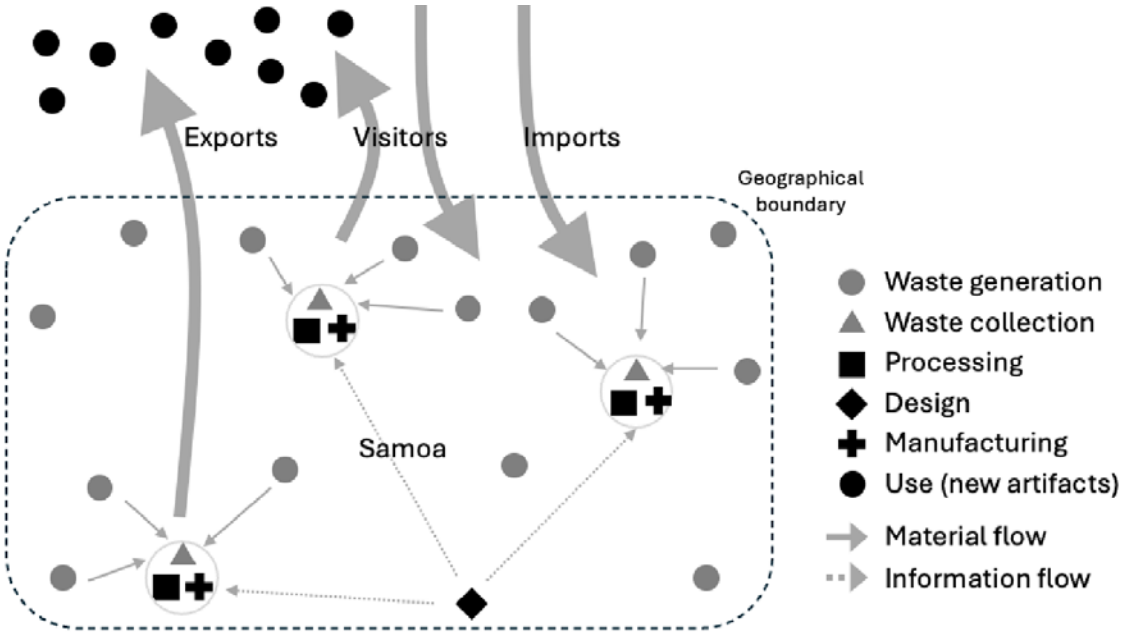


Figure 1. Material flow of plastic waste that enters and exits Samoa.

From the findings, we prepared a scenario-based strategy that aims to reduce the amount of plastic waste left in Samoa by capitalizing on the cultural characteristics. As shown in Figure 1, plastic waste is collected in a decentralized manner across the country. The collected plastic waste is processed locally and used for distributed manufacturing of artifacts at multiple clusters run by local participants (Leavy, 2017). Elevated perceived and material value comes from the artifacts designed to visually and tactilely communicate the essence of the Samoan culture and tradition. The artifacts are given as a souvenir to foreign visitors upon their departures, which serves as a reminder of the grave environmental and economic issue cause by the inflow of plastics from abroad.

To validate the strategy, we collected and processed polyethylene terephthalate (PET) and other types of plastics which together make up the largest proportion of plastic waste found in Samoa, and designed a series of souvenir artifacts, including turtle skull replicas and handgrips for the asi



Figure 2. Turtle skull replicas and handgrips for the asi (photographed by Lionel Taito-Matamua).

The original turtle skull was 3D scanned and 3D printed with our material formulation after digital processing. It embodies a poignantly ironic narrative that the replicas are made from the very material that is threatening the turtle. The vessel that holds the 3D printed skull references the fale, a Samoan house, to endow a ceremonial character to the gift. As a symbolic and tangible reminder of the issue, the gift, at the heart of mea alofa, is designed to entwine the visitor who accepts it with fa'a Samoa, inviting them to play a personal part in disrupting the flow of plastic waste.

The handgrip for the asi represents the Samoan lifestyle and traditional techniques, including dying and lashing that have been used in arts and crafts, celebratory, ornamental, and architectural practices. The handgrip is situated on top of the small stand that also serves as a platform for the taro during scraping. The form references the visual and formal qualities of kava bowls traditionally crafted by carving native hardwood. It is intended to elevate the perceptual status of the artifact beyond disposability to that of a delicate object that will be kept and valued.

Considering that plastic waste issues in many small, isolated areas and countries cannot be effectively addressed by the conventional recycling scheme, our approach can be adaptively applied to other locations, based on this case study (Lupton, 2017).

5. Reimagining cultural heritage

Despite its small size, New Zealand generates large amounts of plastic waste, including more than 700,000 metric tons of packing each year (Recycle New Zealand, n.d.). Although 97% of the population have access to recycling programs, most recyclers only accept PET and high density polyethylene (HDPE) and the majority of other types of plastics, including low density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS) are landfilled (Plastics New Zealand, n.d.). China's strict waste plastic regulations has left fewer options for New Zealand, including exporting the amount to other countries. The problem associated with plastic waste in New Zealand is partly attributed to its relatively low waste disposal levy and low incentives for recycling (Pownall, 2019).

Tourism is an essential part of the New Zealand economy and the largest export industry (NZMBIE, 2022), contributing more than 20% of its total exports of goods and services. The geographical isolation New Zealand allows aviation to be the main means of transportation of tourists. Internally, popular destinations of international visitors include places for natural landscapes, cultural performances, and experience of traditional arts and crafts practices, largely based on Māori culture (Rigby et al, 2011).

The success of the tourism industry in New Zealand is partly the effect of the successful

campaign of "100% Pure" that delivers the image of immaculate nature that coexists with civilization. From our realization of an urgent need for the mounting issues associated with waste plastics in New Zealand, we formed partnerships with an airline and an arts and crafts institute that attracts more than 500,000 visitors annually to natural activity, cultural shows, and experiential classes it features.

Our on-site studies and discussions with the partners identified the types of waste materials generated from their practices. The airline consumes a great number of LDPE bags for in-flight services, including packaging of headphones and blankets. While they are aware of the issue, it is not possible to discontinue the use of plastic bags due to hygienic reasons and requirements. By contrast, the institute mainly produces organic waste, including harakeke (phormium tenax, New Zealand flax) discarded from the weaving classes. In addition to its stiff and strong fibers that put a significant challenge to attempts to repurpose the material, cultural restrictions exclude the option of burning of harakeke waste.



Figure 3. Production and detail of the hybrid material (photographed by Courtney Naismith).

Pursuing an opportunity to combine the two waste streams from the key contributors to the New Zealand tourism industry, we produced hybrid material formulations that demonstrate unique qualities. The harakeke waste collected from the institute was cut into smaller pieces, dried, and pulverized before being blended with the plastic waste processed into flakes. During the blending, the temperature was carefully controlled to process the harakeke waste respectfully according to the recommendations of a Māori advisor from the institute (Chilisa, 2020). Figure 3 shows visual and tactile qualities of the hybrid material across its color, surface, and integrity

produced from the process.

The novel characteristics of the hybrid material strongly informed our design development. The baskets shown in Figure 4 embody New Zealand's identity through multifaceted narratives. The hybrid material's origins track back to the transformation of discarded plastics and harvested harakeke into new, sustainable forms. This narrative captures the significance of the material's past, emphasizing the importance of reducing waste and discovering value from discarded materials in contemporary design; The visual and tactile characteristics of our creation evoke traditional weaving esthetics, yet the manufacturing process is distinctly modern. This narrative highlights the juxtaposition between the old and new, celebrating the rich cultural heritage of New Zealand while embracing innovative techniques and materials; In addition, by incorporating customization into the design, our baskets allow uses to engage with the artifacts and express their unique identities. This narrative emphasizes the importance of creating a strong connection between the user and the artifact, leading to product longevity through emotional durability (Chapman, 2009).







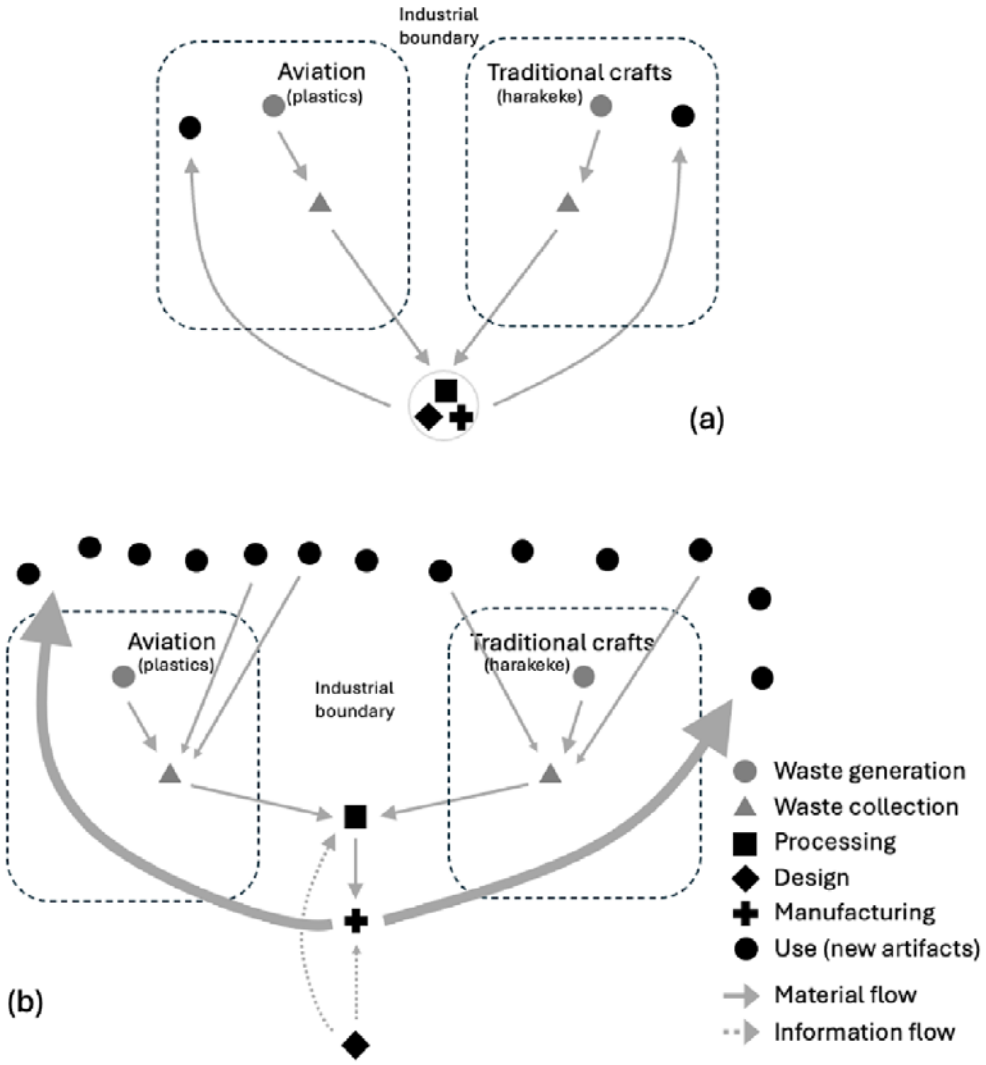


Figure 4. Basket

Figure 5. Material flow of (a) initial implementation, (b) after extension of implementation through contract processing and manufacturing.

Figure 5(a) summarizes the material flow of our implementation. Collected waste materials generated from each partner's practices were processed and produced into artifacts in small quantity mainly for demonstration within the partners. As the artifacts gained attention, a demand for quantity production was identified and our implementation was accordingly extended into contract processing of the waste materials and manufacturing by a startup from entrepreneurial development for commercial distribution. Artifacts that reach end of life are sent back to the partners and merged into the material flow as shown in Figure 5(b).

6. Integrating into education

Recent research emphasizes the role of higher education for successful implementation of sustainability principles such as the United Nations Sustainable Development Goals (UNEP, 2021). Curricular development and interdisciplinary studies are suggested as key agents in the transformation towards sustainability (Bullock & Wilder, 2016). We designed a transdisciplinary study track "Design Mediums" on material literacy, sustainable interventions, and technology competence within our industrial design program, and have integrated our approach into the courses to infuse students with self-motivated design research and practice towards circularity. Within the track, a project titled "the minimum for the maximum" challenges students to propose a real-world design intervention, develop a design solution for circularity, and attempt its implementation through engagement with external partners in five weeks. Additionally, students are required to form an argument that justifies their design intervention in relation to their own definitions of the minimum and the maximum.

Despite positive feedback from students on their practice-based, empirical learning experience within the study track, there was a remaining question how our transformative approach could be applicable to various cultural, economic, and pedagogical settings around the world (Jones et al, 2010). Transformation of higher education into nurturing sustainability-minded future leaders is an imperative regardless of discipline, background, and geographical location, and therefore adaptive application of our approach could accelerate curricular development and implementation in other institutions (Sibbel, 2009).

We discuss a case study of a recent exchange student from Mexico (UDEM) who completed the project with little initial understanding of our curriculum. Facing the design challenge, the student identified an opportunity for design intervention from local cafés near our campus. While the small, independent businesses are an essential element of the prevalent café culture of the city, the student noticed that a significant amount of waste, mostly in the form of coffee grounds after brewing and "compostable" plastic cups, was generated from the locations every day. Although the plastic cups, made from polylactic acid (PLA), are widely advertised as "compostable" containers, composting is only possible under specific temperature and humidity conditions which cannot be achieved in the typical domestic or small business environment. In addition, because PLA is relatively new and its trade volume is not as large as other commodity polymers yet, it belongs to the "7" or "other" category along with a wide variety of plastics that are not suitable for the conventional recycling scheme. Many municipalities around the world therefore do not accept PLA for recycling and instead landfill or incinerate the material.

A few cafés that were aware of the complexity associated with PLA showed interest in collaboration and provided the waste materials. Following our procedure, discarded PLA cups were dried and processed into granules, and coffee grounds were dried and pulverized. The two ingredients were then blended at various ratios, between 3% and 35% of coffee powder in PLA, to produce several material formulations. The processing temperature was maintained below 190 °C to prevent thermal deterioration of PLA that starts to occur at 200 °C (Kervran et al, 2022). The formulations demonstrated light to dark brown colors depending on the type and amount of the coffee included, emitting the coffee aroma (Figure 6).



Figure 6. A material formulation that consists of discarded PLA cups and coffee grounds.

The material flow among the locations is shown on the map (Figure 7). Although the scope was deliberately limited to a few locations close to each other to conclude the project within five weeks, this can easily be extended to include more partners in collection, processing, design, manufacturing, and use.

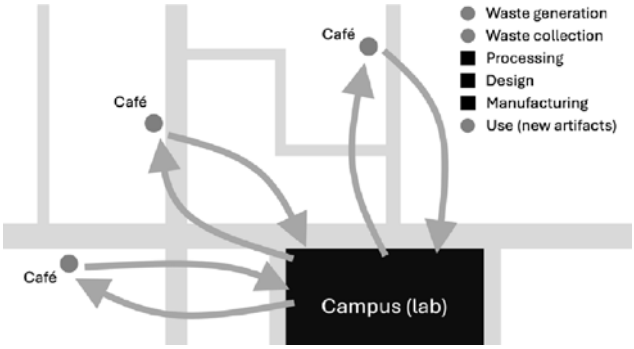


Figure 7. Material flow between campus and nearby cafés shown on a local map.

The design development was effectively informed by the material formulations that represent the main ingredient through multisensory stimulation. On-site observation and discussion discovered most café stores condiments and small utensils in the standard stainless containers on the tables, although café owners, employees, and customers



Figure 8. A multipurpose artifact designed for cafés (photographed by Mariana Avila Amavizca).

7. Building a system towards circularity

Based on our case studies, we propose a conceptual model that consists of three stages as shown in Figure 9.

Analysis is the first stage that decides the scope of an approach through a comprehensive study of the case. Quantitative and qualitative details of the situation, including type and amount of waste stream, impact and severity, stakeholders, relevant precedents, and previous interventions and

outputs are investigated. Engagement with potential partners, such as local community members, activists, industry, businesses, and officials, is crucial for focusing on key factors of the issue and setting the overarching goal of the material and design development.

Synthesis is the main part of an approach in which most of the development activities take place. Waste plastics collected from the site or partners are characterized, processed, and turned into initial material formulations that display some useful properties and qualities.

the maximum.

all preferred more unique features.

The café tree is a solution proposed by the student (Figure 8). The artifact, designed to be placed on the tables in local cafés, communicates its origin through its form and materiality. The leaves serve as coasters that gradually spread the scent of coffee and the pot contains condiments such as sugar. The perceived and material value created by the proposed solution is easily recognizable in the context of the minimum for

Informed by the material formulations, design development starts to produce contextual concepts with amplified perceived value, which inform material development back. The two development processes extend each other, progressing through divergence and convergence towards the final solution for the case that demonstrates augmented perceived and material value. Within the boundaries of the intertwined development, permutations are prepared, evaluated using criteria, and refined for prototyping and production. Implementation entails placement of artifacts in target locations, initiation of supply into distribution, or introduction of products into service, through engagement with partners, including those who were identified in the first analysis stage. In addition, potential pathway options are explored in this stage. A sustainable, lasting circular system requires long-term consideration of material flow and subsequent development, such as a plan for collection and processing of designed artifacts when they reach end of life, quantity production of artifacts through contractors, development into a local enterprise, and product diversification.

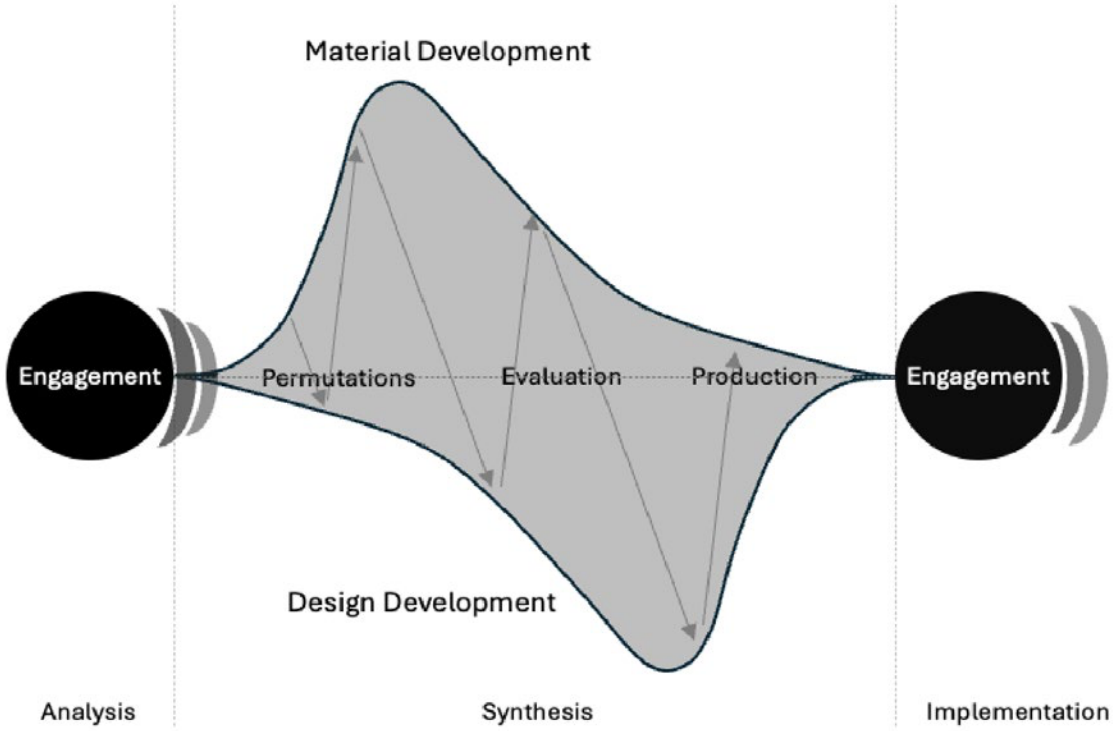


Figure 9. Conceptual model of our design-driven, value-oriented approach for circularity. Note the gray area indicates the extent of the intertwined material and design development processes.

8. Conclusion

The staggering issues associated with plastic waste affect severely the entire Earth system. In response to the limitations that the conventional waste management methods have exposed, we have developed and implemented a transformative approach. Consisting of analysis, processing, material development, design development, production, and implementation, our design-drive, value-oriented approach incorporates decentralized collection, localized processing, and distributed manufacturing towards circularity. The approach has been developed into a conceptual model through implementation in key contexts with stakeholders. The case studies also strengthen the argument that a system-based, multidisciplinary strategy is essential for maximizing effectiveness and longevity of

solutions and minimizing the impacts of plastics (Žalėnienė & Pereira, 2021).

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SPECULATIVE DESIGN EDUCATION: IDENTIFYING AND ANALYZING CRITICAL MOMENTS IN THE PROCESS OF EXTRAPOLATING FUTURE SCENARIOS

Susana Leonor and David Palma.

ABSTRACT | One of the goals of higher education in design is to provide pedagogical practices that promote active learning through exploration and participation in practical projects, where it is possible to introduce and apply methodological and technical skills, such as problem-based learning, which allows through the creative process, to articulate critical and strategic thinking in solving current problems.

However, we are emerging in a global context where it is necessary to encourage future designers to raise systemic and comprehensive issues that require a deeper understanding and an approach that goes beyond immediate solutions and responses, which may obscure or minimize potential future consequences, diverting attention from fundamental issues. Approaches such as speculative and fictional design assume significant relevance in empowering designers to think and extrapolate new solutions and envision beyond the expected. They allow the exploration of solutions capable of generating new concepts and disruptive strategies, potential social and economic changes, and the positive reconfiguration of individual and collective habits and social practices. This also reinforces awareness of the designer's role as an agent of change in society.

Thinking about the environment, society, and political systems in the next fifty or eighty years, imagining utopian and dystopian scenarios, especially with positive propositions for the present, becomes a complex task for students.

This article aims to mitigate this question and identify and analyze recurring patterns of critical moments in elaborating future scenarios. The research is conducted by a bibliographical review of practices in similar contexts and monitoring projects undertaken by final-year students in the Bachelor's degree program in Communication Design.

KEYWORDS | SPECULATIVE DESIGN, CRITICAL DESIGN, SPECULATIVE DESIGN EDUCATION, SPECULATIVE DESIGN PROCESS

1. Introduction

Higher education aims to provide pedagogical practices that promote students' preparation for future challenges and uncertainties (Király & Géring, 2019). In design education, students are frequently introduced to methods and challenges that encourage them to explore diverse pathways and achieve tangible results. This process familiarizes them with rapidly materializing their ideas experimentally and concretely. While design encompasses commercial aspects, leveraging fields such as graphic design and industrial design, it also functions as an evolving discipline aimed at resolving complex, ill-defined problems as well as broader systemic issues in business, society, and the public sphere. In this context, methodologies such as design thinking are employed to devise solutions for "wicked problems" (Buchanan, 1992).

Moreover, other approaches within design diverge from commercial interests and focus on areas beyond the commercial spectrum, such as speculative design and fictional design (Dunne & Raby, 2013). Constant social and economic transformations have led society to adopt unsustainable habits, lifestyles, and social practices. These practices necessitate a new orientation and the adoption of methods that promote disruptive change (Angheloiu et al., 2020), including approaches like speculative and fictional design, which challenge students to navigate uncertainty and new challenges. Through these approaches, students can acquire skills and the capacity to analyze and develop a reflective and critical attitude to help them thrive in a specific (future) context (Barendregt et al., 2024).

This article presents a framework applied to communication design students since the 2020/21 academic year. This framework introduces and explores future scenarios that offer new perspectives on addressing wicked problems. However, extrapolating future scenarios is a complex process with critical moments, during which we identify gaps and patterns among students who struggle to disconnect from the present and from projects that can be tangibly realized. Consequently, we will analyze and discuss the most critical moments for final-year communication design students.

2. Framing Speculative and

Fictional Design

Speculative design, like design fiction, aims at exploring and extrapolating alternative future scenarios, making it difficult to differentiate between the two and leading to a standard interchange of the terms. The term design fiction was coined by science fiction writer Bruce Sterling (2005), when he felt the need to reflect on and differentiate between science fiction and design fiction. Later, David Kirby (2009) defined design fiction as a 'diegetic prototype,' a concept adopted by Julian Bleecker (2009). He interprets it as prototypes or artifacts that provide greater expression and context to fictional narratives, visualizing specific technologies within a fictional context and society. Filmmakers and scientists can situate and sketch possible types of technology used in areas such as medicine, computing, or space (Bleecker, 2009; Kirby, 2009).

"Diegetic prototype" can be exemplified through science fiction films like "Minority Report" (2002), in which a computer prototype with a gesture-manipulated interface is presented. In 2005, CNN reported on actual prototypes being developed based on the idea from the film (Kirby, 2010; Bleecker, 2009). Another example is the "Apple Vision Pro" launched in 2024, which allows an immersive augmented reality experience in the real world, similar to gesture-based interaction with the interface.

Design fiction can be understood as an integral part of speculative design (Dunne & Raby, 2013). Although they are similar and difficult to dissociate, subtle differences can be identified between them. For Bleecker (2009), design fiction combines elements of design, scientific facts, and science fiction to create scenarios and artifacts that project entirely new worlds without constraints on the consequences and needs of the natural world, even if scientific facts confirm they are not possible. On the other hand, speculative design was popularized by Dunne and Raby (2013) as an exploration of alternative futures aimed at understanding current issues and discussing the type of future we wish to create. This approach proposes alternative solutions, critiques, and possibilities for the future, which can also result in artifacts that help represent these concepts and critiques (Dunne & Raby, 2013).

Dunne and Raby (2013) state that while design fiction concentrates more on creating narratives and imaginary worlds, speculative design is focused on reflecting on the social, ethical, political, and cultural implications in the future. Although both emphasize speculation and creativity, their applications and objectives may diverge in specific contexts.

In summary, despite nuances between the two terms, design fiction, and speculative design emerge as enablers for exploring the future, fostering critical thinking, and allowing reflections on ethical, political, or environmental issues.

3. Pedagogical Methodologies for

Extrapolating - Cases revision

Dunne and Raby (2013) characterize "speculative design" as a catalyst for shifting the emphasis from solving problems for clients to solving problems for societies. By developing fictitious scenarios and views concerning society, politics, technology, and culture, speculative design allows designers to evaluate their contemporary cultures. Its framework centers on feasible, probable, and favored futures. (Bardzell Forlizzi, Zimmermann et al. 2012). One of the goals of communication design speculations is to highlight societal issues that require attention to potentially spark change, not to deceive or persuade the audience about issues they do not wish to relate.

By developing methodologies that conduct learning processes with tools that raise questions about their future, mainly about the world's future, under the question "what if," they are opening their competencies for the next level—what is the purpose of designer role-play?

With the use of the speculative design framework, graphic and communication designers can use their skills as a potential catalyst for change and be equipped with a potent tool (Rynning, 2017). The ability to conduct careful design and facilitation, supported by research tailored to stakeholders' needs, anticipate shocks, support engagement, and co-create are among the skills and competencies required. Other competencies include creative, cross-sector, and cross-disciplinary decision-making and innovation (Wilde, 2020). Mostly, sustainability brokers must be able to create global communities of like-minded individuals that bridge disciplinary boundaries and are united by shared values and understandings, as well as methods to support knowledge integration and behavioral change. (Wilde, 2020)

The transition between deconstruction—of preexisting conceptions and ideas of the future—and generation—of new images of the future—reflects Freire's (1970/2005) emphasis that, in order for their efforts to be transformative, oppressed communities themselves must participate in both introspection and action. Thus, a critical future needs to develop ways to involve the public rather than implementing "futuring from above" to live up to its name. Thus, democratizing futures has emerged as a central claim supporting incorporating co-creative or participatory design methods into future endeavors to encourage teamwork and make futures less theoretical and more concrete (Farias, et al., 2022). This does not imply that such skills are out of place in a critical design futures curriculum; in fact, they frequently are. Instead, it means that an analytical way of thinking should be applied to social and emancipatory goals in a group setting while considering the epistemological presuppositions that the field mobilizes (Barendregt, L. et al., 2024).

We also need to think carefully about how

we challenge and reinforce the status quo in our educational activities and rethink them to serve better and reflect emancipatory goals. By positioning ourselves as co-learners with our students and allowing them the freedom to take the lead and contribute to social transformation, we can demonstrate our commitment to criticality in both methods and aims (Barendregt, L. et a.l, 2024).

The interdisciplinary fusion is the foundation for Design Futures' emergence, which has greatly aided in researching future visions (Angheloiu et al., 2020). Incorporating scenarios, long-term critical thinking, and other foresight techniques into their work, designers are, on the one hand, becoming increasingly future-focused. However, futurists are actively involved in creating prototypes, employing them to produce immersive experiences that put their futuristic ideals into context (Candy & Dunagan, 2017).

The expansion of future studies into the area of practice and the adoption of materials, techniques, and approaches from design and art are significant examples of the convergence of design and futurology (Candy, 2010 & Dunagan, 2017). As a result, it is both appropriate and highly beneficial to employ real-world examples as a breakthrough in the subject of design future studies. (Li, T. & Fu, Z., 2024) One of the guiding principles of frameworks such as forecasting, which aims to anticipate the future based on current trends or backcasting, is to define the objective and then ask, "What shall we do today (and subsequently) to achieve the objective?" This question is answered by following the procedures outlined above (Schwartz, 2009).

Speculative design, design fiction, visionary design, transition design, and technological innovation are the five subtypes under the design futures context on which the research focused. It also established a preliminary analytical framework for design futures practice cases, Li, T. & Fu, Z. (2024) raised two fundamental questions for the understanding of the framework and tagging system: First, how can we build a thorough descriptive framework and carry out preliminary framework validation for future practice scenarios in design? Second, how can we identify and measure the unique characteristics and differences of the many genres (subtypes) of design futures to help in educational and creative endeavors and develop heuristic design tools? Their work enables us to recognize that the primary goal of Design Futures is to inspire people, raise awareness of current issues, and motivate them to take action by empowering them to shape the future responsibly and deliberately choose among available options. It also aims to create captivating experiences of future predictions. It offers a complementary approach to design and futures that can be used in exploring transformative changes that align with the social and environmental challenges of our time (Li, T., & Fu, Z., 2024). Li, T., & Fu, Z. (2024) analyzed cases where identified frameworks, models, and

techniques were utilized, which we summarized:

Table 01.: Resume of frameworks, models, and techniques, adapted from Li, T., & Fu, Z. (2024)

Cluster	Theoretical frameworks, models, and tools	Authors
Domain/ Theme-related	STEEP	Inayatullah, 2004
	STEEP +	Saritas & Smith, 2011
	DEGEST	Ratcliffe & Ratcliffe, 2015
	PESTLE	Warner, 2010
	PESTEC	Makela, Parkkinen, Lyytimaki, & Nygren, 2020),
	STEMPLE-Plus	Burrows & Gnad, 2018
	STEEP-V	Manual, 2018)
Worldview/ Scenario-related	Six meta-archetypes: scenario archetypes.	Boschetti, Price, & Walker, 2016
	Global Scenario Group (GSG) with six scenario archetypes: Policy Reform (PR), Market Forces (MF), Breakdown (B), Fortress World, (FW), Eco-Communalism (EC), and New Sustainability Paradigm (NSP)	Gallopín et al., n.d.
	Divergent world end-states: Conventional, Great Transitions, Barbarization, and "Muddling Through."	Gallopín et al., n.d.; Raskin, 2010
	Scenario archetypes can be considered as a statement of worldview, encompassing four states: continued growth, collapse, discipline, and transformation	Dator & Dator, 2019
	Forward five archetypal future images: Evolution and Progress, Collapse, Gaia, Globalism, and Back to the Future	Inayatullah, 2008
	Future archetypal images from 140 sci-fi movies set in the future to propose a new set of scenario archetypes, identifying six archetypes: Growth & Decay, Threats & New Hopes, Wasteworlds, The Powers that Be, Disarray, and Inversion.	Fergnani & Song, 2020
Ideology-related	Ideology is a way of thinking about worldviews and the narrative glue that connects values, beliefs, priorities, hopes, and fears together	Dunne & Raby, 2013
	Political Spectrum Diagram	Eysenck & Coulter, 1972
	The original form of the Nolan Chart has two dimensions: the X-axis represents "economic freedom" and the Y-axis "personal freedom," divided into five sections, each with a label: Statism (bottom left), Left-wing political philosophies (top left), Right-wing political philosophies (bottom right), Libertarians (top right)	Roubelat, 2006
	New ideological systems, proposing four national forms based on the political stance chart comprising left-right, authoritarianism, and liberalism: Communo-nuclearists, Digitarians, Bioliberalists, and Anarcho-evolutionists.	Dunne & Raby, 2013

A mix of methods is necessary, starting not only with the tools but, above all, with an

Possibility-related	Futures Cone: This classification begins by considering all potential futures and then gradually zooms in on the more likely and/or desired ones.	Hancock & Bezold, 1994
	Voros' taxonomy: wildcards and alternative futures: possible, plausible, and probable futures, as well as one preferable future.	Voros, 2003
	Futures Cone	Gustafson, 2010; Hines & Bishop, 2013; Scheepers & Timpe, 2003).
	Extended the original Futures Cone concept, providing additional subdivisions, including seven alternative futures: Potential, Preposterous, Possible, Plausible, Probable, Preferable, Projected, and Predicted futures.	The Futures Cone, Use and History – The Voroscope, n.d.
Temporal/ Phased Frameworks related	Temporal frameworks inherent in practice cases	Brown & Michael, 2003; Heilbroner, 1995
	Temporal characteristics of future research encompass the short term (considered to range from the present to five years), the medium term (from five to ten years, and for some authors, up to twenty years), and the long term (from 20 to 50 years).	Masini, 1993
	In operative or operational management, the timeframe extends up to one year, in strategic management up to ten years, and in visionary management up to thirty or even fifty years	Kaivo-oja, Katko, & Sepp¨al¨a, 2004
Element Composition/ Creative thinking techniques related	The use of structured approaches to scenario planning and mnemonics (such as the SCAMPER acronym) therefore facilitating qualitative improvements in the outputs	Curnin, Brooks, & Brooks, 2022
	Techniques include sense-breaking	Danish Emergency Management Agency, n.d.
	Reframing	Ramírez & Wilkinson, 2016
	Paradigm change	McFadzean, 2000
	SCAMPER- uses idea-stimulating questions to help participants generate different ideas, solutions or products, including creative techniques such as Substitute, Combine, Adapt, Magnify&Minify, Put to another use, Eliminate and Reverse	Serrat, 2017
Creative Generation/ Intention related:	The 'Verge' Ethnographic Futures Framework consists of 6 domains: Define, Relate, Connect, Consume, Create and Destroy	Schultz, Crews, & Lum, 2012

understanding of who we are and the human values in design, which can be listed: Carefulness, Ecology, Justice, Meaningfulness, Personal development, Pleasure, Respect for oneself, Respect for others, and Status. Kheirandish et al. (2020), these nine value items open for a more extensive list, allowing the development of a framework that provides a comprehensive perspective on human values that different design approaches can apply. These values are fundamental, considering the envisioning of Maldonado (1971), who believed that design duties necessitated a strong sense of ethics based on the designer's solid cultural foundation (Celaschi, F., & Celi, M. 2015).

Eriksson et al. (2022) defined it as a teaching activity, Envisioning Future Scenarios based on the

SOLO taxonomy by starting with gaining a deep understanding of the topic and applying their knowledge in various contexts framed with various values-based design approaches. It is essential to introduce support materials in the initial phase, such as a characterization of cases, theoretical texts, and visual media such as series or fiction films. Students may approach their own or others' designs from a single, limited perspective while examining users and user experiences, failing to recognize the possible impact on a broader society. Designs can have positive and negative long-term effects on an extensive range of stakeholders beyond those initially considered. After, students are asked to conceive and examine long-term repercussions, social ramifications, and widespread consequences of their own or other people's designs by creating scenarios for the future. Beyond what they would often define as the intended application of their design, the students visualize at least one usage or user scenario, which may cause them to reconsider their designs and design choices. With the support of Cards and Prompts, for questions, for developing future scenarios to analyze and explain a use or user situation based on four criteria (stakeholders, time, values, pervasiveness) (Eriksson, et al.; 2022).

According to Eriksson (2022), students should be able to achieve the intended learning outcomes:

- create future scenarios to envision and analyze possible long-term effects, widespread consequences, and societal impacts of their own or others' designs;
- apply their understanding of potential long-term effects, widespread consequences, and societal impacts to rethink their design and design decisions.

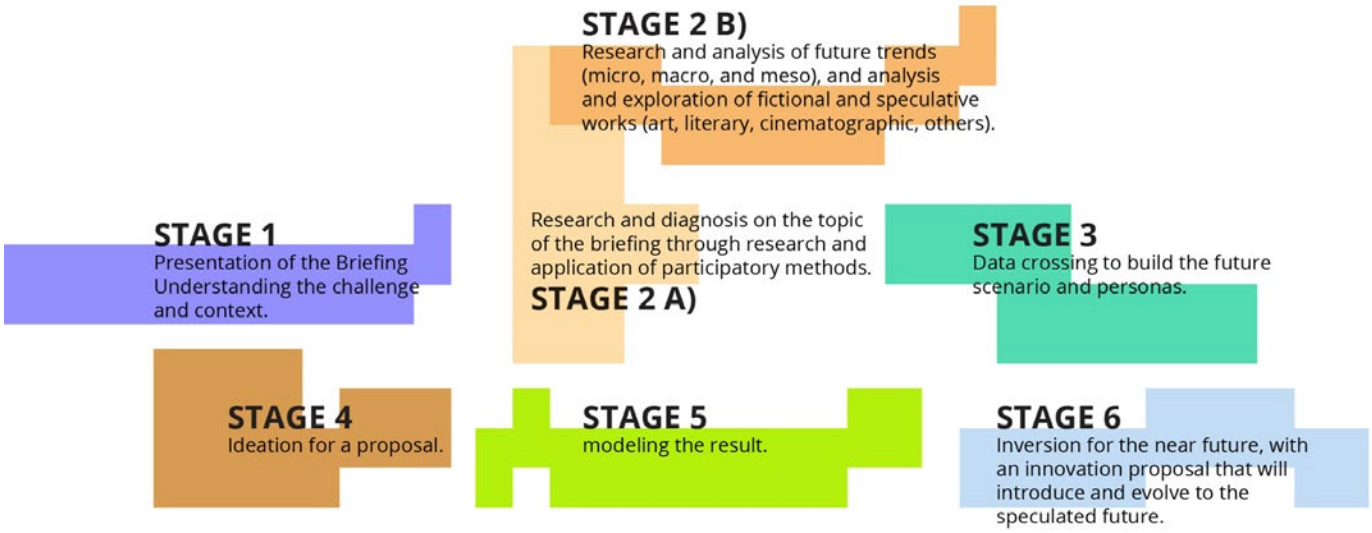
Designers are becoming more future-conscious, incorporating long-term thinking, scenarios, and other foresight tools (Li, T., & Fu, Z., 2024).

On the other hand, they also need to understand the importance of connecting with the public. The idea will not connect with the viewers if it goes too far into the future to show unbelievable ideas or extraterrestrial technology environments. A design hypothesis, thus, necessitates the existence of a bridge between the fictitious aspect of the notion and the audience's view of their reality. This "perceptual bridge" draws inspiration and influence from various disciplines, including observational humor, psychology, ecology, horror cinema, and illusion, due to the insights these areas provide into the intricate workings of the human mind and how it may be skillfully manipulated to elicit a response (Auger, 2013).

4. Apply Pedagogical Model Extrapolating Future Scenarios — Results and quali-quanti evaluation

This article is related to the analysis conducted by applying a framework used in the Advanced Project course. This course is part of the third year of the Communication Design undergraduate program at ISMAT. The course introduces students to speculative design and fictional approaches, starting from an initially given topic or subject to explore; students are required to identify problems and project alternative scenarios and futures in response to the identified questions through different steps. Ultimately, the process culminates in an inversion for the near future, with an innovation proposal that will introduce and evolve toward the speculated future (published by authors.).

Figure 01. The Workframe for Advanced Design Project, by the authors



The framework used in this course is divided into six stages (see Figure. 01)

Phase 1 - presentation of the brief, understanding of the challenge and context;

Phase 2 - divided into two timelines:

2a) research and diagnosis on the topic of the briefing through research and application of participatory methods and,

2b) research and analysis of future trends (micro, macro, and meso), and analysis and exploration of fictional and speculative works (art, literary, cinematographic, others);

Phase 3 - data crossing to build the future scenario and personas;

Phase 4 - ideation for a proposal;

Phase 5 - modeling the result;

Phase 6 - inversion for the near future, with an innovation proposal that will introduce and evolve to the speculated future.

This framework aims to enable students to comprehend, map, and apply the speculative and fictional design approach in a structured manner throughout the semester. Mainly, it is designed with the understanding that by the third year, students are accustomed to processes and methodologies focused on solving problems in the present or near future. This framework seeks to gradually help students understand and visualize the differences in creating a project that extrapolates future scenarios. In this context, instead of presenting a problem to solve, students are given a theme from which they must identify problems, fostering their ability to think and design ideas for what does not yet exist.

Based on interactions with different students from various classes from 20/21 until 23/24, we identified a pattern of similar critical moments within our context experienced by the students. Intending to map this clearly and optimize the framework we presented, which assists in introducing speculative design and fictional design to final-year design students, we prepared questions for 12 former students from different years. So that we can gain a better understanding and analyze their perspectives on their speculative design projects at different stages of the process. Nevertheless, to improve understanding of both the framework that we apply with students throughout the semester to develop for the project and identify the challenges and most critical moments encountered by students during the process, we initially present examples of work carried out during these academic years in this context and using this framework.

4.1 Results

Despite maintaining the framework, a new briefing is presented every year, with different characteristics and themes to be explored. Therefore, we present a selection of various works that illustrate the diversity of themes developed within this framework over the years.

The first class in which we introduced the speculative design approach in the 2020/21 academic year was focused on repositioning the Delta brand for 2060, a leading coffee brand in Portugal.

In this context, we present Ana Silva's project, "Flow Powered by Delta" (see Figure 02). While focusing on the Delta brand, this project required an assessment and projection of different future scenarios of what society could be like in 2060 and what role Delta might play. This former student envisioned optimized and technological urban spaces for 2060. Furthermore, in this future projection,

cities are silent spaces, leading citizens to greater efficiency in work and education with fewer chronic effects.



Figure 02. Flow Powered by Delta Project, by Ana Silva student, published by the authors.

In this future scenario, Delta Flow consists of an experience inside spherical capsules that offer moments of decompression and isolation within urban centers reminiscent of the current cultural tradition of coffee consumption in Portugal. The result of this project reflects a new lifestyle and an innovative vision of technological interfaces for human-machine interaction. For example, booking a moment in a Flow capsule is done through retina recognition screens. This approach also promotes critical reflection on digital security, interaction, and usability of new products and services embedded in urban environments (Leonor & Palma, 2024).
During the 2021/22 academic year, we encountered a new reality that brought about sudden changes in behavioral and professional habits due to the emergence of the SARS-CoV-2 virus. In response, we challenged our students to explore the topic of social nomadism, a broad subject that allowed for diverse lines of inquiry and the extrapolation of various future scenarios.

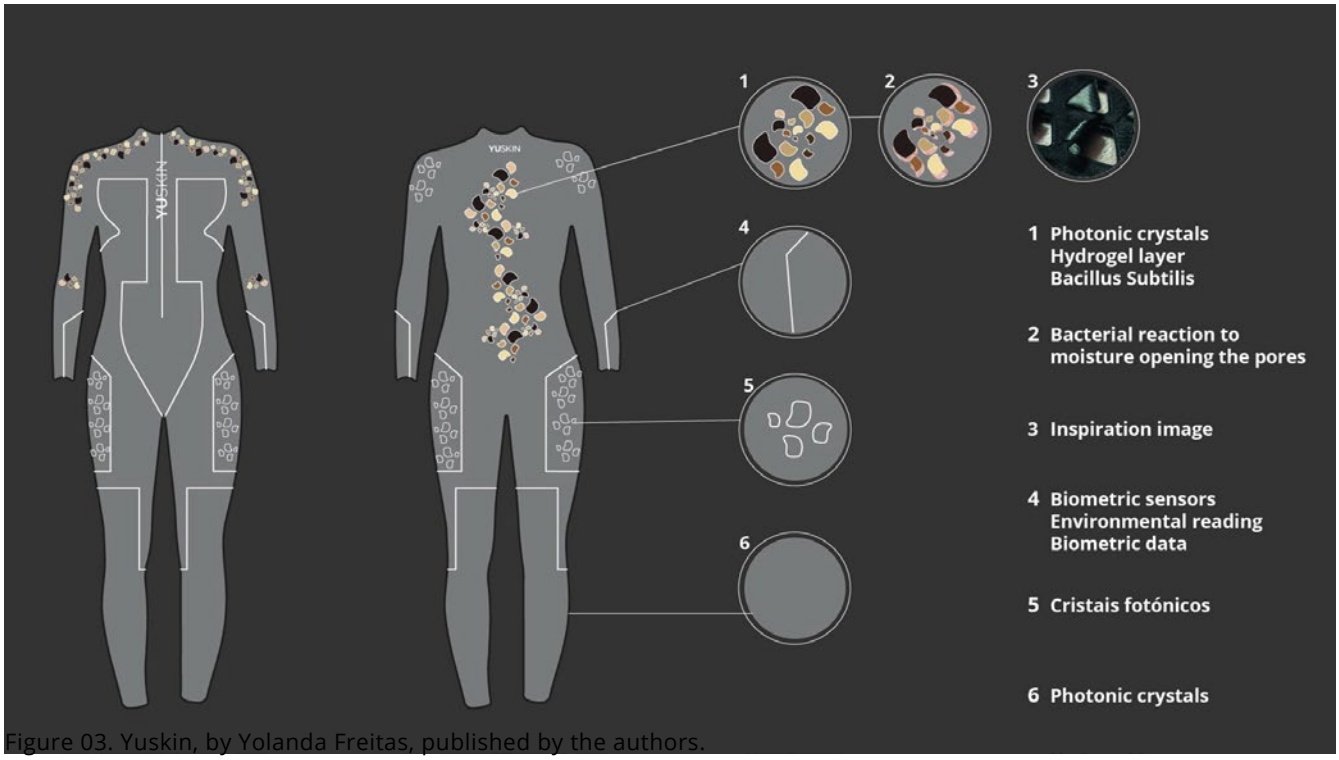


Figure 03. Yuskin, by Yolanda Freitas, published by the authors.

An illustrative example is Yolanda Freitas's project, YUSKIN (see Figure 3). In this project, the former student offers a novel perspective on clothing by envisioning an alternative future for 2050, where smart clothing incorporates nanotechnology and photogenic crystals. The project focuses on issues such as mobility, sustainability, durability, and heat retention. Furthermore, it prompts discussion on problems related to textile waste and fast fashion. This speculative textile product was also designed to allow users to customize colors and shapes through connections with personal electronic devices, enabling a single garment to assume different configurations (Leonor & Palma, 2024).

In the following year, 22/23, the focus was introduced on how we will interact with culture and information repositories in the future, explicitly addressing how museums will evolve. This involves interpreting what they will look like, what to expect from museum experiences, and how they will be structured.

An illustrative example is the work of former student Inês Crisóstomo. Inês focuses on the user experience, envisioning how a museum could offer an immersive visit to Mars without leaving Earth (see Figure 04). The concept revolves around the idea of visiting a museum by simply wearing a suit with a helmet that allows the user to experience all senses as if they were indeed on Mars. This project integrates various fields of knowledge,

including interaction design, equipment design, engineering, information design, and textile design.

The project also considers future developments of the suits, incorporating technological advances such as motion capture and smart fabrics, inspired by megatrends and science fiction. Additionally, it addresses the potential colonization of Mars, emphasizing the need to learn from the mistakes of Earth's colonization and to promote respect and efficient management of natural resources (Leonor & Palma, 2024). We concluded this journey of various challenges and projects developed over the years with a project by the final-year students of 23/24. This year, the students were tasked with envisioning a society in 2080 that honored the legacy of Manuel Nabeiro, a prominent Portuguese coffee entrepreneur known for his philanthropy, entrepreneurship, and innovation. This project challenged the students to speculate and generate future scenarios of how Nabeiro's influence and legacy could make a difference in a new society.

Figure 04. Astronomer - From Earth to Mars, by Inês Crisóstomo student, published by the authors.

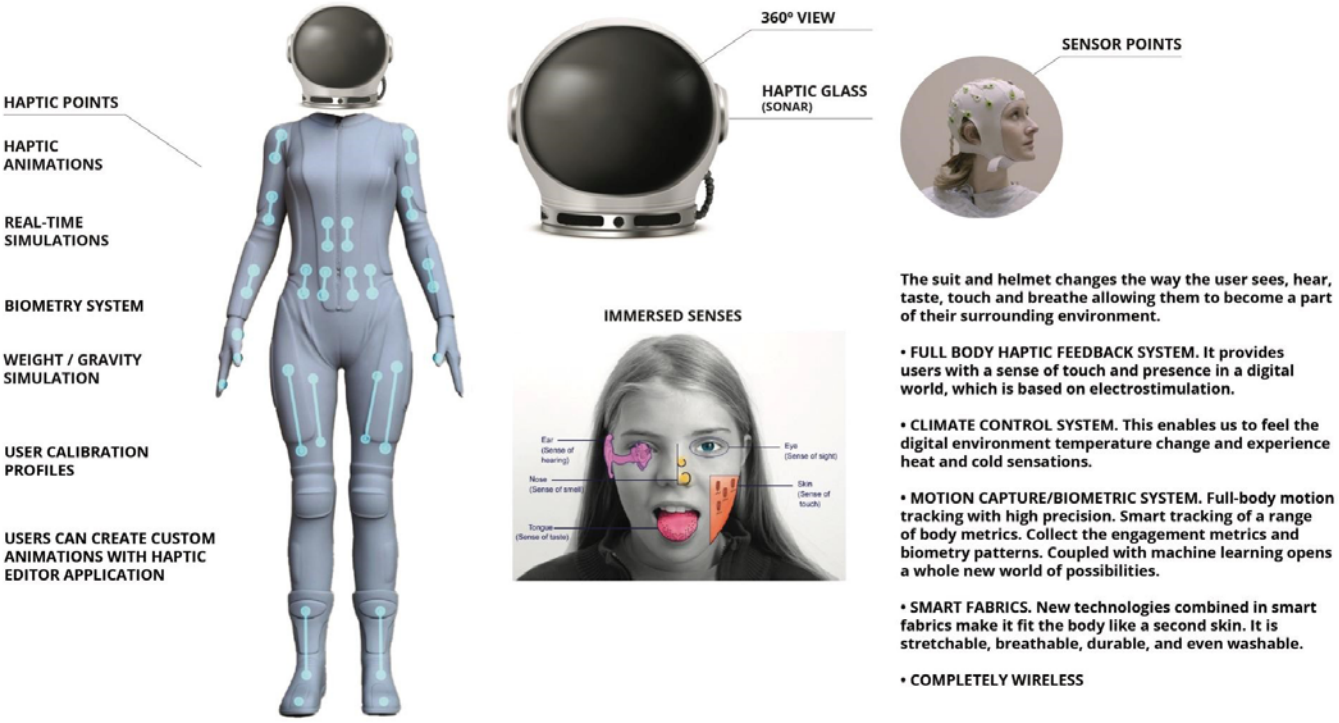


Figure 05. CADAP (images generated by IA), by Pedro Medeiros.

Based on the proposed challenge, Pedro Medeiros presents a complex system for a new way



scenario proposed by Pedro for 2080 envisions society living in hub-like buildings globally, of living and interacting, with a greater consciousness about work and sustainability. The aimed at enhancing human development and sustainable living. This society comprehends the planet's fragility, including ecosystems, animals, and resources, and learns from past actions to adopt thoughtful, informed behaviors focused on THINKING. It prioritizes reflection before action, study before creation, and participation over mere labor. This non-capitalist society lives by the principle that we are part of the Earth's system and must live harmoniously within it, striving for happiness, purpose, and quality of life for all community members.

In this scenario, CADAP (Self-Sufficient Community for Action and Thought Development / Comunidade Auto-suficiente de Desenvolvimento de Ação e Pensamento) (see Figure 05) cities are integrated. These expansive cities, built in harmony with nature, house communities in single structures that provide new professions, social spaces, housing, and local production. CADAP stimulates learning and knowledge generation, fostering communities that uphold values, encourage territorial entrepreneurship, and reject the capitalist model in favor of human knowledge

development.

Figure 06. NADAI (images generated by IA), by Pedro Medeiros.

The community focuses on three core values: Regeneration, Innovation, and Circularity. It



by NADAI (Nabeiro's Artificial Intelligence for Action constantly explores new ways of living and enhances its capacities and surroundings. Managed Development/ Inteligência Artificial de Desenvolvimento de Ação de Nabeiro) (see Figure 06), this technology enhances human capabilities by managing, stimulating, and storing community knowledge. Humans oversee NADAI and serves as a tool for advice and stimulation, accessible to all via a bracelet.

NADAI functions in three key areas:

1. Management: It manages all community resources in an accessible database.
2. Stimulation: It fosters understanding, rethinks concepts, and creates responses to improve human life.
3. Storage: It securely and systematically stores knowledge, facilitating access to present and past information.

NADAI introduces a new learning method through Super Foods, which creates a modular "workspace" in the brain for thinking, learning, and simulating even during sleep. These foods provide essential components for this process, stimulating knowledge through a customized learning system. Biometric sensors in the bracelet record all generated knowledge inspired by Blockchain for secure storage.

This set of student projects from different years allows the perception and interpretation of how various themes and issues can be framed in a future speculation approach. In all cases, there are common points and questions, such as the positive presence of technological evolution and its relationship with humans and the interpretation of new, more sustainable, and conscious lifestyles. Additionally, this project helps extrapolate potential new professions, social habits, services, and experiences that do not exist and that still need to be thought.

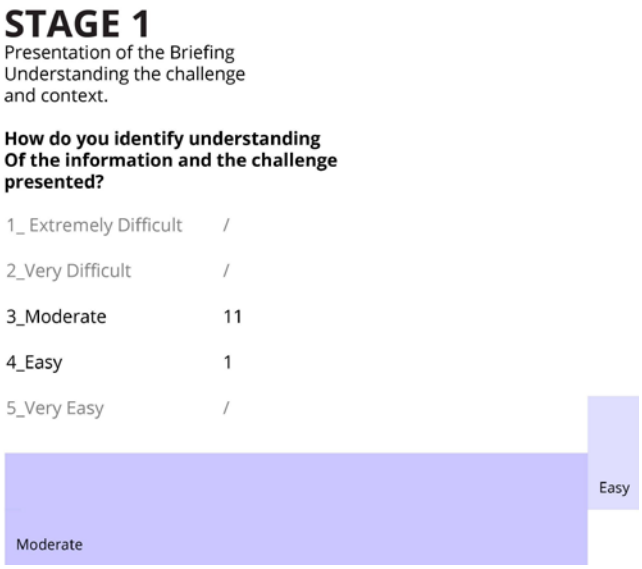
4.2 Quali-quanti evaluation

To understand the results of this pedagogical practice over the last years, we applied a qualitative and quantitative questionnaire to students who attended the curricular unit. This questionnaire, composed of evaluation weights, used Likert scales with 5 points to systematically collect a range of viewpoints and attitudes and development questions intended to obtain feedback on each of the six STAGES of the framework.

Regarding STAGE 1 - presentation of the brief, understanding of the challenge, and context - the response was unanimously moderate. However, the final assessment identifies a need for more understanding in the initial phase, perhaps a naive interest in the real purpose of the challenges launched (see Figure 07).

Figure 07. Results from the question for Stage1, by the authors

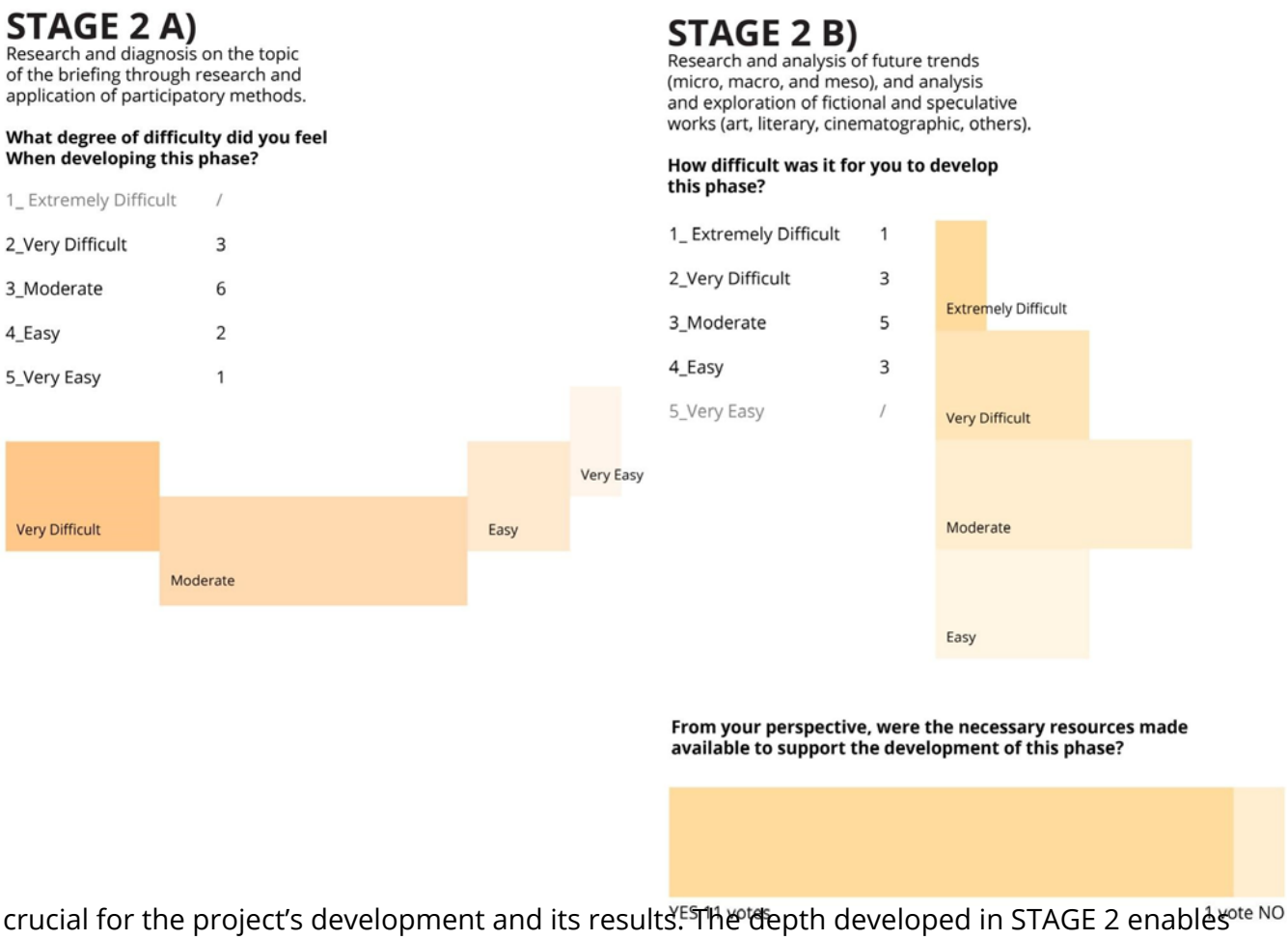
STAGE 2 - is divided into two timelines: 2a) research and diagnosis on the topic of the



briefing through research and application of participatory methods and 2b) research and analysis of future trends (micro, macro, and meso), and analysis and exploration of fictional and speculative works (art, literary, cinematographic, others); a more excellent dispersion in the responses were identified, which allowed us to draw some conclusions such as students with a greater capacity for critical thinking, reported greater ease in carrying out the task, as well as those who selected moderate considered the support resources made available by teachers essential to develop the analyses.

Figure 08. Results from the question for Stage2 A) and B), by the authors

The previous results indicate the progress of STAGE 3 - data crossing to build the future scenario and personas. This phase is



crucial for the project's development and its results. The depth developed in STAGE 2 enables the student to extrapolate possible imaginaries and point out more divergent paths. While the number of students finding this stage difficult is increasing, the majority feeling some moderation demonstrates their progress. They expressed some 'discomfort' in their development responses but also a sense of achievement and growth: "I reached it, but there were several adjustments and some setbacks at the beginning, which could have been avoided. The process was not linear, and there were times when I did not have such a consistent and comprehensive view of the scenario's potential, hence some doubts and incomplete details. So, at first, I was confused about what to do next. However, I think I managed to complete it little by little and move on to the next phase" (Emilia Faria).

Figure 09. Results from the question for Stage3 and Stage4, by the authors

Despite the specificity and the stage being the moment to apply all the knowledge acquired in previous years, STAGE 4 - ideation for a proposal, is surprising because students need more confidence in the work they

STAGE 3

Data crossing to build the future scenario and personas

How difficult was it for you to develop this phase?.

1_ Extremely Difficult	/
2_Very Difficult	5
3_Moderate	4
4_Easy	3
5_Very Easy	/



Based on your answer, do you feel that you managed to achieve an integrated and consistent vision to progress to the next phase?



STAGE 4

Ideation for a proposal.

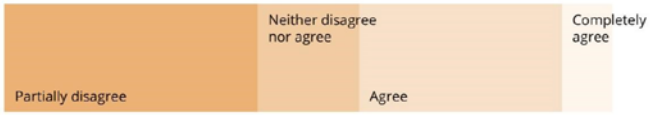
How difficult was it for you to develop your creative idea?

1_ Extremely Difficult	/
2_Very Difficult	4
3_Moderate	5
4_Easy	3
5_Very Easy	/



Depending on your previous answer, consider that you had an absolutely speculative/fictional idea?

1_Totally disagree	/
2_Partially disagree	5
3_Neither disagree nor agree	2
4_Agree	4
5_Completely agree	1

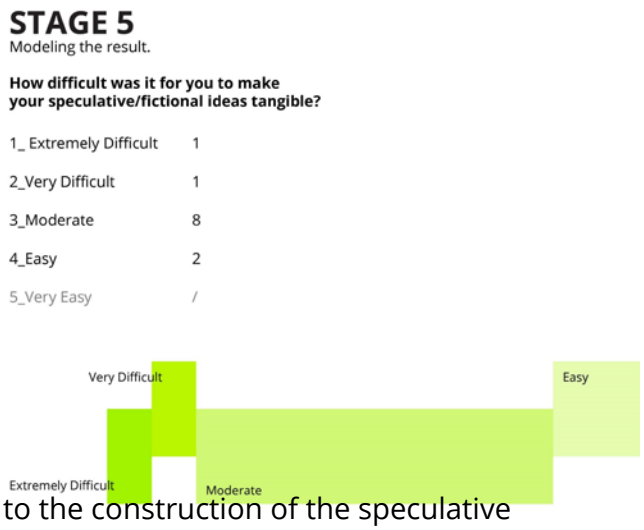


develop. However, they also recognize the importance of this phase and the value of the knowledge they receive: “After the initial idea of creating the project and

doing research on the state of the art, it was a gradual process in which everything made sense" (João Espirito Santo).

Figure 10. Results from the question for Stage5, by the authors

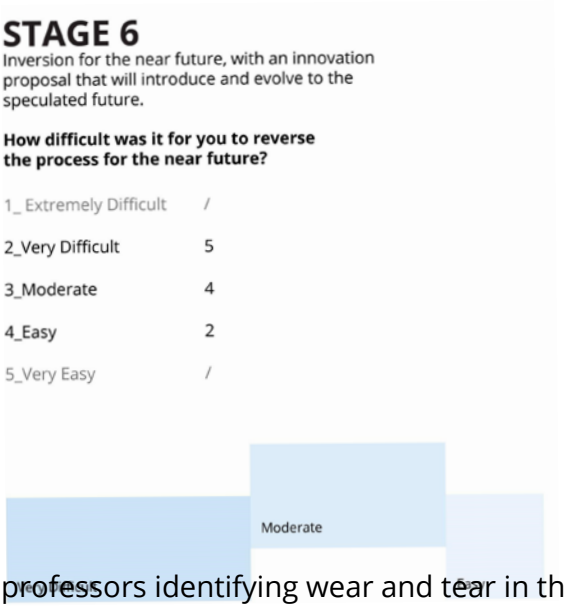
In STAGE 5 - modeling the result, students need some help making it tangible, significantly when they could elevate the prototypes to unique pieces complementary



to the construction of the speculative or fictional narrative. One of the factors continues to be a lack of confidence in the result and maximizing time so that this phase allows greater efficiency and mastery of technologies that allow the creation of "prompts" in the most differentiated results: "It was more difficult to make the ideas tangible. There were doubts and problems before and after arriving at the speculative idea. Which were rectified but still had to be more speculative. Where the objective was to think outside the box and have an even more innovative and futuristic vision than expected" (Emilia Faria).

Figure 11. Results from the question for Stage6, by the authors

To complement STAGE 6 - inversion for the near future, with an innovation proposal that will introduce and evolve to the speculated future, the standards are maintained, with



professors identifying wear and tear in the final stretch, which reveals a lack of time and motivation to respond to this last phase. This phase is fundamental in the methodology, as it conveys to the student that today's actions have repercussions in the future and that the designer must "look" from a distance at the achievements of what is designed today. The majority reveal interest and value in the project developed. "Being able to position ourselves 25 years ahead of time expands our vision even to other projects. To think about the future and not just the present" (Catarina Cordeiro).

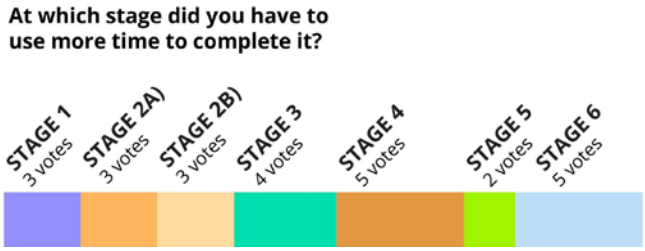
Figure 12. Results from the question, by the authors

Time management continues to be an issue, especially with STAGE 3, 4, and 5, where they waste much time researching and converging data to diverge towards a utopian or dystopian scenario. However, the students know the importance of these phases and the need for efficient time management in the learning process.



Figure 13. Results from the question, by the authors

In short, it will be necessary to reinforce increasingly, in complementary UCs, projects developed over time and crossed over into different disciplines for a more refined culture and creativity that becomes part of the student's imagination. Students who play,



have more cinematography literacy or have more life experience respond faster to the phases, with better results.

5. Critical Stages in the Process of Extrapolating Future Scenarios - Results discussion

The selection of projects, combined with feedback from surveys, indicates that despite the ability to extrapolate future scenarios, students predominantly develop not only future scenarios but also proposals for products, services, new technologies, and professions that do not yet exist, regardless of the given topic to explore. By understanding the nature of the speculative approach, they sometimes use the same reasoning to envision how visual identities and communication will evolve. They integrate communication and graphic design within the professional context, merging speculative and fictional aspects to project utopian futures and engage in critical reflection (Rynning, 2017).

However, moments of tension and difficulty arise, necessitating a reconsideration of project time management and the introduction of more intermediate exercises to aid in extrapolating future scenarios and personas. It is equally essential to motivate students to explore more insights and creative stimuli concurrently.

Over time—partly due to the course's structural demands—it has become evident how crucial a thorough design research process is. This process underscores that creativity is a product of a structured approach and that effective time management is necessary.

There is also some skepticism towards this

process, particularly among those less critical of the world around them. The ongoing deconstruction and devaluation of creative and critical thinking processes lead to a noticeable lack of interest in developing more positive frameworks and constructing a better world.

Nevertheless, utilizing AI tools has been pivotal in fostering these futuristic or speculative initiatives. AI has facilitated the creation of imagery for characters, scenarios, and anticipated outcomes for goods, services, and communication, resulting in futuristic or fictitious representations that further enhance the work. These representations are presented with the appropriate depth in the final presentations and prototypes.

6. Future Directions

To refine the framework and address the challenges observed in the course, it is essential to incorporate elements that encourage engagement, provide intermediate support, and ensure effective time management.
Here is a revised framework that integrates these aspects:

Stage 0: Provocative Stage

In this reformulation of our framework, we propose introducing a STAGE 0, an initial phase preceding the delivery of the briefing. This stage aims to immerse students in new themes with provocative topics related to 'wicked problems,' fostering an environment of debate and cultivating critical awareness. Similarly, existing resources and toolkits for introducing future projections can be incorporated.

Stage 1: Brief Presentation, Challenge

Understanding, and Contextual Analysis
Objective: Introduce the project brief, ensure a comprehensive understanding of the challenge and its context, and identify a purpose for the student.

Activities:

- Presentation of the brief.
- Group discussions to clarify doubts and define the scope.
- Contextual research to understand the background and current state.
- Identifying the values that are involved in the challenge for a better world.
- Conduct workshops focused on project management and time management skills.

Stage 2: Research and Diagnosis

Stage 2a: Participatory Research Methods

Objective: Gather in-depth insights from stakeholders and users.

Activities:

- Conduct interviews, surveys, and

focus groups.

· Apply participatory design methods to gather qualitative data.

· Intermediate Exercise: Students present initial findings and receive feedback.

Stage 2b: Future Trends Analysis and Exploration

Objective: Analyze trends and speculative works to envision future scenarios.

Activities:

· Research micro, macro, and meso trends.

· Analyze and explore speculative fiction (art, literature, film).Use case studies of successful speculative projects to inspire and motivate students.

· Intermediate Exercise:
Students create mood boards or trend reports and share insights.

Stage 3: Data Synthesis and Persona Development

Objective: Synthesize research data to build future scenarios and develop personas.

Activities:

· Cross-reference participatory research with future trends.

· Create detailed personas and future scenarios.

Integration of AI Tools:

· Provide training sessions on using AI tools for design and visualization.

· Encourage students to experiment with AI-generated content to enhance their projects.

· Intermediate Exercise:
Students draft personas and scenarios, presenting them for peer review.

Stage 4: Ideation and Proposal Development

Objective: Generate innovative ideas and develop proposals based on future scenarios.

Activities:

· Brainstorming sessions.

· Use of creative techniques like mind mapping and sketching.

· Intermediate Exercise:
Conduct ideation workshops with peer and instructor feedback.

Stage 5: Modeling and Prototyping

Objective: Transform ideas into tangible models and prototypes.

Activities:

· Develop prototypes using various media (digital, physical).

· Utilize AI tools to create imagery and

visual representations.

Integration of AI Tools:

- Encourage students to experiment with AI-generated content to enhance their projects.
- Intermediate Exercise: Present prototypes in a mock presentation for critique.

Stage 6: Near-Future Innovation Proposal

Objective: Propose innovations that bridge the gap between the present and the speculated future.

Activities:

- Invert future scenarios to propose immediate innovations.
- Develop a detailed plan for implementation.
- Intermediate Exercise: Final presentations with comprehensive feedback sessions.
- Auto-evaluation and peer review assessment.

These revisions, to the course framework, will address the observed challenges and enhance student engagement, creativity, and critical thinking. This will lead to more innovation and be centered on a global problem.

7. Conclusions

Integrating intended learning outcomes with pedagogical strategies to enhance awareness of evolving behaviors and incorporating self-assessment activities can address the limitations inherent in systematic approaches and instructional materials for values-based design methodologies, such as speculative and critical design. This integration challenges students and facilitates their understanding of how these approaches are already being applied within professional contexts. The reflections presented in this article underpin this assertion. The proposed framework demonstrates how educational strategies fostering critical thinking about emerging technologies can be systematically planned, executed, and evaluated.

Additionally, integrating greater interdisciplinarity in the execution of projects fosters continuous and simultaneous discovery. It is crucial to promote greater autonomy through student-led initiatives by designing a learning experience guided by their own discoveries and beliefs. This necessitates a more integrated vision of intergenerational relationships, enabling students to understand the connections and purposes inherent in building futures oriented towards the common good.

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DESIGN FOR BEING HOME AND CONNECTED: EMERGING TYPES OF DWELLING AT HOME TOWARD SMART FURNITURES

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ABSTRACT | Seeing smart furniture as a design space where technology redefines the dwelling at home, we formed a design project, "Design for Being Home and Connected," for third-year industrial design studio class. In this regard, we further analyzed the notions of "smartness" and "being connected" in the context of household furniture through student projects. Our analysis framework consisted of three types of connectivity: emotional, digital, and functional, and five types of smartness: the ability to cooperate, autonomy, environmental agility, upgradability, and two-way communication. Furthermore, our contribution is twofold: first, we reveal how humans are still omnipresent through smart furniture despite being at home, and second, we scrutinize how smart furniture can provide a more sustainable lifestyle in households.

KEYWORDS | SMART FURNITURE, CONNECTIVITY, SUSTAINABILITY, SMARTNESS, FURNITURE DESIGN

1. Introduction

Furniture has always been a key element in the home environment. Recently, the meaning attributed to furniture has been expanding with technological improvements. Moreover, individuals are physically present in their homes and connected to various digital platforms and identities in the digital age. This shift has created new needs and opportunities for furniture to accommodate and reflect the user's digital identity and lifestyle. Considering the changing needs of dwellers, smart furniture is becoming part of daily life by responding to various novel needs. In other words, by integrating digital features, sensors, and connectivity options, smart furniture can cater to the recent needs of generations x, y, and z. Furthermore, calling them "furniture units," Mohamed et al. (2021) state that smart furniture's capacity to feel, detect, and respond to the wishes and needs of dwellers. IoT and AI are the most prominent technologies that turn furniture into smart (Li & Han, 2022). However, few studies considered the emotional side of this transformation (Li & Han, 2022) and this transformation was continuous reflecting on both society and design. As a way to demonstrate the interrelation between the design decisions of settled life and lifestyle, the designer Ken Isaacs aims to emancipate spaces with new meanings using modular frames around the middle of 20th century (Margolin, 2002). In this sense; considering the furniture as a reflection of society (Baudrillard, 2005), the design and use of smart furniture also provide a discussion space for the novel dwelling types and changing social practices.

The objective of this study is to investigate the ways in which technology, as its utilization in furniture increases, can potentially shape future lifestyles by introducing new possibilities and connections through design. In this regard, we planned a term project "Design for Being Home and Connected" for third year industrial design students to discuss the concept of smartness in furniture design and to analyze how the change in technology related to smartness and connectivity can be reflected in everyday life. In this paper, the design strategies for smart furniture design are discussed through the analysis of student

projects, and our discussion reveals two significant contributions in terms of being connected at home: (1) the omnipresent human, meaning that humans are still connected to the social and organizational networks despite being at home and; (2) sustainable households, addressing how smart furniture can encourage more sustainable lifestyles at home.

2. Changing meaning of dwelling at home and smart furniture

Current research and emerging product scape show that the improving technologies shape the standards and habits of dwelling at home (Desjardins et al., 2019), and current studies on smartness at home have been criticized due to the consideration of only the classical family structures with two parents and two children (Desjardins et al., 2019). Currently, we observe new lifestyles along with new house types; of course, these two are co-shaping each other. Moreover, these changing novel lifestyles and households, such as co-housing (Jenkins, 2018), divorce (Odom et al., 2010), and working at home (Crabtree & Rodden, 2004) have been studied in the design literature. For example, Li and Han (2021) state the need for smart furniture for small-sized households. On the other hand, other variables such as culture (Bell et al., 2005), religion (Woodruff et al., 2007), and financial capacity (Woodruff et al., 2008) have a significant impact on the design of daily life and space. According to a study that explores the added value of furniture, functionality, space-saving, multiple functions, and modularity are the five most important aspects, whereas families with income care more about the security in use, and high-end users give value to design, material, and customization (Blažević, et al. 2021).

The regional and planning design literature defines smart furniture as a touchpoint of smart cities (Krejcar et al., 2019; Nassar et al., 2019; Chesher et al., 2023; Wang & Shmelova-Nesterenko, 2024) along with smart devices, home, security, and environment systems. More precisely, smart furniture is defined as "furniture which brings added value, functionality, comfort and elegance to fit every personalized requirement issued by the user" (Vaida et al., 2014), whereas a more technical definition is "composed of hardware such as computers, sensors, and appliances, and developing software technologies for realizing smart hot-spot services (Ito et al., 2003)." Li and Han (2022) categorize smart furniture as a mechanic, electronic, and AIoT (AI+IoT) intelligent, and the dimensions of smartness are identified as "ability to cooperate, autonomy, environmental agility, upgradability, two-way communication" through overviewing the literature review related to the smartness of products by Rokonuzzaman et al. (2022).

As security is among the important dimensions in dwelling, products such as August smart lock, Amazon key, and Nest cameras allow surveillance of households, and home assistants operate as hubs such as Amazon Alexa, Apple HomePod, and Google Nest of

product networks related to the households. Moreover, Krejcar et al. (2019) consider smart furniture as an opportunity for vulnerable people such as the elderly and people with health issues (Shidiq et al., 2019; Majumder et al., 2017; Hu et al., 2021). In the context of the work environment, Foxels (Perteneder et al., 2020) is studied as a modular smart furniture that allows the user to modify the structure through building blocks. Considering all the definitions and examples, we argue that the definition of smart furniture covers a wide range of furniture, and they do not need an interface or digital connections to be smart. In this sense, we argue that smartness can be provided through distinctive features such as modularity and stackability as well as strengthening its value on the emotional side.

3. The Studio Project: "Being Home and Connected"

Aiming to explore the smartness of furniture and the novel social practices in the home environment, we designed a term project, "Design for Being Home and Connected," for third-year industrial design students in the design studio. The product range included furniture, furniture accessories such as side tables, coffee tables, or products that communicate with each other. Designing furniture in an educational setting can be challenging in certain aspects (Arıburun Kırca, 2021). Following the literature review, we defined the meaning of "being connected" through three criteria emotional, digital, or functional connectivity; we elaborated on these definitions in our methodology section. The project continued for 14 weeks of critique sessions via in-person and online classes twice a week. The project steps until the preliminary jury (sixth week) were introduction (first two weeks), ideation (third to fourth week), and conceptualization (fifth week). Then, we continued with the detailed design phase and product finalization, and; by the end of the project, students were expected to:

- understand the concept of smartness, connectivity, and originality of the concept,
- design the user experience / human-product or product-product interaction,
- comprehend the concepts of semantics/ ergonomics / functionality (ease of use, interfaces, signs of smartness, being connected, etc.),
- consider sustainability in mass production and upgradability,
- demonstrate a visual appeal on the furniture design.

4. Methodology

We followed a research through design (Frayling, 1993; Zimmerman & Forlizzi, 2014) approach since we aimed to create knowledge through design artifacts that the students built. However, we do not see these artifacts as final results, but rather, we see them as part of the design research process (Wakkary et al., 2016). Therefore, we aim not to produce generalizable outcomes but rather contingent

and situated design knowledge (Höök et al., 2015). In this sense, we use design as a form of research (Zimmermann, 2003) to create a space for the discussion on changing social practices since the opportunity to reflect on ourselves comes from reflecting on things (Cila et al., 2015), as well as explore the design strategies in the context of smart furniture.

Student projects (n=33) were collected as digital A3 sheets, and the works were presented on the final assessment day. We used visual content analysis (Rose, 2011) while interpreting the visual data gathered from the students' artifacts. Thus, throughout the study, we followed a back-and-forth deductive and inductive analysis approach (Hatta et al., 2020).

For deductive analysis, we categorized the project contents into six (see Table 1) based on their design concept. Furthermore, we extracted basic explanations, keywords, connectivity types, and dimensions of smartness as the project outcomes were analyzed, see Table 1 in Findings. For the inductive analysis, we considered three types of connectivity: emotional (senses, face-toface communication, etc.), digital (internet, Bluetooth, RFID, etc.) , and functional (charging, cables, etc.), and dimensions of smartness were "ability to cooperate, autonomy, environmental agility, upgradability, visual appeal" gathered from Rokonuzzaman et al.'s study (2022). We described these to justify our further analysis. We elaborated on the definitions of connectivity as follows:

- "emotional connectivity" concentrating on bonding with its users through senses, face-to-face interactions, and in, further levels, building trust and sharing feelings;
- "digital connectivity" addressing the digital networks that are equipped through technologies such as the internet, Bluetooth etc.;
- "functional connectivity" marking the achieved connectivity through the physical materials such as cables and the capacity of the furniture having more functions through stackability, modularity etc.

Subsequently, we adapted five Dimensions of Smartness from Rokonuzzaman et al.'s study (2022) as follows:

- ability to cooperate is the capacity to form connections with other objects;
- autonomy reflects the independence of furniture's actions with no or little input from the user;
- environmental agility is the capacity to adapt and react to changes in the environment;
- upgradability is about furniture's capacity for upgradability with the latest technological improvements;
- two-way communication is the furniture's capacity to respond and allow two-way communication between itself and the user.

5. Findings

The smart furniture projects are categorized under eight titles based on their functions, connection type, and social impact: working at home, for organizing, for memories, for health & well-being, for living with non-humans, for clothing, for isolation and for leisure. Smart furniture for working at home addresses more efficient spaces while working at home, whereas smart furniture for organizing emphasizes making space management more efficient for certain purposes such as waste management and sleeping routine. Smart furniture for memories is designed to highlight the value of friends and family by reminding their significance to users. Moreover, another product category that benefits from emotional connection is furniture for non-humans since these products improve our bond with non-humans (plants and pets) and their life qualities. On the contrary, smart furniture for isolation aims to cut off interaction with other dwellers at home. Furniture for clothing assists the wardrobe and laundry management at households. Furniture for leisure and health & well-being is important for keeping track of our health and enjoying our time at home. Table 1 shows the related data for all projects, here we limited dimensions of smartness types to two of the most prominent for further analysis (a detailed version with explanation of projects and keywords is presented as Appendix A.

Table 1. List of student projects with their concept category, connection type and dimensions of smartness

Concept Category	Project Title	Connection Type	Dimensions of Smartness
working at home	Nomad	functional	environmental agility, ability to cooperate
working at home	Portable Smart Desk	functional, digital	environmental agility, ability to cooperate
working at home	Extendesk	digital	environmental agility, ability to cooperate
working at home	Duo-Desk	functional, digital	environmental agility, ability to cooperate
working at home	Work & Shoot	functional	environmental agility, ability to cooperate
isolation	Foldex	emotional (dis)connection, digital	environmental agility, upgradability
isolation	Serene	emotional (dis)connection, digital	two-way communication, environmental agility,
memories	Nortia	emotional	autonomy, upgradability
memories	Monumentai	emotional	autonomy, upgradability
memories	Morpheus	digital, emotional	two-way communication, autonomy
health & well-being	Pillo	functional, digital	ability to cooperate, two-way communication,

health & well-being	Diabethelp	functional, digital	ability to cooperate, two-way communication,
health & well-being	Hivefit	emotional, functional	two-way communication, environmental agility
health & well-being	Domat	functional, (emotional?)	two-way communication, environmental agility
health & well-being	Detoxfresh	emotional, digital	autonomy, two-way communication
health & well-being	Yogapy	emotional	two-way communication, environmental agility
living with non-humans	Soil0	functional	environmental agility, ability to cooperate
living with non-humans	Cat-Scan	functional, emotional	autonomy, two-way communication
living with non-humans	My Green Diary	emotional, digital	ability to cooperate, two-way communication
leisure	Smart Tea Bar	emotional, digital	two-way communication, ability to cooperate
leisure	Cosion	emotional, digital	two-way communication autonomy
leisure	Pumpkin	emotional	two-way communication, upgradability
leisure	Relaxknit	emotional, functional	two-way communication
leisure	Spe-Light	emotional, functional	environmental agility, two-way communication
clothing	We-Drobe	emotional, digital	two-way communication, autonomy
clothing	Smuv	emotional, digital, functional	two-way communication, autonomy
clothing	Selfy	emotional, digital	two-way communication, autonomy
clothing	Smarty	emotional, digital, functional	two-way communication, autonomy
clothing	Cornert	functional, digital	two-way communication, environmental agility
clothing	Epignosi	emotional	two-way communication, autonomy,
organizing	Garb-E	functional, digital	two-way communication
organizing	Smart Waste Separation and Storage Modules	functional, digital	two-way communication, environmental agility
organizing	The Start of a Sunrise	functional	autonomy, two-way communication

In total we have the concept categories as follows: five home-office furniture, three furniture as organizer, two furniture for isolation, three furniture for memories, six health & well-being furniture, three furniture for non-humans, five furniture for leisure, and six clothing furniture, see Figure 1. Here, we can read the tendencies of smart furniture application areas inherited by third year design students.

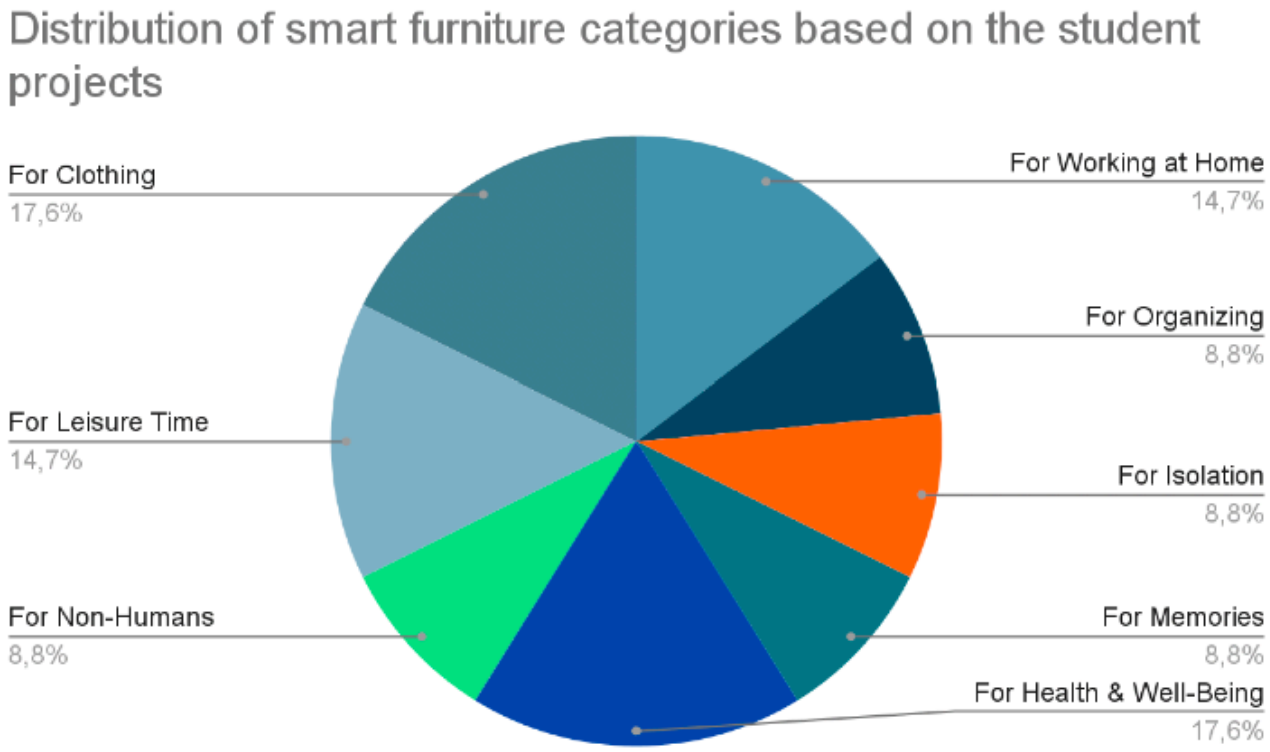


Figure 1: Distribution of smart furniture categories based on the student projects

Working at home is a common issue, especially after the pandemic, and most of the projects involve a surface to use computers and work on. Environmental agility and ability to cooperate were the most prominent smartness features for this category since current working practices require multitasking on the working such as eating, exercising, and streaming while working. To adapt to these needs, students designed flexible products that allow co-working (Duo-Desk), environmental flexibility (Extendesk, Work & Shoot), and portability of the work environment (Nomad, Portable Smart Desk) during work hours, see Figure 2.

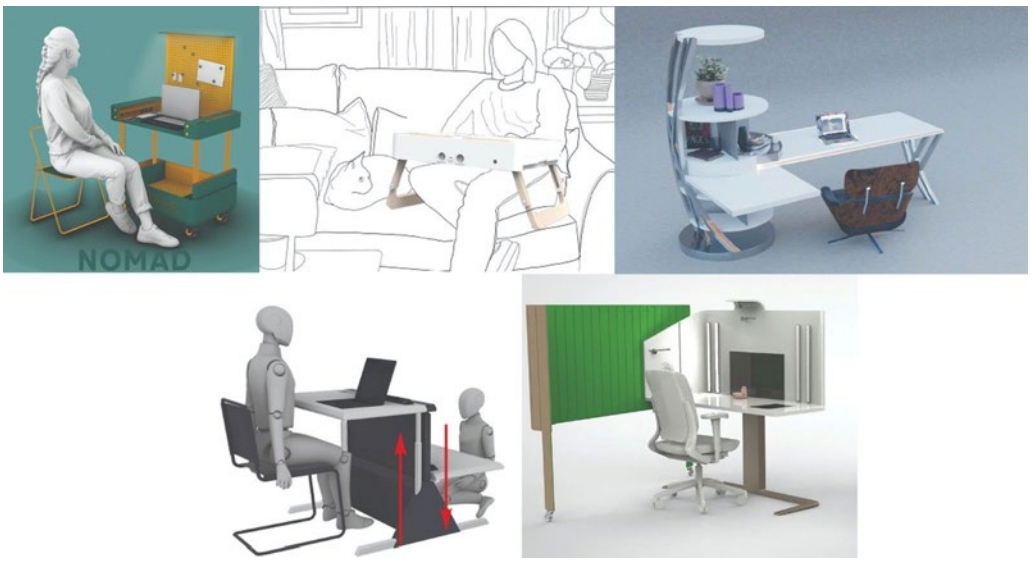


Figure 2. Work At Home Student projects: (Up- Left to Right) Nomad by Elif Özfidan, Portable Smart Desk by Zeynep Konyalıoğlu, Extendesk by anonym student; (Down- Left to Right) Duo-Desk by Hatice Nur Savan, Work & Shoot by anonym student

The smart furniture of the health and well-being category prioritizes two-way communication in terms of smartness since the user shares their health data with the system for tracking. Thus, the furniture gives feedback to the user based on their health condition. Furthermore, environmental agility was significant for the recent need to exercise and meditate at home. Figure 3 shows the visuals from the projects; Pillo and diabethelp were medicine storage tables to track the medicine-taking routine of the patients, whereas Hivefit, Domat and Yogapy operate as workout assistants that track the exercise routine. Detoxfresh tracks nutrition and stores fruits and vegetables with an air filter.

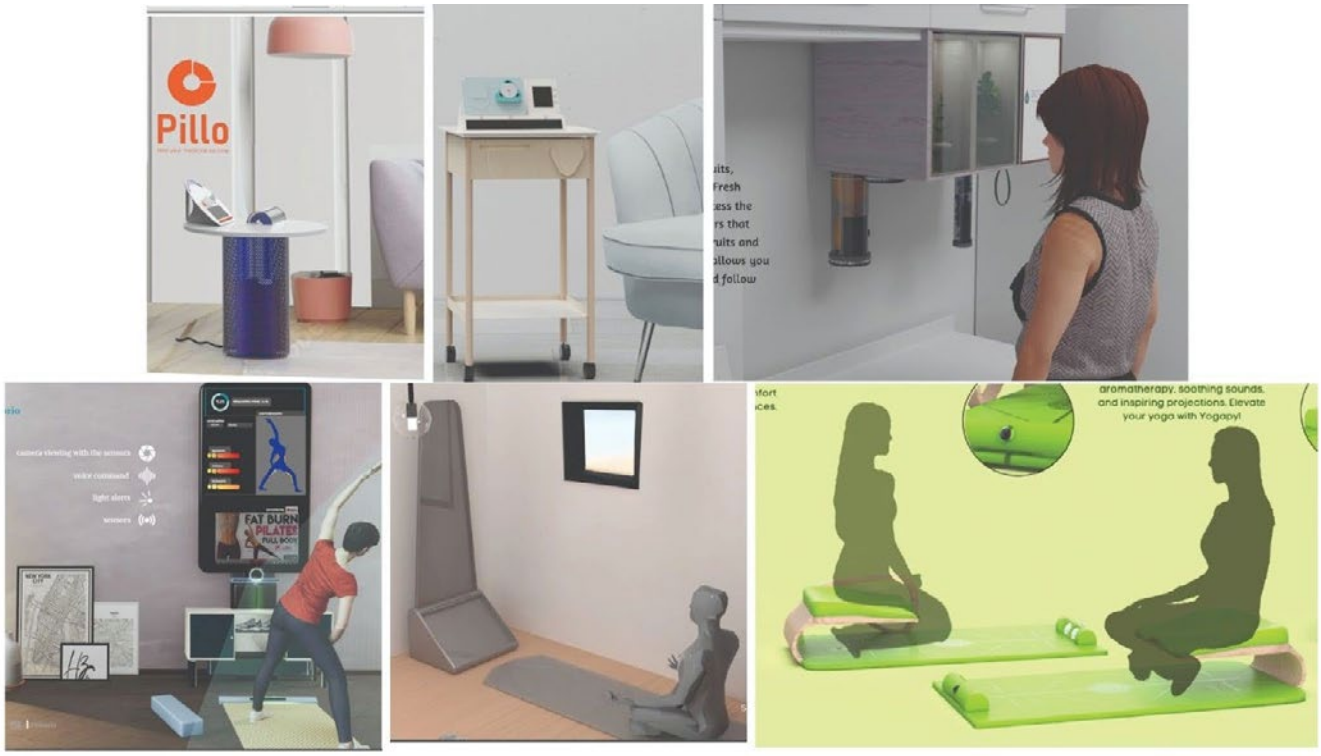


Figure 3. Health & Well-being student projects: (Up- Left to Right) Pillo by Dilara Uçar, diabethelp by Fatma Nur Demir, Detoxfresh by anonym student; (Down- Left to Right) Hivefit by anonym student, Domat by anonym student, and Yogapy by anonym student

As a physical significance of emotional connectedness, smart furniture for memorizing demonstrated tremendous potential. Here, the autonomy of the furniture came front since they receive and process data for a satisfactory synthesis of the user. For example, Nortia and Monumentai remind memories to the household members through digital screens, see Figure 4. In contrast, Morpheus animates the dreams of the user even if he may not be able to remember them, see Figure 4.



Figure 4. Memories student projects (Left to Right: Monumentai by Osman Arif Kurtuluş, Morpheus by Burak Kıvanç, and Nortia by Mine Koca)

People have lived with non-humans, such as pets and plants, for centuries. In this sense, the furniture is also theirs, and two-way communication of the furniture with both the non-human and house owner becomes prominent. Subsequently, the shared furniture creates a potential to magnify the emotional connectedness. Soil0 and My Green Diary focused on plants whereas Cat-Scan touched upon the issue of tracking the health of a cat, see Figure 5.



Figure 5. Living with non-humans student projects: (From Left to Right) Soil0 by anonym student, Cat-Scan by Sıla Arıca, and My Green Diary by anonym student

The leisure category involves furniture to allow users to enjoy activities such as listening to music, knitting, and reading. This furniture category features their capability of two-way communication since they assist the user in certain activities. Moreover, the furniture becomes an emotional touchpoint for the user by allowing them to relieve stress through such activities at home. Smart Tea Bar allows an interactive tea experience. Cosion and Relaxknit support the user while knitting, and Spe-light is a modular speaker and lighting. In the context of the parentchild relationship, Pumpkin helps children adapt to reading (Figure 6).



Figure 6. Leisure student projects: (Up-Left to Right) Cosion by anonym student, Pumpkin by anonym student, Relaxknit by Eylül Çakır; (Down-Left to Right) Smart Tea Bar by anonym student, Spe-Light by Buse Akar

The clothing practice is a private activity that mostly belongs to the bedrooms of households. On this occasion, the users share their clothing inventory data with smart furniture AIs to get recommendations for their daily clothes. Certainly, the ability to communicate in two ways was significant in discussing smartness. However, we argue that autonomy also has a substantial role since, this time, the furniture was able to direct the appearance and preferences of the user by analyzing the given data. Students mostly studied this as smart wardrobes (We-drob, Selfy, Smarty, Epignosi), whereas few of them studied it as a smart mirror for make-up (Smuv) and laundry basket (Cornert) for tracking the availability of clothes, see Figure 7.

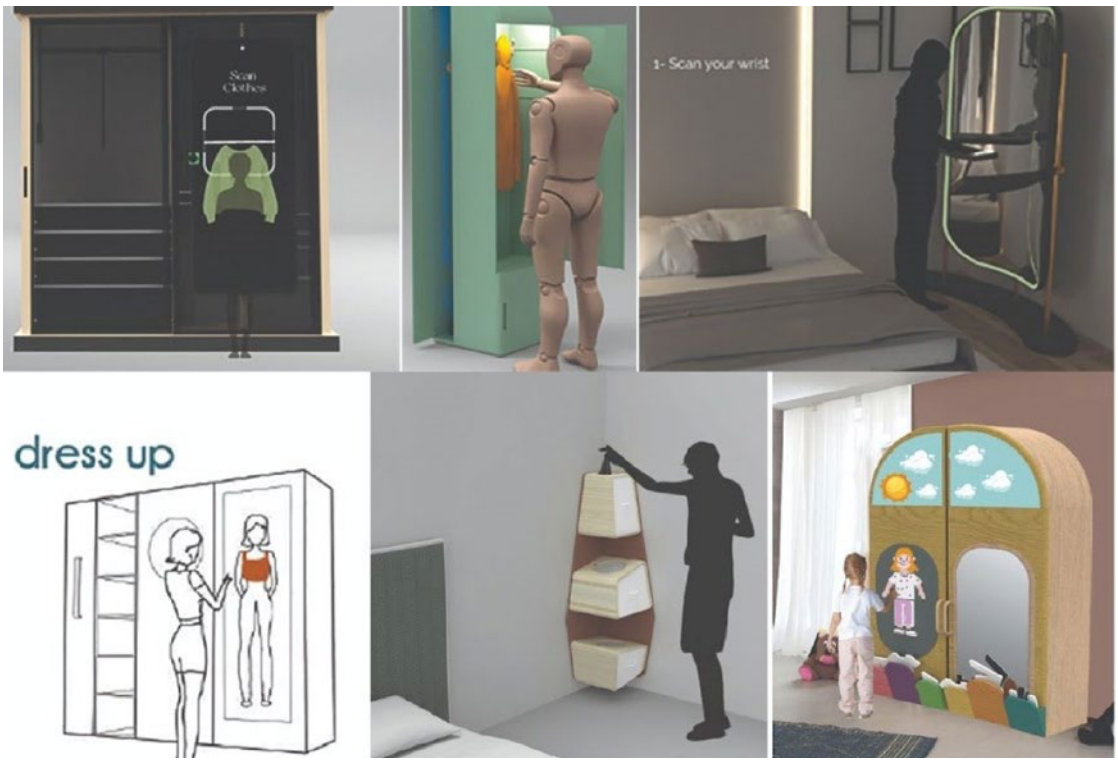


Figure 7. Clothing student projects: (Up-Left to Right) We-Drobe by anonym student, Smuv by anonym student, Selfy by anonym student; (Down-Left to Right) Smarty by anonym student, Cornert by Onur Çelik, Epignosi by anonym student.

With the household going small and increasing number of accessories, packages make the issue of organizing crucial for novel generations. In this sense, recycling management at home has been an issue that people struggle with, and two smart furniture examples (Garb-E and Smart waste separation and storage modules) create solutions for that by raising the awareness of the user as well as facilitating the waste management process. On the other hand, The Start of a Sunrise touches upon the issue of morning routines and organization of belongings in the bedroom, see Figure 8.



Figure 8: Organizing student projects: (Left to Right) Smart waste separation and storage modules by Emir Sahil Yüksel, Garb-E by anonym student, The Start of a Sunrise by Onur Taşdönderen

One of the most apparent effects of smart technologies in daily life is increased individualism. For that reason, people prefer to enjoy their time themselves rather than interacting, even at their homes. Based on that need, students designed smart furniture that allows isolation at home through sound and visual blocks featuring environmental agility. Foldex is a minimalist separator with screen foldable surfaces that can make white noise, which strengthens the isolation, whereas Serene is a foldable meditation unit that allows the user a space for stress relief and self-peace, see Figure 9

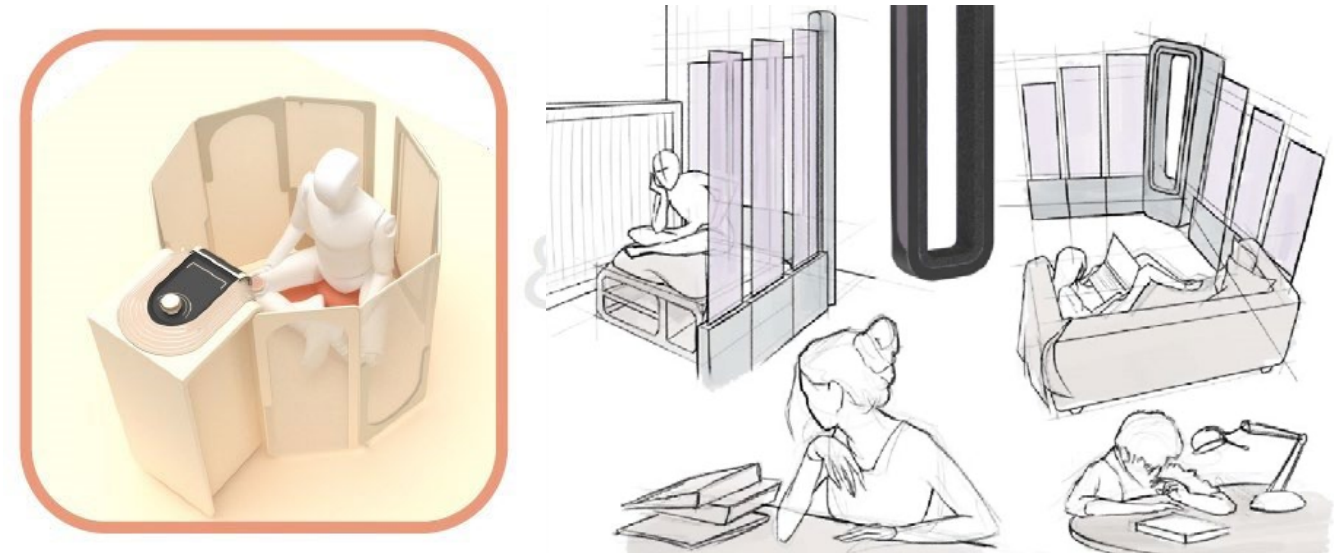


Figure 9. Isolation student projects: (Left to Right) Serene by Aleyna Gök and Foldex by anonym student

Figure 10 compares the inclusion of dimensions of smartness based on the projects. Two-way communication comes to the front, showing that the most significant feature of smart furniture is its capacity to respond to the users. Secondly, environmental agility reflects how significant it is for furniture to adapt to the environment and be flexible. Third, autonomy is definitely increasing as a concept. However, some people still prefer some level of control in the context of furniture. Moreover, this is also a good point to discuss the changing definition of furniture. For example, a robot vacuum cleaner is a strong representative of autonomy at home due to its capability to move and clean autonomously. However, it has a place like a piece of furniture when it is in passive mode. In this sense, the inclusion of autonomy in the house questions the definition of what should be called furniture. Fourth, the ability to cooperate and upgradability are crucial, and we expect it to be more dominant in the future since it allows the furniture to be an extension of other objects or a base of different objects. In the current world, we are glued to our smartphones, meaning that we are glued to plugs or any energy transfer points, and furniture is taking this role. Moreover, another way of cooperating with

other objects for smart furniture is sharing data. For example, smart wardrobes and medicine tracker furniture gather the data from phones and cooperate with it.

The findings address that the students have demonstrated two main approaches to the projects: (1) adding features to the existing products by making them smarter, (2) designing a new furniture type based on a need that exists with digitalization, aiming to activate digital identities at home. Through the existence of smart devices such as PC, tablet, and smartphones as anchor points to the furniture, it becomes an extension of these digital needs at home. We see this as a crucial step for our further discussions.

For the first category of products, we can mention Smart tea bar (Figure 6, Down-Left), a kitchen table supported by an interactive interface. By adding the interactive interface, the design responds to the need for emotional disconnection at home. However, in its most basic form, this is still a table. For the second category of products, Serene (Figure 9, on left), a meditation unit for households, can be given as an example. Here, this product is totally and responds to the need to do meditation and isolation at home. In this sense, it is a niche furniture that is adapted to the novel needs of people.

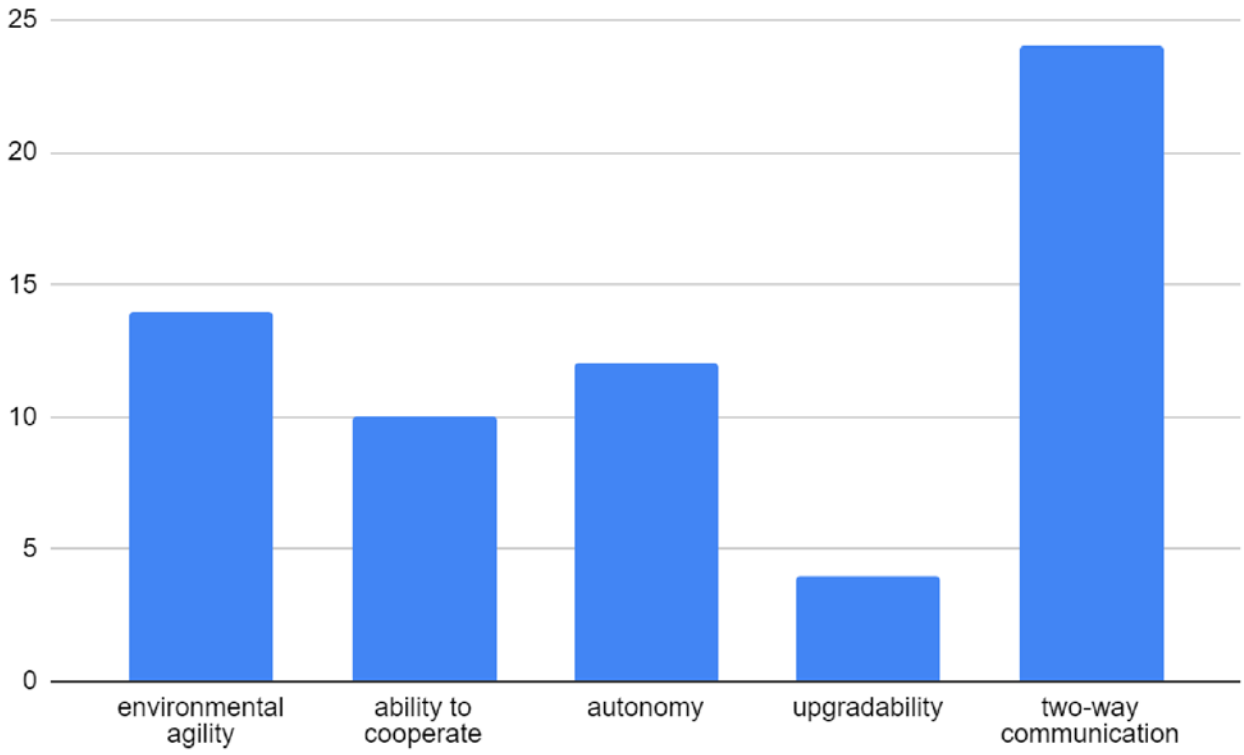


Figure 10. Comparison of dimensions of smartness included in smart furniture projects

6. Discussion

We argue that the existence of smart furniture is inevitable, and we see the awareness of its effects and future consequences as a significant step in smart furniture design. Therefore, in this section, we discuss the smart furniture phenomenon from two different perspectives. First is the omnipresence of humans; this issue was prominent for us since two-way communication and environmental agility were the first two types of smartness marked by the projects. In this sense, smart furniture magnifies a human's capacity to be present in multiple spaces and turn the home into different spaces. Hence, both the human and the household are flexible and can have distinct identities. For example, the human can work, exercise, and meditate while still being social and following the practices of its owner, the house turns into a gym, a workspace, or a temple. The second issue that stepped forward was sustainability; we see smart furniture as an opportunity to spread sustainable behaviors and well-being. Similarly, two-way communication and the ability to cooperate are crucial dimensions of smartness for us since tracking behaviors and habits is critical to maintain routines. We discuss these by aligning with two Sustainable Development Goals; SDG 3: Good Health and Well-being and SDG 12: Responsible Consumption and Production.

6.1. The omnipresent human

All the digital networks knitted around people allow easier communication; thus, the need to physically be somewhere has started to fade away. It is deduced that as furniture gets smarter, it is compelling to change the definition of furniture. The main reason behind that is the new needs that have emerged as our lifestyles have adapted to technological improvements. Here, the notion of co-performance (Kuijer & Giaccardi, 2018) is a significant aspect of the discussion of smartness, since the capacity of smart furniture allowing two-way communication, brings both advantages and disadvantages. According to Kuijer and Giaccardi (2018), humans coperform with technological artifacts both co-shaping each other. For example, Kuijer (2019) studies this on clothes washing practice, considering how it has changed with the involvement of washing machines. In this sense, we co-perform with smart furniture, giving them certain tasks to ease daily practice. Furthermore, this attachment allows background relations (Verbeek, 2008) with the furniture, allowing the user to operate multiple tasks simultaneously, making the user omnipresent.

Moreover, this omnipresence requires instant space managements, allowing both digital and emotional connections as well as disconnections in the household. Particularly in two projects, we observed that the design enables emotional disconnection, which addresses the category of isolation, see Figure H. Hence, when we are interacting with

technology via alterity relations (Verbeek, 2008), we are already being present in a different reality. These furniture examples also magnify these senses with physical and emotional isolation techniques, reducing the necessity of being physically present in certain cases.

Contrary to the definition of furniture, the products are becoming more mobile. This was also a game-changer for society; for example, typewriters played a role in the movement towards the liberation of women (Herkimer County Historical Society, 2019) since they gave independence to their users. In this sense, by making smart devices such as PCs, tablets, and smartphones an anchor point, furniture is becoming an extension of these digital needs at home. Vice versa, mobile products use furniture as base stations; primarily, their dependency on energy necessitates this. However, it also reflects our dependency on them by emphasizing how deeply digitalization is embedded into our social practices. Continuing with the typewriter, Heidegger (1982) mentions the transformation from pen to typewriter, and he was concerned about the lost character of handwriting. In this sense, any new technology comes with its cons and pros. Although we are concerned with immobilization, we also see that smart furniture has beneficial sides for sustainability, especially through behavior change, as we will discuss in the next section.

6.2 Sustainable Households

We see a potential for the design of smart furniture to be aligned with Sustainable Development Goals (SDGs) and here we discuss it through project examples. The study emphasizes the issue of connectivity in smart furniture through digital, physical, and emotional connections. Smart furniture can enable individuals to seamlessly interact with their digital identities and enhance their overall experience at home. Whether it is through integrating smart features that allow for remote control of home devices, personalized settings based on user preferences, or even emotional interactions through ambient lighting or music, smart furniture has the potential to transform the way people live. The changes initiated through smart furniture can contribute to sustainability in several aspects by supporting SDGs.

First, one of the most prominent themes during the project was tracking medical conditions at home. Health applications are currently in use; however, to improve this connectivity and ability to track, there was a need for furniture that is connected to those applications. Thus, adapting furniture within the context of health and well-being was promising for some students, and it was observed that these smart furniture aimed to track medicine use or improve sleep patterns, supporting SDG 3: Good Health

and Well-being. Second, another theme was waste management at home; through smart furniture for organizing projects, students created a positive effect towards the behavior change for sustainability since the users will be more aware of their consumption and disposal rituals, supporting SDG 12: Responsible Consumption and Production.

7. Conclusion

Through "Design for Being Home and Connected" projects, it is deduced that as the furniture gets smarter, the definition of furniture dislocates, becomes mobile and independent, reflecting the recent human character of "being omnipresent" and the main reason behind that the new needs emerged through our lifestyles adapted to technological improvements. In other words, the furniture reflects the user's identity and evolves into smart furniture because of the digital needs in society. Moreover, with its potential as a tool for connectivity within the home setting, furniture holds significant potential to revolutionize everyday life through various forms of smartness and make people's lives better by pursuing a future with sustainable households.

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Appendices

Appendix A: List of students' projects with their concept category, explanation, keywords, connection type and dimensions of smartness

Nomad	**mobile and adjustable workspace**	**mobility, working, studying**
Portable Smart Desk	portable smart desk	working, studying
Extendesk	an extendable table for work and leisure	working, studying, leisure
Duo-Desk	work table for two people in a shared room context	working, studying
Work & Shoot	adjustable work table for streamers	working, video-making
Foldex	extendable separators for isolation at home	white noise, working
Serene	meditation units-cabin for home	meditation, well-being
Nortia	table to collect and display physical objects and photos	memories, being connected to others
Monumentai	enhance your memories with AI to carry them to the future	memories, being connected to others
Morpheus	a bed and integrated audio visual system that reproduces images of dreams through AI according to the prompts given by the user	sleeping
Pillo	smart medication table that allows the user to track and store the medicines	health
Diabethelp	smart side table for diabetic people to organize their medical belongings	health
Hivefit	a console system with screen and mat to enable the user workout interactively	exercise, well-being
Domat	smart mat system	exercise, well-being
Detoxfresh	fruits and vegetable dispenser with air filter and tracks nutrition	eating, well-being
Yogapy	yoga chair for enhanced comfort and immersive yoga experiences	meditation, well-being
Soll0	a furniture designed for tracking and practicing hydrophonic agriculture at home	growing plants
Cat-Scan	smart furniture for cats - early diagnosis of diseases	tracking pets

My Green Diary	a gardening space with seat to emotionally connect and grow plants	tracking, growing plants
Smart Tea Bar	interactive table for tea time	drinking, hanging out, connection with others
Cosion	side table that operates as an interactive smart assistant with sound and display	leisure
Pumpkin	smart library for kids that improves parent-child relationship	leisure, reading
Relaxknit	knitting for stress relief	knitting, leisure
Spe-Light	speaker and ambiance lighting with a modular structure	ambience
We-Drobe	a wardrobe that is also a clothing assistant-organizer	clothing
Smuv	clothing organizer- smart mirror	tracking, clothing
Selfy	smart mirror-make-up & clothing assistant	make-up, clothing
Smarty	smart wardrobe - organizer	tracking, clothing
Cornert	smart laundry basket with a tracking system	laundry, clothing
Epignosi	wardrobe to increase physical and personality awareness in children	clothing
Garb-E	smart recycle bin that separates waste	organizing waste
Smart Waste Separation and Storage Modules	smart waste separation and storage modules	organizing waste
The Start of A Sunrise	bedside organizer with night stand with lighting & alarm	morning routine, organizing

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ADAPTIVE LEARNING EXPERIENCE FOR ART AND DESIGN GRADUATES IN A CHANGING WORLD

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ABSTRACT | In today's fast-paced world characterized by rapid technological advancements, preparing professionals in art and design fields has become crucial. This necessity stems from the transformative impact of technology across society, highlighting the need for adaptable skills and continuous innovation in future professionals, especially considering projected scenarios up to the year 2050.

The research aims to address this urgency by equipping students with skills to navigate a rapidly changing environment. A key insight from Garry Bolles is the accelerated pace of technological progress, leading to increased job scarcity or abundance based on automation levels. 35 years ago, Shoshana Zuboff further adds that disruptive technologies create a dual labor scenario, emphasizing the importance of training strategies and flexible labor policies, when referring the computer disruptive technology, today's disruption is Artificial intelligence and in 35 years into the future would be any other disruptive technology.

To meet these challenges, an innovative adaptive learning experience was introduced in 2023 at a Mexican university, focusing on empowering students with a forward-thinking point of view (Mindset), developing their set of competences and skills (Skillset) through portfolio creation, and providing the necessary knowledge in cutting-edge technologies (Toolset) for navigating a digitized work environment. The approach is holistic, considering cognitive, emotional, and professional aspects to foster human flourishing.

The World Happiness Report and academic literature stress the importance of holistic education, emphasizing personal strengths, positive relationships, meaning in life, and positive emotions alongside technical knowledge. This approach aims to prepare students not just for the

workplace but for life's challenges, contributing to a balanced and prosperous society. The methodology for the design of this adaptive experience included historical analysis, interviews with industry professionals, and research on cutting-edge technologies. These approaches ensured alignment with current and future industry needs, creating a dynamic educational environment.

The course implementation focused on three modules: exploration for career paths, exposure to cutting-edge technologies, and development of a personalized professional portfolio. Feedback from teachers and students was mostly positive, highlighting benefits in personal and professional development. However, challenges such as overwhelming tasks and delayed feedback were noted, suggesting areas for improvement in future iterations.

The adaptive learning experience prepares students for a constantly changing world by promoting personal purpose, positive relationships, and adaptability. Future iterations should consider the importance of feedback, to enhance student participation and timely feedback, emphasizing the importance of comprehensive education encompassing technical, personal, and social aspects to support holistic development and successful navigation of life beyond university.

KEYWORDS | EDUCATIONAL INNOVATION, HIGHER EDUCATION, ADAPTIVE LEARNING, HUMAN FLOURISHING

1. Introduction

In the current context, characterized by a rapid pace of changes and constantly evolving technological advancements, the education of professionals in the fields of art and design emerges as a key imperative. The transformative influence of technology across all spheres of society, from industry to everyday life, underscores the need to equip these professionals with the necessary skills to face future challenges. This becomes even more crucial when considering speculative futures and education in the arts and design area, projecting the training of these future professionals towards the year 2050. In this time horizon, a more complex and changing landscape is anticipated, requiring future professionals to be equipped with adaptable skills, knowledge, and a mindset for continuous innovation and adjustment.

The objective of this research is to address the urgent need to equip students in these fields with the skills and competencies required to navigate an environment characterized by rapid technological and social changes. The general context of the designed adaptive learning experience was implemented as part of the final course in various technological professional paths of the Bachelor's Degree in Digital Arts at Tecnológico de Monterrey, State of Mexico Campus.

The rapid technological advancement poses an urgent need to adapt to it. Garry Bolles, in his conference "The Next Rules of Work" (2023), pointed out that what used to take a year in terms of technological progress in 2000, is now achieved in just a week in 2023. This phenomenon underscores the urgency of educating students according to the "next" rules of work: the Mindset, Skillset, and Toolset, as mentioned in his eponymous book. Additionally, Gary Bolles presents three possible scenarios for the future of work. In the first prospective scenario, automation and the increasing integration of robotic technologies dominate the workplace, leading to a scarcity of job opportunities. This situation, a result of the efficiency and productivity of technological innovations, leads to increased unemployment and challenges in wealth redistribution and job

retraining. There is a need for redefining economic and social structures to address these implications.

The second projected scenario outlines a landscape characterized by an abundance of job opportunities, where the intervention of robots and automated systems acts as a facilitator in the workplace. In this context, technological advances have triggered exponential job growth, to the extent that the demand for labor surpasses the supply of available human workers. This situation arises as a direct result of the efficiency and enhanced productivity that robots bring to industrial and service processes. Consequently, there is a growing dependence on technology in the creation and execution of work tasks, leading to a wide range of professional opportunities across various sectors.

In the third prospective scenario, according to Shoshana Zuboff (1988) in her work "In the Age of the Smart Machine: The Future of Work and Power," a labor duality emerges due to disruptive technologies, with elements of scarcity and abundance. Aspects of dystopia and utopia coexist, with an increase in job opportunities but also significant underemployment and unemployment. Adapting allows for thriving, while lack of adaptation leads to job failures and social exclusions. Strategies for training and flexible labor policies are needed to address this labor duality.

Due to the need to prepare future professionals to face the challenges of the future, an innovative design of adaptive learning experience was conceived, first implemented in 2023 as part of the final course in various technological professional paths at Tecnológico de Monterrey, State of Mexico Campus. This revolutionary pedagogical approach is based on the premise of enhancing human flourishing, comprehensively addressing students' cognitive, emotional, and professional aspects. The essence of this proposal lies in its threedimensional approach, represented by the key components of the Mindset, Skillset, and Toolset, declared as Gary Bolles' (2023) next rules of work.

Firstly, the mindset focuses on empowering the student to chart and explore possible career paths beyond the conventional limits of university, fostering a mindset of adaptability and continuous growth. On the other hand, the skillset focuses on validating and developing the skills acquired throughout university life, through the creation and refinement of a professional project poraolio. Finally, the toolset, composed of cubng-edge technological tools, provides the student with the necessary skills to navigate effectively in an increasingly digitized and dynamic work environment. At the same time, the design of this adaptive learning experience invites reflection on the impact of our actions in shaping the future we collaboratively create, aspiring to a scenario where no individual is lec behind and where future engineering professionals are adequately equipped to face upcoming challenges with confidence and resilience.

The comprehensive analysis presented in the 2023 World Happiness Report, issued by the United Nations Sustainable Development Solutions Network (2023), provides a complete view of well-being and happiness in various regions of the world, assessing a range of key factors such as per capita Gross Domestic Product (GDP), level of social support, and healthy life expectancy. This study represents an essential pillar for understanding the environment in which human flourishing is sought, serving as an essential guide to addressing challenges in promoting the overall well-being of society.

On the other hand, the relevance of human flourishing has been extensively examined in academic literature, emphasizing the urgent need to promote holistic well-being. According to Seligman and Csikszentmihalyi (2000), human flourishing encompasses the promotion of personal strengths, cultivation of positive relationships, search for meaning in life, and experience of positive emotions. These research findings highlight the importance of an education that not only focuses on preparation for the workplace but also aims at the primary goal of forming well-rounded individuals.

In this sense, holistic education not only focuses on imparting technical knowledge but also seeks to cultivate aspects such as happiness, physical and mental health of students. Human flourishing thus becomes a key objective of 21st-century education, promoting a holistic vision of personal and professional development. Student preparation for life becomes equally crucial, providing them with the tools and skills necessary to face everyday challenges with resilience and confidence, thereby contributing to a more prosperous and balanced society.

The rapid technological advancement, as Bolles (2023) points out, has become a key component in the design of adaptive learning experiences. This constantly evolving technological landscape demands that students acquire specific skills to tackle a future of constant change. This implies, as the author mentions, developing a Mindset that allows them to effectively manage changing challenges, a Skillset that empowers them to adapt to these changes, and a suitable Toolset for the digital era in which we are immersed.

The importance of these elements for designing an effective educational experience that fosters human flourishing and prepares students for future challenges cannot be underestimated. By integrating the Mindset, Skillset, and Toolset into the educational process, students are provided with the necessary tools to develop a sense of purpose in their learning, cultivate positive interpersonal relationships, and strengthen their personal and professional skills. This comprehensive combination of elements also enables them to effectively adapt to technological and social changes, preparing them to face current and future challenges with confidence and resilience. Despite the mostly positive results observed in the implementation of this adaptive experience, some limitations were identified that need

to be addressed in future iterations. In particular, the need for increased student participation and timely feedback was highlighted, as well as the importance of adapting the design to the different realities and contexts of university campi.

2. Methodology

The methodology employed for creating this adaptive experience preparing future professionals in arts and design was grounded in a multifaceted approach that incorporated historical analysis, interviews with industry professionals, and exhaustive research on current and cubng-edge technologies. This comprehensive approach was meticulously designed to ensure that the resulting educational experience was innovative and aligned with both the current and future needs of students and the industry.

Firstly, historical analysis provided a solid foundation for understanding the evolution of education in these areas and the challenges that have emerged over time. By studying past trends, key paferns and lessons were identified that helped inform the design of the adaptive experience. This historical analysis allowed not only an understanding of the current context of higher education in arts and design but also projected possible future scenarios and anticipated emerging needs of both students and the industry.

Additionally, interviews with industry professionals played a vital role in the methodology as they provided valuable insights into the skills and competencies that are most valued in the current work environment. These interviews helped identify the most relevant technical and soc skills for future professionals, as well as understanding emerging trends and areas of specialization that could be important in the future. Lastly, research on current and cubng-edge technologies provided a deep understanding of the tools and resources available to enhance the educational experience. By staying abreast of the latest innovations in technology, it was possible to effectively integrate them into the design of the adaptive experience, ensuring that students were exposed to tools and practices that are relevant and necessary in both the current and future work environments.

Together, this combination of methodological approaches allowed for the development of an adaptive educational experience that not only addresses the immediate needs of students but also anticipates the future demands of the industry. By integrating historical analysis, interviews with industry professionals, and research on current and cubng-edge technologies, a dynamic and relevant educational environment was created that prepares future engineering professionals for success in an ever-evolving world.

The implementation process of the course that included the adaptive learning experience was carried out meticulously and structured, focusing on the integration of three main modules, each designed to address one of the dimensions of Bolles' (2023) next rules of work.

The first module, titled "My Life Plan Beyond Tec", focused on the Mindset and sought to promote deep reflection among students about their post-graduation plans. Through this module, students were guided to explore a variety of career paths, from teaching to entrepreneurship, and were provided with advice and practical recommendations from professionals who had traversed those same paths before them. This approach allowed students to broaden their perspective and consider various options for their professional future.

During the "My Life Plan Beyond Tec" module, activities were designed to prepare students for their next path outside of university, aiming to develop a wide range of soc skills that are essential for success in the current and future job market. These skills are not only necessary for effective performance in the workplace but are also valued by employers and significantly contribute to the professional and personal development of individuals.

One of the key skills sought to be cultivated is self-awareness and management, which involves the student's ability to understand their strengths, weaknesses, values, and personal goals, and use this understanding to make informed decisions and effectively manage their own emotions and behaviors.

Additionally, fostering innovative entrepreneurship is encouraged, which involves the ability to identify opportunities, generate creative ideas, and effectively implement them, demonstrating initiative, creativity, and resilience in the face of challenges.

Furthermore, promoting social intelligence is sought, which refers to the student's ability to understand and manage their own and others' emotions, establish and maintain effective interpersonal relationships, and work collaboratively in diverse teams.

Another important skill sought to be developed is ethical and civic commitment, which involves acting with integrity, responsibility, and respect towards others, as well as contributing positively to society and the environment.

A cross-cubng competence that is sought to be promoted is reasoning for complexity, which involves the student's ability to analyze, synthesize, and evaluate information critically and solve complex problems creatively and effectively.

Effective communication is also a fundamental skill sought to be developed, as the student must be able to express their ideas clearly and persuasively, actively listen and understand others' perspectives, and adapt their communication style according to the context and audience.

Lastly, but not least, fostering digital transformation is sought, which involves the student's ability to effectively use information and communication technologies to access, analyze, interpret, and share information, as well as to adapt to technological changes and seize

the opportunities offered by new technologies. The second module, named "cubng-edge technologies," plays a fundamental role in the comprehensive approach of the adaptive learning experience, focusing on the Toolset aspect according to Bolles (2023). This module provides the student with a deep and updated understanding of emerging technological tools that are transforming the industry. It consists of lectures delivered by industry experts, including distinguished alumni and external professionals with experience in the field. These lectures allow students to firsthand learn about the latest trends and advances in socware and hardware technology.

In these interactive sessions, industry professionals address a wide range of topics related to cubng-edge technologies, from socware and application development to the implementation of innovative hardware and the implications of artificial intelligence and machine learning. In addition to presenting concrete examples and relevant case studies, experts highlight the importance of staying abreast of the latest trends and advances in technology and provide practical advice on how the student can stay updated and develop relevant skills for the ever-evolving job market.
Particularly emphasized is the need to acquire specific technical skills related to cubng-edge socware and hardware tools, as well as the importance of developing critical thinking, problem-solving, and adaptability skills to tackle the challenges posed by rapid technological innovation. Additionally, topics such as cybersecurity, data privacy, and ethics in technology are discussed, highlighting the importance of addressing these aspects responsibly and ethically in the development and implementation of new technologies.

The third module, named "Professional Poraolio," constitutes an essential part of the adaptive learning experience approach, focusing on the Skillset aspect as proposed by Bolles (2023). This module was carefully designed to adapt to the specific needs and professional goals of each student, recognizing that each individual possesses a unique set of skills, experiences, and professional aspirations. From the beginning, a flexible structure was established to allow the student to personalize their learning experience and develop a poraolio that accurately and meaningfully reflects their strengths and areas for development.

During the first week of the module, a comprehensive assessment process was carried out to validate the competencies acquired by the student throughout their professional career. This process focused on identifying the technical, cognitive, and soc skills that the student had developed during their academic training and previous experiences. Based on the results of this assessment, each student's career integrator project was adapted to address specific areas for improvement and provide opportunities to demonstrate their level of competence in various areas.

One of the main goals of this module was to create awareness in the student about the

competencies and soc skills they had acquired throughout their professional career. To achieve this goal, activities and reflections were implemented that allowed the student to identify and value their interpersonal skills, problem-solving ability, leadership, and teamwork, among others. Additionally, the importance of these skills in the current job market was emphasized, and resources and guidance were provided for their continuous development. The research was carried out using a convenience sample, consisting of students to whom the researcher was assigned as co-teacher.

Data was primarily collected through a opinion survey conducted by students each semester, a focus group with implementing teachers to assess the understanding of the design, and a semi-structured survey of the students themselves to gain a more detailed insight into their experience acer completing the experience. Acer data collection, a qualitative analysis was conducted to extract meaningful conclusions. This methodological approach allowed for the design of an adaptive educational experience that not only addressed the immediate needs of the student but also anticipated the future demands of the industry, thus preparing them for success in a constantly changing world.

3.Results

The results obtained from the implementation of the adaptive learning experience revealed a mostly positive reception from the teachers, who expressed having gained valuable insights for future training instances. According to the analysis conducted by the academic communities board and the questionnaire applied, there was a notable interest in the integrative project modules and cubng-edge technologies. However, it was identified that some of the adaptive activities might be overwhelming for certain students, as not all campuses offered the same level of choice flexibility.

Regarding the first module, focused on life beyond university, it was evident that in some implementations, it was not executed according to its adaptive approach. For example, in certain campuses, tasks related to creating resumes and cover lefers were assigned as part of this module. Upon investigating students' experience in relation to the university's purpose toward the 2030 vision of preparing students for life, a perception of lack of comprehensive preparation to face the challenges of the job market was found.

In contrast, in other campuses where the design was implemented as planned, the purpose of the module was achieved thanks to continuous support and feedback provided by the teachers, which gave students the necessary freedom to explore their interests and make informed decisions about their future. Some students expressed that this module encouraged them to question their goals and aspirations, facilitating clearer and more authentic decision-making.

In the second module, focused on cubng-edge technologies, conferences were held with industry experts who shared their experiences and tools used in the professional field. This allowed students to understand the importance of tool knowledge and the need for lifelong learning. Although some conferences were perceived as beneficial, other students felt that they took away time from developing their integrative project.

Regarding the third module, "Professional Poraolio," most campuses implemented it as planned, resulting in high-quality projects. However, in some cases, students were asked to submit a preliminary version of their poraolio as part of the initial diagnostic process, allowing for the assessment of achievement levels and the establishment of strategies for their development.
One of the aspects that possibly affected some implementations was the lack of timely feedback, as well as waiting until nearly the end of the course to request activities.

4.Conclusions

The study conducted highlights the relevance of preparing students not only for the workplace but also for facing life's challenges in a constantly transforming context. The adaptive learning experience proved to be highly beneficial in promoting personal purpose, cultivating positive interpersonal relationships, strengthening soc skills, and efficiently adapting to the technological and social changes that characterize the contemporary world. The implementation of this educational design closely aligns with the constantly evolving vision of the university where it was implemented, which aims to foster leadership, innovation, and entrepreneurship as key pillars for the holistic human development of its students.

It is important to note that future iterations of this adaptive experience should carefully consider the feedback and suggestions received during the initial implementation. This approach will ensure greater participation from students and allow timely feedback that contributes to the continuous improvement of the program. Likewise, there is an emphasis on the need to promote greater awareness and understanding of the importance of comprehensive education that encompasses both academic and personal, emotional, and social aspects.

Furthermore, it is crucial to design specific strategies to support students' holistic development, providing them with the tools and resources necessary to successfully face the challenges they will encounter in their life outside of university. This entails not only strengthening technical and cognitive skills but also fostering autonomy, resilience, and critical thinking, which are key aspects for their personal and professional growth.

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“DECONSTRUCTING THE TRADITIONAL BOUNDARIES OF THE AUTOMOTIVE SYSTEM THROUGH THE RECYCLING OF COMPOSITE MATERIALS IN THE DESIGN AND PRODUCTION OF THE FUTURE CAR”.

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ABSTRACT | The automotive sector is one of the most environmentally impactful contexts, not only in terms of the car production chain, but also in the use phase, which is still associated with the consumption of fossil fuels. The type of materials used also contributes to its overall impact. However, what happens when eco-design is followed in the automotive scenario, deconstructing traditional boundaries of design and production phases, and embracing the circular economy approach? Experimentation in bio-based materials and the recycling of high-performance materials is developing a broad strand of research. Therefore, investigating consumer perceptions of sustainability in the automotive industry is crucial. Although the demand for products with a low environmental impact lifecycle is steadily increasing, in the automotive context the research for sustainable solutions has to deal with other priority requirements, such as mechanical performance, fuel consumption, etc. The requirement of environmental sustainability often remains secondary. This contribution aims to present the research conducted by the Department of Applied Sciences and Technologies of the Polytechnic University of Turin (Italy), which explores new possibilities of recycling carbon fiber and glass fiber-based composite materials, which, for the same performance, can be reintroduced circularly in the production of new components, to contribute to the reduction of emissions by 2030. The ultimate goal is to design a systemic scenario based on the recycling of composite materials in the automotive industry, in which the user will be able to ‘drive sustainability’, expanding the boundaries of what the car product has identified until now.

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KEYWORDS | CAR SYSTEMS, ECODESIGN, RECYCLED COMPOSITE MATERIALS, AUTOMOTIVE SUSTAINABILITY, CIRCULAR ECONOMY

1. Introduction

1.1 The impact of the automotive sector and the value of material selection

Nowadays the automotive sector contributes significantly to the social well-being of several urban and peri-urban areas of the world, as it allows the rapid mobilization of one or more individuals and the reaching of more or less distant destinations with comfortable methods and less effort, compared to the past. This industrial product, of intricate design and production, has been able to modify the lifestyle of entire communities enormously and, at the same time, the structure of cities and neighborhoods, encouraging the development of districts and outskirts, in this way not more isolated from the workplaces, health services, places of leisure, etc. (Handy, 2005; Jacobs, 1961).

Therefore, the car has also changed the urban infrastructure, requiring the planning and construction of roads, highways, parking lots, etc. However, the complex production and supply chain of current cars is progressively leading to negative environmental and social impacts, such as air pollution and climate change, due to the constant extraction of resources, the consumption of fossil fuels, and the consequent emission of greenhouse gasses (Levente, 2021; Hawkins, 2012).
In the past, the research for sustainability in this production field has focused exclusively on the use phase of the motor vehicle rather than on its entire life cycle. This direction was motivated by the fact that the use phase represents a key point in terms of economic impact on the end user and energy consumption (Traverso et al., 2015).

These elements, added to the increase in crude oil prices and the introduction of stringent limits for vehicle emissions, have led to a growing interest in the design and production of more efficient and less impactful cars on an environmental level, influencing consumer purchasing choices. Automotive companies have thus expanded their research into the materials sector,

with a specific focus on very light materials, capable of reducing the overall weight of the car and improving its efficiency during use. In this, Automotive Design has played a significant role, in particular for its ability to study and design aerodynamic shapes, as well as Materials Technology. Currently, however, to reduce the environmental impact of the automotive industry, the focus extends to the entire life cycle of the product, also contemplating the impact of the extraction of raw materials, the production of materials and components, the assembly and manufacturing of the car, of its disposal at the end of its life. In the automotive production chain, the selection and processing of materials is a fundamental phase that consistently contributes to the level of sustainability of the finished product, its use, and its end of life. Nevertheless, it is good to point out that a material is also characterized by its own life cycle and, therefore by its ecological burden (Lanzavecchia, 2000). For this reason, a growing interest has emerged in the use of less energyintensive materials, secondary source materials (generally composite, thermoplastic, and metallic materials), and biobased materials, to facilitate the recyclability of components at the end of their life and a reintroduction of recycled materials into the production chain.

In this scenario, the tools and approach of EcoDesign, and in particular of Systemic Design, are fundamental for considering the entire life cycle of the car upstream, up to evaluating the methods that can facilitate the recycling of its technical components, once decommissioned. Furthermore, these approaches can support the analysis of the complexity of current supply chains and their impacts, facilitating the development of future predictive scenarios, to trigger a change in production models starting from the design of more sustainable products, in their complexity. In this context, the research conducted by the Department of Applied Sciences and Technology of the Polytechnic of Turin (Italy) was born, which intends to explore new possibilities for recycling composite materials based on Carbon-Fiber and Glass-Fiber (S.R. Naqvi et al., 2018, Chen et al., 2019), which with the same performance can be circularly reintroduced into the design and production of new components of the car, to contribute to a 50% reduction in emissions by 2030.

1.2 The high-impact linear production processes of Carbon Fiber and Glass Fiber used in the Automotive Sector

The present project intends to contribute to the decarbonization process through the awareness of the composition and impacts of a set of innovative materials for automotive applications. Specifically, the project assesses the impact in terms of carbon footprint of the production of carbon fibers and glass fibers.

Carbon fiber is a fibrous material with a carbon content of more than 92 %wt [Huang, 2009]. The atomic structure of carbon fibers consists of carbon atoms

organized in hexagonal structures. These fibers have interesting characteristics in terms of mechanical strength as well as electrical and thermal conductivity [Huang, 2009], making them an attractive material in various industrial fields, such as aerospace, sports (suits, shoes, frames), and automotive. Currently, about 90% of commercially available carbon fibers are produced from polyacrylonitrile (PAN), a polymer derived from oil exploitation. The traditional process consists of three main steps: spinning, stabilization, and carbonization (Figura 1). The first consists of treating the starting compound, called precursor, to obtain a raw filament product. The latter is then treated with oxygen in a furnace between 200 and 400 °C, and then passes into the stabilization phase, to stabilize the fiber. Subsequently, the filament undergoes gradual heating in a no oxygen atmosphere, up to a temperature of 1000 °C, to remove all non-carbon from the fiber surface [Huang, 2009].

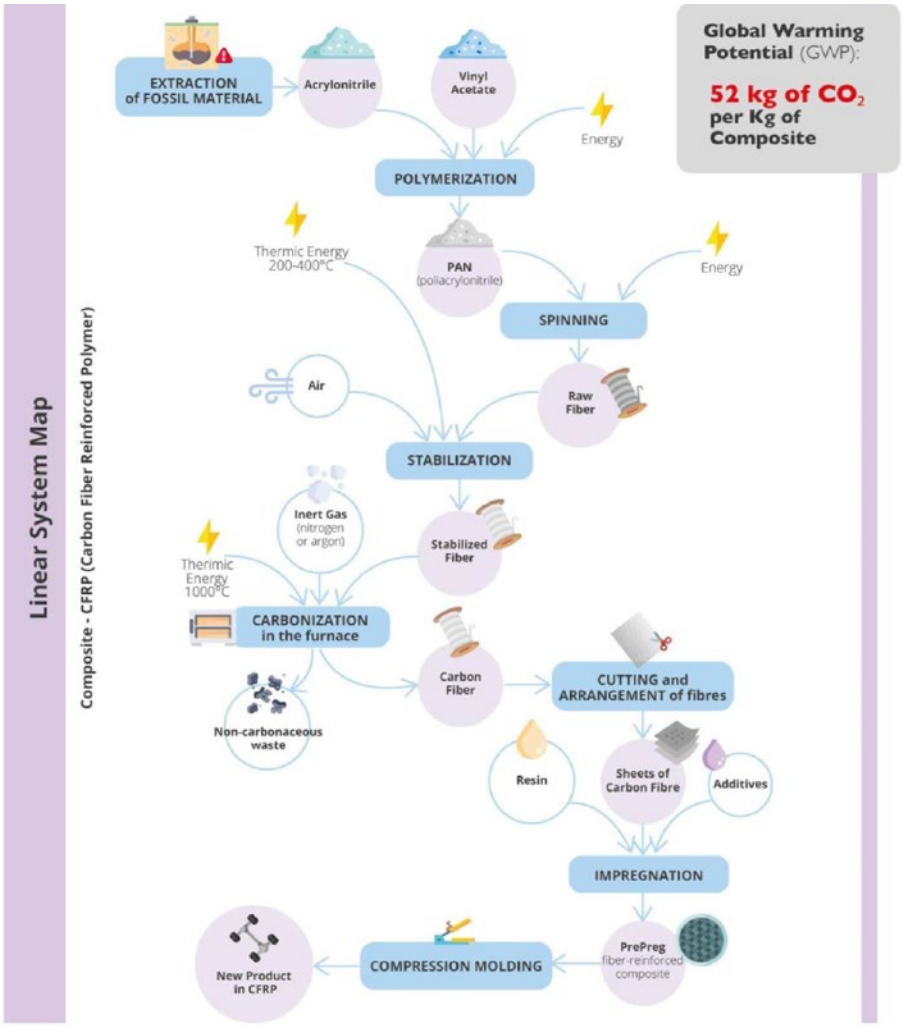


Figure 1. Design of the graphic map of the high-impact linear production system of Carbon Fiber, evaluating inputs and outputs through the Holistic Diagnosis phase described in the methodology.

The conventional carbon fiber production process is critical in terms of the cost of the precursor, which accounts for 53% of the total process [Le et al., 2022], and does not guarantee the sustainability of the process itself, since polyacrylonitrile is a fossil polymer. Consequently, it becomes necessary to focus on the choice of raw material that will be transformed into fiber, thus proceeding to a change of compound, preferring a bio-based precursor (lignin, cellulose), or implementing the use of recycled carbon fiber.

The main application of carbon fibers in the industry is their use in composites with a polymer matrix (epoxy resin, PP, PA6, etc.), defined as a 'fiber-reinforced polymer composite' (FRPC). Specifically, carbon fibers constitute 'carbon fiber reinforced plastic' (CFRP) with percentages between 30-60%wt. These composites are widely used in the aerospace, renewable energy (wind power), and automotive sectors, due to their high mechanical strength, high stiffness, and good corrosion resistance. In addition, they exhibit low density, making them a suitable candidate as a substitute for steel parts in chassis, in the context of weight reduction in cars, with a consequent saving in fuel consumption and thus environmental impact [Das, 2011].

The lifecycle of CFRP is 15 to 20 years [Chen et al., 2023], and considering an increase in the use of this material, attested by the passage from 28,2 to 48,7 billion dollars of global revenue from the sale of CFRP in 2020 [Karuppannan, Karki, 2020], makes the issue of the treatment of the composite at its end-of-life preponderant to avoid the intensification of the environmental impact of the production chain. As a consequence of this, the multidisciplinary research group of the Politecnico di Torino focused on the recycling treatment of the carbon reinforced composite, considering it interesting to search for a recycled treatment that would guarantee both sustainability and adequate mechanical properties to the fiber. In particular, pyrolysis (thermal degradation without oxygen) has been chosen as the best way of treatment, because the fiber recovered has mechanical properties similar to virgin fiber's ones and it does not request a high energy to operate at a commercial level.

Glass fiber is a fibrous material generally consisting of silica, used in several industrial applications, and can be classified into different categories according to its chemical composition and consequently its technical characteristics. A common application is within composites with plastics, to strengthen thermal resistance, gas penetration, and impact resistance. According to the EuCIA (European Composites Industry Association), 95% of the FRPC trade is for glass fiber composites (GFRP). These composites are used in many industrial sectors, such as building, electrical and electronics, transport, production of renewable energy (wind), etc. Their life cycle is around 20-25 years and the estimated waste production of GFRP in 2025 will be 80,000 tonnes from the transport sector only, including the automotive one. This is the third contribution to overall waste production, behind the building industry and electronic sector. In addition, the increase of waste glass fibers due to the development of a growth sector such as wind energy production should not be underestimated, as blades are made of

62%wt GFRP [Gonçalves et al., 2022].
In the automotive sector glass fiber composites are implemented in internal components such as center stack retainer, pull handle, console reinforcement etc. The cost of virgin glass fibers is around 1,20-1,90 €/kg, while carbon fibers cost 105 €/kg in the highest quality cases [Naqvi et al., 2018]. This significant price difference means that the valorisation and disposal costs of glass fiber waste are crucial in seeking to implement an improvement in waste management. As a consequence of the low cost of raw materials for virgin glass fibers, mechanical recycling is the most widely used process to recycle, reducing the size of composites through a grinding machine. The resulting mill is composed of resin, fiber, and possible filler, which are separated by gravity (Figura 2). It has several advantages such as industrial scale-up, low environmental impact, and cost-effectiveness, but It causes a significant degradation of fiber that will not be used in the same components as a virgin material. In this project we evaluate the impact of mechanical recycling compared to the traditional process of manufacturing glass fiber composite.

With a view to applying the Circular Economy to the production system of materials used in the automotive sector, in the following paragraphs the design methodology applied in the explored research project will be described and the experiments carried out with a view to recycling materials and producing new components of the car starting from greater sustainability of the system.

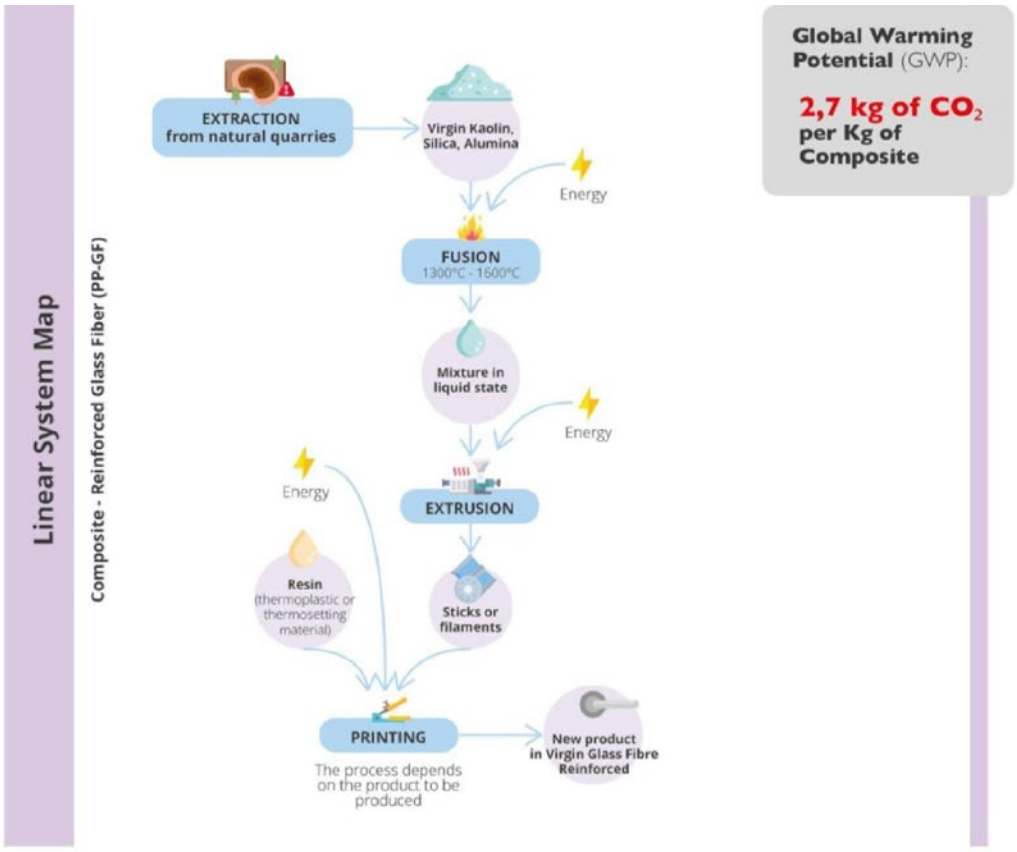


Figure 2. Design of the graphic map of the high-impact linear production system of Virgin Glass Fiber, evaluating inputs and outputs through the Holistic Diagnosis phase described in the methodology.

2. Methodology

2.1 The EcoDesign approach in the methodological path undertaken

For the general development of the project, the typical EcoDesign methodology was followed, with a specific focus on systemic design. EcoDesign is an ecological approach applied to the design of products, structures, architectures, technologies, industries, and processes, aimed at bridging the gap between sustainable ecological systems (therefore what is part of the great system of Nature) and artificial human scenarios (thus what has been designed, produced and created by man to develop his contemporary lifestyle). For this reason, the EcoDesign principles reflect the organizational ones that Nature has always used to support life. Adopting the EcoDesign approach requires first of all a change of cultural, design and production paradigm (Capra & Luisi, 2014). It overcomes the linear production model (Take-Use-Dispose)(Ellen MacArthur Foundation, 2012) whose objective is to exclusively exploit natural systems for the constant extraction of resources, in order to develop new design and production strategies that look to Nature as a model, measure, and guide and try to understand how to cooperate with it, rather than dominate it (Benyus, 1997).

For simplicity, it is possible to summarize two large macro-categories, intrinsically connected, into which EcoDesign is dissected:

- the recycling of elements, materials, and waste products mainly within the production chains, where further specific approaches are used that are compatible and complementary to those of eco-design, such as the Systemic Design and Circular Economy approach;

- the sustainable design of products, structures, processes, architecture, and even cities, giving space to Design by Components or the development of EcoCittà and Green Architecture which follow the Biomimicry approach, according to which many human problems have already been largely solved by other living organisms present in Nature.

At the basis of these approaches is the key principle of ecology (Commoner, 1971) according to which nature knows no waste, therefore every manufactured product, every transformed material and all industrial or domestic output produced must necessarily become a form of nourishment for others systems, compatible with the first pillar of Systemic Design, according to which the outputs of a system must be valorized as inputs of another system (Bistagnino, 2011). This form of nourishment depends on the type of metabolism (biological or technical) in which a working group operates. In the case of production chains such as the automotive

one, the outputs are considered real technical nutrients, i.e. all those non-biodegradable elements that belong to industrial cycles and which consequently cannot be metabolized by other living organisms, as instead happens in biological metabolisms (e.g. composting or fermentation processes) (McDonough, 2013). A technical nutrient is designed to be part of a technical cycle, therefore its recycling in the industrial field is profoundly different from other types of ordinary recycling (such as domestic recycling), as it is necessary to preserve the high intrinsic quality of the material, which must undergo reduced levels of contamination and degradation.
In this research the discipline of EcoDesign met that of Chemical and Environmental Engineering and that of Materials Technology, developing a technical methodology in which the evaluation of environmental impacts is fundamental.

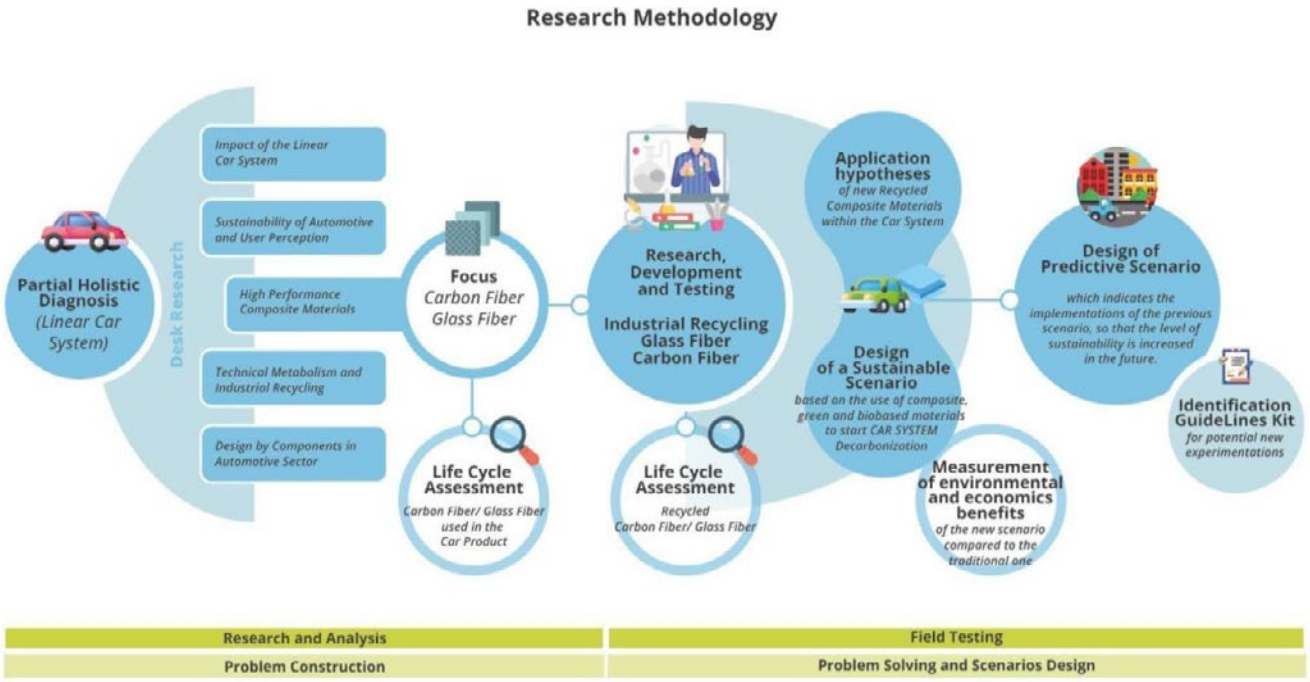


Figure 3. The methodology followed in the research undertaken for the application of circularity to the car system: the complementarity of EcoDesign and LCA approaches and tools

The starting point was the development of a partial Holistic Diagnosis of the car's high-impact linear system (Figura 3). Considering the complexity and breadth of this system and the choice of predefined materials (Carbon Fiber and Glass Fiber), only the car components made of these materials were considered, but it was also useful to evaluate those which, although produced in different materials, they could potentially be produced with study materials, in the future.

Through desk research, the generic environmental impacts of the motor vehicle and the perception of sustainability in the purchasing decisions of a car by the end user were investigated. Furthermore, the existing scientific literature on traditional production models of carbon fiber and glass fiber and their recycling possibilities was examined. Finally, considering the technical metabolism to which the automotive supply chain belongs, the potential of Design for Components (Felfernig et al., 2014) in the Automotive sector was explored. The latter is an approach adopted upstream in the design of a product, in order to facilitate its disassembly at the end of its life cycle, the recovery of materials and components, differentiation according to materials and, in cases of reconditioning, the replacement of specific damaged components. It is therefore fundamental in the case of complex multi-material products, especially if the objective is to extend their life cycle and/or that of the materials used in them.

The second fundamental step was carrying out the Life Cycle Assessment of Carbon Fiber and Glass Fiber currently used in the automotive sector, which supported the start of the phase of concrete experimentation and the development of recycling techniques for these composite materials. The objective will be to develop a new LCA on new materials obtained from the recycling process to evaluate the benefits of using the latter in the same sector, as well as in others.

Subsequently, specific hypotheses for the application of the new circular materials to the car system will be developed, designing a more sustainable scenario based on the recycling of composite materials to contribute to the process of decarbonization of the car product. In this way, it will be possible to compare the new scenario with that emerging from the Holistic Diagnosis of the high-impact linear system.

To conclude, the last step involves the design of a predictive scenario that can indicate the necessary implementations of the project, so that the level of sustainability achieved is expanded, also considering additional factors in addition to decarbonization (e.g. water footprint, social sustainability, etc.). In this sense, a kit of guidelines will be developed for new potential experiments not only in the sector of the materials investigated, but also in the use of further materials explored by the Polytechnic of Turin, such as bioplastics, lignin, hemp, and the use of low impact alternative batteries.

2.2 The role of Life Cycle Assessment in ongoing research

As already mentioned, within the methodology followed, the evaluation of the environmental impacts of the life cycle of the materials investigated was a key element. In detail, the Life Cycle Assessment (LCA) is an international standardized methodology (ISO 14040-44) adopted to evaluate the environmental impacts of products, processes, and services. The assessment

encompasses all stages from raw material extraction through materials processing, manufacturing, distribution, use, repair and maintenance, and disposal or recycling. The study of Life Cycle Assessment (LCA) in the automotive sector plays a crucial role in evaluating and reducing the environmental impact of vehicles throughout their entire life cycle. LCA can quantify the vehicle's environmental impact from the raw material extraction phase, through production, use, and disposal, by identifying the life cycle stages with the highest environmental impact. This stage represents the bottleneck and requires to be reduced to decrease the whole environmental impact associated with the investigated product, process, and services. Currently, the key actions taken by the automotive sector include optimizing materials and resources to design vehicles with lower environmental impacts across various impact categories and contributing to the decarbonization of vehicles in their whole life cycle. Specifically, the optimization of materials and resources for vehicle design involves two fundamental points: 1. material recovery and recycling and 2. optimization of production processes. Material recycling involves studying the life cycle to improve the recycling of vehicle components, reducing waste, by enhancing material efficiency and preventing resource consumption (Del Pero et al, 2018). Optimization of production processes identifies energy-intensive production stages and develops strategies to reduce energy consumption and emissions, like for instance considering alternative and renewable energy or increasing efficiency. For automotive companies, the LCA represents a credible tool for clear and transparent communication of their commitment to environmental sustainability to stakeholders (customers, regulators, investors). Environmental studies based on LCA can support marketing strategies and corporate social responsibility initiatives. Information obtained from LCA supports strategic decisions regarding research and development, new product design, and supply chain management. Companies can make informed choices to improve the overall sustainability of their operations.

In the present study, the LCA aims to evaluate the impact of the processes of manufacturing traditional composite and composite made of recycled fiber, either for glass and carbon fiber.

This comparison is based on global warming potential (GWP) ($kg_{CO2}/kg_{Composite}$). For the production process of composite from virgin fiber, we will analyze production "from cradle to gate", meaning that we consider the production system from the raw materials to the composite ready for the application stage in the car. The production system of recycling process is evaluated "from grave to gate", so from the composite at the end of its life to another composite ready for the use phase (Gregson et al., 2015; Braungart et al., 2007; Hauschild et al., 2005),. The scope is increasing use of materials from circular economy processes in the overall design of automotive production chains. In this sense, we aim to contribute to the general

sustainability of the car product, acting on the steps that precede the use phase and which do not have direct contact with the end users, although they can influence in them purchasing choices.

3. Results

3.1 The recycling of Carbon Fiber and Glass Fiber as a process to increase the level of decarbonization of the cars of the future

As mentioned in the previous paragraph, the first phase of analysis of the methodology undertaken involved carrying out the Life Cycle Assessment of the materials analyzed in order to evaluate the current environmental impact of carbon fiber and glass fiber in the traditional car product.

Specifically, concerning results of LCA for carbon fiber, the amount of carbon dioxide released into the atmosphere from the production of the composite from virgin carbon fiber is 52,4 kg CO2 eq. The process of treating CFRP to obtain rCFRP releases 11,4 kg CO2 eq into the atmosphere. In the carbon fiber production process, the carbon dioxide impact of the initial compound is considerable, as it accounts for around 53% of the total. This is due to the use of raw material of a petroleum nature, but above all also due to the energy-intensive nature of the process, as the high energy required to produce one kilogram of carbon fiber, a value that is also consolidated in the literature [Chen et al., 2023]. As far as the composite calculation is concerned, carbon fiber plays a greater role than epoxy resin. On the other hand, the carbon footprint of the thermal recycling treatment of CFRPs is mainly dependent on the energy required for pyrolysis process and on the impact related to the use of new epoxy resin to produce composites from recycled fiber. The latter is the raw material that can be considered as the main contributor to the environmental impact of the recycling treatment. Possible process improvements to reduce the CO2 release are the possibility of exploiting the pyrolysis gas, initially by trying to recover possible condensable compounds that together with a liquid phase produced by pyrolysis (not considered in this first analysis) can constitute a compound comparable to a resin of a phenolic nature [Quan,2010].

To evaluate possible improvements of the process, experimental tests were conducted on the pyrolysis of a carbon fiber composite to evaluate the products obtained, analyze them, and hypothesize energy and chemical enhancement solutions. Experimental tests designed showed the excellent recovery of carbon fiber from the composite, with the production of a gas phase and an oil component (Figure 4). These two phases are composed of all those molecules resulting from the degradation of the resin present in the starting composite. The gas phase was analyzed, showing the increased presence of compounds such as hydrogen and methane, making it actually interesting from the point of view of energy utilization for the purpose of powering the recycling process itself. The oil phase has compounds called "phenols," which

have various applications in industry, from nylon production to cosmetics. Moreover, the presence of such molecules in the oil phase is also attested in literature [Quan, 2010].

To better trace the qualitative comparison between the traditional production systems of the investigated materials and the circular systems experimented with their recycling and reuse in the automotive sector, graphic relational maps (generally typical of Systemic Design) were developed. Indeed, through a graphic representation, understanding the inputs and outputs of both processes, as well as the different phases used in them, is more immediate.

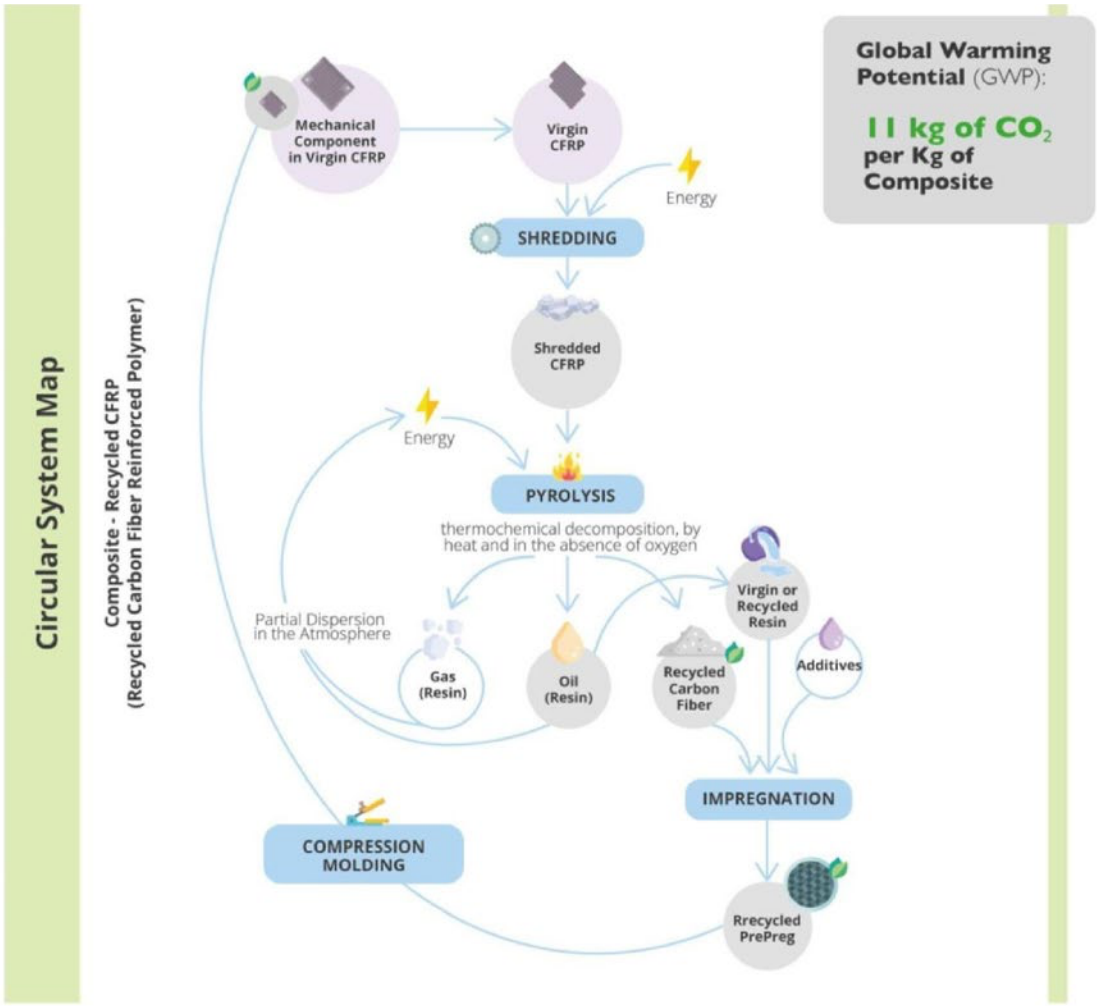
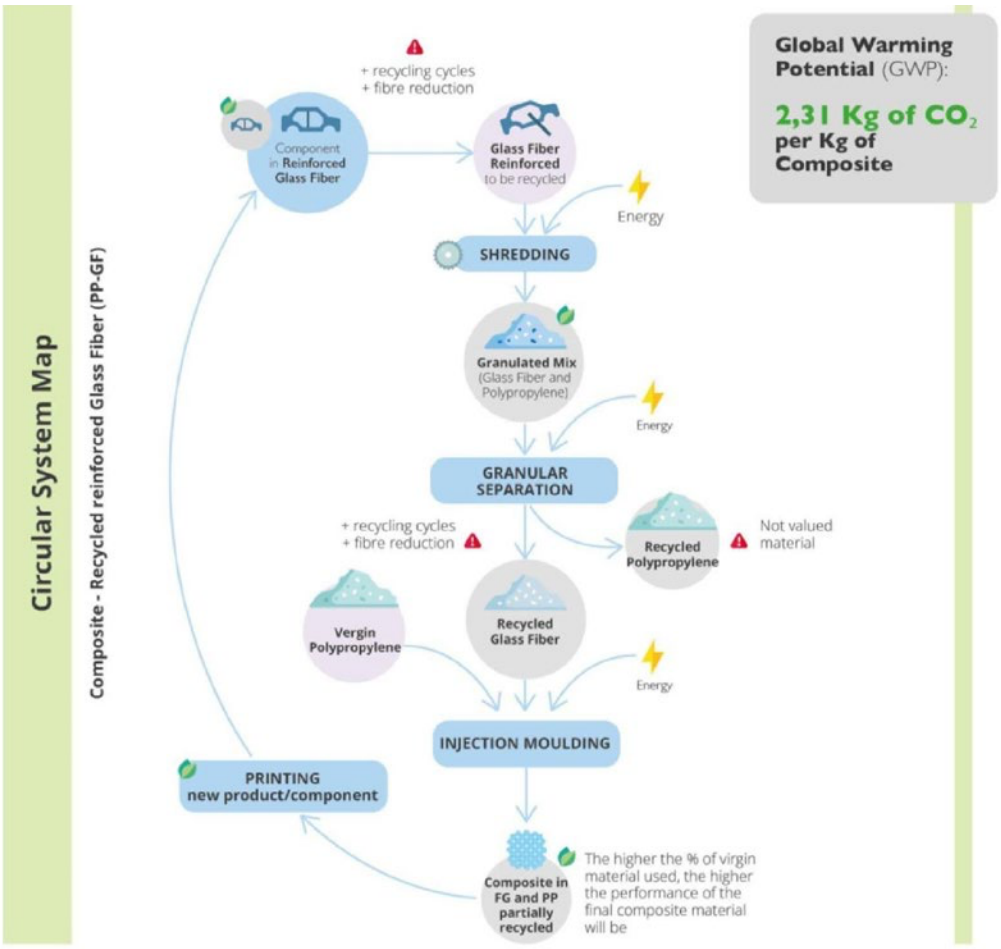


Figure 4. Design of the graphic map of the circular production system designed, experimented and tested for the Carbon Fiber Composite. Inputs and outputs reintroduced into the system were evaluated.

The same evaluation and design process for new recycling processes was also carried out for glass fiber. The amount of carbon dioxide released into the atmosphere from the production of glass fiber composite (GFRP) is 2,7 kg CO2 eq. Instead, the alternative process of grinding GFRP and re-moulding recycled glass fiber with virgin fiber and polypropylene releases 2,3 kg CO2

eq into the atmosphere (Figure 5). The main contribution to the carbon footprint of the composite with only virgin fiber and with the virgin/recycled blend is given by polypropylene (respectively 59 and 65% of the total GWP calculation). There is a difference between the two processes: the recycling process is less impactful than the traditional one, but this is not so wide. It could be a consequence of not reusing the polypropylene from the mechanical separation by grinding, stressing the concept of consumption. The mechanical recycling process of composites can be improved through the above-mentioned reuse of recovered polypropylene, but also by considering a higher percentage of recycled fiber within the composite. Consequently, a further project could be the evaluation of all the blend options proposed by Kang et al. (2021), including the use of long glass fibers, both virgin and recycled. To assess the consistency of the work carried out, it is interesting to compare the results obtained with what can be found in the literature. As far as the modeling of the traditional process is concerned, the GWP related to the traditional production of GFRP is around 3-5 kg CO2 eq, thus in line with what was calculated through this analysis [Rajendran et al.,2012] [Reichenbach et al.,2021]. In fact it is necessary to consider that the process of recycling and producing a composite has one more step compared to the traditional one, namely the



mechanical treatment, which, by its nature, requires the use of energy.

Figure 5. Design of the graphic map of the circular production system designed, experimented and tested for the Glass

Fiber Composite. Inputs and outputs reintroduced into the system were evaluated.

To conclude, it is possible to assert that the mechanical performances, properties of the composite made from recovered carbon fiber are about 90%, compared with the composite made from virgin carbon fiber [Chen et al., 2023]. To prove this, experimental mechanical stress tests will be conducted in the future in order to have direct data. Also regarding glass fiber reinforced composite, the formation process of the composite made from the recycled fiber was modeled in order to have mechanical properties not less than 90% of those of the virgin fiberreinforced composite. The blend (recycled fiber + virgin fiber) that allows the composite to meet this standard is at 60:40 (wt%). This choice has been made by taking in consideration a similar study conducted by Kang et al. (2021), where the authors tested blends of virgin mixes (glass fiber + polypropylene) with recycled ones. In this case we model a blend of virgin and recycled glass fiber with virgin PP. For these reasons, investing in the recycling of these composite materials is an important direction to achieve greater levels of sustainability of the vehicle.

Considering that they are adequate to offer good structural resistance and durability, comparable to virgin fiber in many cases, some application hypotheses have been presumed in the automotive system to reduce the overall weight of the macro-product, increasing efficiency in terms of speed, emissions, and fuel costs. It has been estimated that recycled carbon fiber composite can be used in some components of the external bodywork of the car, such as the bonnet, bumpers, and doors, and other internal components, such as the dashboard, the internal structures of the seats, defined as underbody sections and frame, handles, etc. Complementarity, the recycled fiberglass composite can be used to cover side mirrors and grilles, which, in addition to requiring a weight reduction, need excellent resistance to atmospheric agents. However, it can also be used in the production of the center console and trunk linings, acoustic/thermal insulation panels.

3.2 The uses of EcoDesign for a more sustainable Automotive System

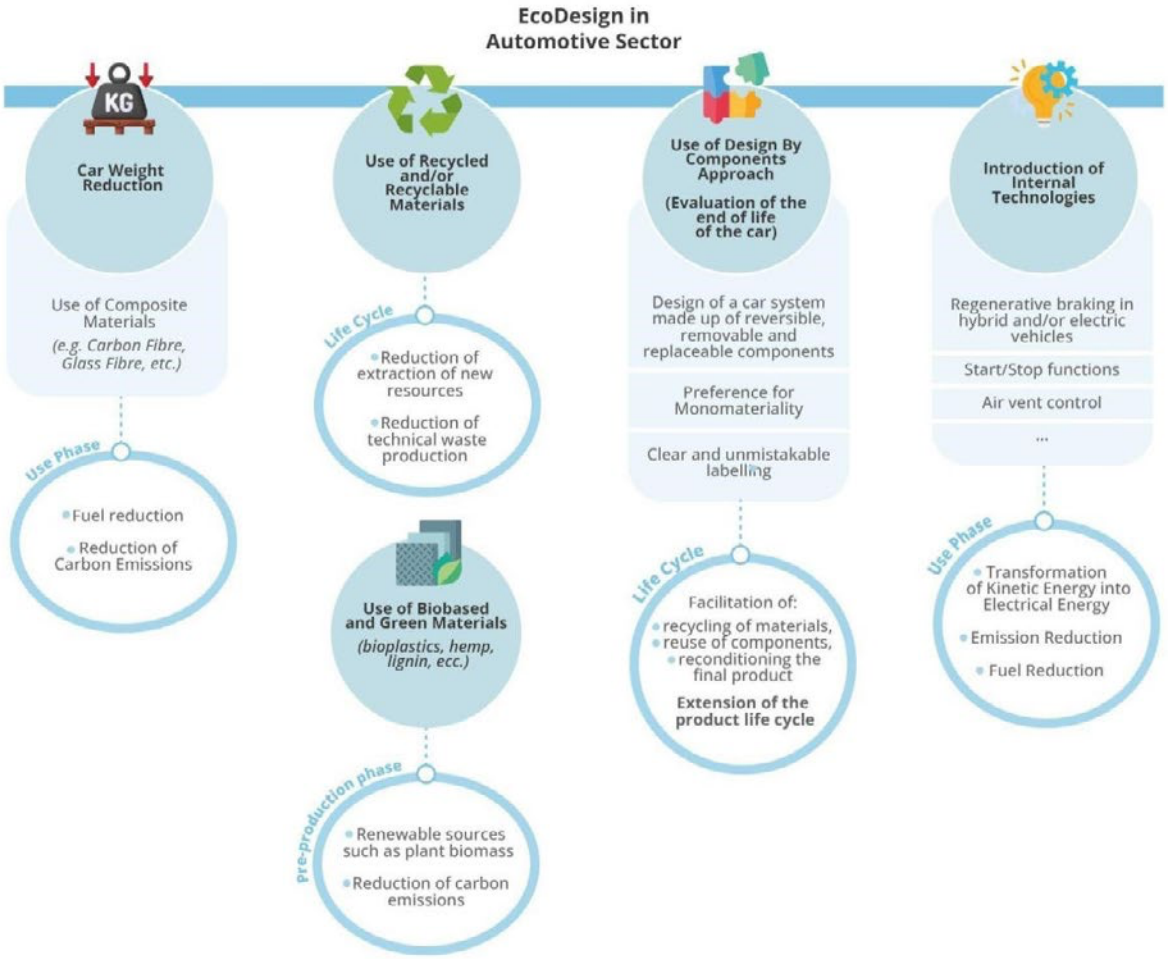


Figure 6. Applications of EcoDesign Approach in the Automotive Sector

Designing products with a minimum weight, by reducing the quantity of materials used and through the use of lightweight, high-performance, and durable materials at the same time, is a challenge that does not only belong to the automotive sector but in general to any market segment who wish to design and produce sustainable and easy-to-use everyday products. The scenario of increasingly lighter products (to the point of reaching dematerialisation) and with a reduced ecological burden is also increasingly requested by consumer communities. In the case of extremely complex products that require numerous components, some of which are characterized by high thicknesses and metallic materials, good eco-design is fundamental. This is the case of the car system, which increasingly requires a change in the design of its life cycle. In this project, fundamental guidelines have been drawn up which, through the adoption of the EcoDesign approach, can lead to the production of increasingly green cars, not only in terms of decarbonisation (Staniszewska et al., 2020), where the requirement of a correct choice of materials remains imperative.

These guidelines can be summarized in (Figure 6):

- Reduction of the overall weight of the car, through a formal and functional design of its components and the use of highly performing composite materials characterized by a low specific weight, such as carbon fiber and glass fiber. The reduction in weight, in fact, allows to reduce the need for fuel during use phase, consequently minimizing the emissions produced.

- The use of recycled and/or recyclable materials, coming from the automotive production chain (closed system) or other supply chains (open system), in order to decrease the extraction of new resources and the disposal of difficult-tomanage technical waste.

- A significant growth in the use of green materials and/or biobased materials, coming from renewable sources such as plant biomass, to reduce the extraction of resources from fossil sources. An example of these materials are hemp, lignin, and the entire family of bio-polymers, characterized by a less impactful life cycle.

- The adoption of Design by Components as a design approach, although considered upstream in the life cycle of a car, allows for efficient and sustainable actions at its end-of-life. The design of a system characterized by reversible, removable, and replaceable components, distinguished as much as possible by monomateriality and clear labeling, would greatly facilitate the recycling of materials used in the automotive system and their reintegration into the same or other production chains, thereby extending the life cycle of both the materials and the vehicle itself (also overcoming the barrier of planned obsolescence).

- Finally, the adoption of technologies inside the car capable of strategically reducing emissions and fuel use during use (a good example could be the design of regenerative braking, in the case of electric cars, useful for transforming energy kinetics into electrical energy to power the batteries).

These design directions demonstrate the fundamental role of the eco-designer in the preproduction phase of a product's life cycle. The eco-designer is capable of having a systemic view of the production chain, evaluating the inputs and outputs of each phase of the chain, and consciously designing an end-of-life for the product that avoids material and energy losses, thereby extending the life of materials and products. However, implementing such a design and production change in the automotive sector requires overcoming a series of organizational and economic obstacles. These are not only connected to the research and development of new technologies but also, and more importantly, to managerial resistance (Kayikci, 2021). For this reason, it is essential to plan training and awareness programs for stakeholders throughout the production chain to promote a corporate culture oriented

towards sustainability. Additionally, fostering partnerships with other companies, research institutes, and governments is crucial to creating true ecological clusters where the exchange of resources, energy, and information is fundamental to deconstructing the traditional boundaries of the automotive system.

4. Conclusion

The experiments initiated within the project presented in this paper are not yet concluded. The project is considerably broader, and the Politecnico di Torino, through the transdisciplinary collaboration of various departments (Department of Applied Science and Technology, Department of Environmental, Land and Infrastructure Engineering, and Department of Energy), where several designers are working, is indeed initiating a series of research and development tests on additional materials and technologies of interest for a more sustainable and comprehensive automotive system scenario, with the aim of modeling a design and production change for the latter in the coming years.

The results presented focus exclusively on the recycling of high-performance composite materials, such as carbon fiber and fiberglass; however, their use in the automotive industry must be considered by evaluating all the dimensions and requirements of EcoDesign previously explored.

Similarly, it is possible to assert that the use of Life Cycle Assessment (LCA) is not exhaustive if the goal is to calculate the most comprehensive dimension of a product's sustainability (environmental, social, and economic). In fact, in the experimental tests presented, LCA was primarily used to evaluate the Global Warming Potential (GWP) of the composite materials investigated. However, currently, techniques such as the Life Cycle Thinking Approach (LCT) (Traverso et al., 2015) exist, which are capable of implementing a joint evaluation of the results derived from Life Cycle Assessment, Life Cycle Costing (LCC) (evaluation of all costs related to the product life cycle and translation of these into environmental costs), and Social Life Cycle Assessment (SLCA) (evaluation of the social performance of a product's life cycle, considering working conditions, impact on the local community, etc., and extending this evaluation to all actors in the production system).

Within the sustainability of the automotive system, the final consumer also plays a key role, influencing product and technology design through their preferences and purchasing choices. Although the car is an extremely functional consumer good, it is not uncommon for it to represent a status symbol, especially as brands, models, and materials used increasingly align with the luxury sector, thus distancing themselves from the concept of sustainability (Fitt, 2023). While in the agri-food sector and fast fashion, there is a progressive increase in the demand for products with a low environmental and

social impact life cycle, in the automotive context, the search for sustainable solutions and processes must contend with other priority requirements, such as mechanical performance, maintenance needs, consumption, costs, safety, and so on. In this regard, environmental sustainability often remains a secondary requirement, especially during the demand phase by buyers (Hetterich et al., 2012; Saari et al., 2020). Nevertheless, growing environmental awareness is having a direct influence on diverse purchasing decisions. Linked to the introduction and strengthening of increasingly stringent government regulations regarding vehicle emissions and air pollution, as well as appealing tax incentives, it is leading consumers to be more willing to spend more on more sustainable products and vehicles, which can result in future fuel savings and a reduction in environmental impact even during use. Environmental impact is indeed an increasingly important factor in the purchasing process. In this context, which certainly presupposes a transitional era, designing for low-impact life cycles can lead to substantial changes in the production sector and in the daily lives of consumers, who are increasingly eager to "live" and "drive" sustainability.

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BRIDGING THE GAP: LINKING TRANSFERABLE SKILLS TO POTENTIAL FUTURES IN GRAPHIC DESIGN.

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ABSTRACT | This paper discusses the concerns related to the future of the graphic design profession. It analyzes the international educational context and how the programmes adapt to respond to the VUCA environment, including the change in the naming of the programmes. In order to contribute to this discussion and find a way to improve the "Graphic design" educational programme, we chose "Futures Thinking" as a metacognition methodology to apply for self-reflection and adaptation to the turbulent context. The achieved result positions graphic design describes "Meta-communication design" as one of its potential futures. Thus, this paper represents a discussion on the future of graphic design as a profession, the reflection on the design methodologies, the skills that will be needed, how educational programmes should behave in future contexts, and eventually, the students' aspirations regarding their future career paths. In the following steps, we aim to conduct a "Back-casting" workshop to understand which strategic decisions the students could take now to prepare for the future.

KEYWORDS | VUCA (VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY), FUTURES THINKING, GRAPHIC DESIGN EDUCATION, TRANSFERABLE SKILLS, STRATEGIC FORESIGHT, SCENARIO-BUILDING, ADAPTABILITY

1. Introduction

In light of the rapidly emerging technologies, there is an ongoing discussion on the future of art and design and a concern about whether the graphic design profession will disappear. In other words, the graphic design profession is subject to a volatile, uncertain, complex, and ambiguous (VUCA) environment, as identified in futures studies (Bennett & Lemoine, 2014). However, Graphic Design educational programmes still exist, and current and future graphic design students may question their future career trajectories due to the rapid transformations occurring in the field, particularly driven by emerging technologies and changing business landscapes.

In recent decades, the training of designers has shifted from obtaining traditional hard skills to a variety of transferable soft skills (Meyer & Norman, 2021). Bell (2004) and Slaughter (2004) stated that in the face of this VUCA scenario, designers should adopt a long-term vision and strategic foresight approach to cope with uncertainties and anticipate potential changes.

Moreover, in light of the ongoing societal, economic, environmental, technological, and political challenges, designers are increasingly expected to transcend their traditional roles and become strategists and decision-makers capable of analyzing long-term dynamics and proactively responding to change (Brown, 2008; Norman, 2023). To address the rising anxiety among graphic design students and to explore the future of the graphic design profession, an iterative futures thinking practice can be integrated into the educational curriculum. After the completion of each year/semester of studies, students will delve into an intensive hands-on workshop, where they will go through the Futures Thinking research and design methodology: identifying trends, scenario-building, and world visualization (Balagtas, 2021), – to rethink their own future. At step one, students will analyze the environment of the Graphic Design profession using trend research and analysis methods from foresight. In step two, students will develop alternative scenarios emphasizing the implications of the technology and other identified factors

on the creativity of future designers and their response to the challenge using available skills. Eventually, they will brainstorm and visualize the potential deliverables the future designer can bring to the world.

This practice would enable students to explore potential future scenarios and link them with the transferrable skills they acquire throughout their studies. In addition, if carried out regularly, this practice can serve as a research methodology on the relationship between emerging technologies, the future of the design profession, and creativity. This paper will share the first results of the tester workshop and discuss the visions of the future of graphic design and the value of this methodology for educational programmes.

2. Context

2.1 Continuous transformations

The research "AIGA Designer 2025", dating back to 2017, examines the trends that would affect design careers and design education in the future. Referring to the US Bureau of Labor Statistics, it suggested that "the growth in traditional graphic design positions between 2014 and 2024 will estimate 0-1%, which is well below the anticipated 7% growth in all sectors of employment" (AIGA, 2017). Today, in 2024, the US Bureau of Labor Statistics reports that "employment of graphic designers is projected to grow 3% from 2022 to 2032, about as fast as the average for all occupations" (Bureau of Labor Statistics, 2024). Despite unfulfilled predictions about the numbers, the ongoing crisis in the profession cannot be denied. The preconditions of the crisis are the long-standing contradictions between the education system and the industry: there is a certain mismatch between design education programmes objectives and average job requirements. As Juliette Cezzar writes, "Nowhere is this incongruence more evident than in the field of graphic and communication design, which has vigorously debated its boundaries, histories, and even its name" (Cezzar, 2020, p. 214).

Indeed, along with the common revision of values, approaches, and tools in design, we observe gradual changes in the names of educational programs in different schools all over the world. The Icograda manifesto (Poggenpohl & Ahn, 2002) declares that within the developments in media technology and the information economy, the term "graphic design" is becoming "technologically undermined" and suggests that "visual communication design" is more relevant. Schools are trying to distance themselves from the traditional wording "Graphic Design" as it is related to the negative connotations that accompany the discipline. The description of the Graphic Communication Design educational program at the University of the Arts London (UAL) says that "historically, graphic design has serviced various imbalanced power structures, and in this way, has contributed to perpetuating climate, racial, and social injustices". Today, design schools are striving for names that will reflect the challenges students will have to work on.

Ubiquitously, the wording "Graphic design" is being replaced by "Communication Design," and there is an emerging trend of inventing new names, primarily for master's degree programs, e.g., "Communication Complexity" at UAL, "Information Experience Design" at the Royal College of Art. There is also a tendency to form problemoriented and transdisciplinary programs: "Contextual Design" and "Geo-design" at Design Academy Eindhoven, "Transdisciplinary Design" and "Strategic Design for Global Leadership" at Parsons School of Design, "Approaching Language", "Voice Master" at Sandberg Instituut.

These new names are consistent with the values and objectives of these major design schools. The "Graphic Communication Design" educational program at the University of the Arts London aims to "continuously remix and redefine the future of our discipline and how it interacts with environmental, cultural, and social complexities." The Parson School of Design encourages students to "create and share compelling messages from concept stage to final form while exploring the social and environmental dimensions of communication". Department of Design at Sandberg Institute guides "students to develop tools and methods for research, articulation, and visualization that enable them to express and intervene with current discourses and the politics inherent in design". Throughout these texts, design schools promote the idea of a designer as an agent of change. At the same time, if we take a closer look at the reality of the industry, we may find that average design assignments are rather trivial. According to the description of the design duties (Bureau of Labor Statistics, 2024), graphic designers typically do the following:

- Use digital illustration, photo editing software, and layout software to create designs;
- Create visual elements such as logos, original images, and illustrations to help deliver a message;
- Design layouts, including selection of colors, images, and typefaces;
- Present design concepts to clients or art directors;
- Incorporate changes recommended by clients or art directors into final designs;
- Review designs for errors before printing or publishing them.

Following this industry-related vision, design practice has no space for critical and even creative thinking. Designers seem to be the executors of someone else's will, be it the will of the market, the target audience, or the client. Despite the rapid progress in communication technologies, there is a relatively slow pace of change in the industry, which leads to stagnation throughout the system. There is a certain vicious circle: Design educators and academics are willing to develop critical approaches but have to face the reality of the industry, where conventional forms and methods are still dominating. At the same time, graduates become hostage to

the situation when their competencies can't be applied in practice and often have to work on assignments that lag behind contemporary social, technological, political, and economic contexts. The question is how to resolve this contradiction between the intentions that are shaped in the academy, the framework that the industry dictates, and the reality in which problems continue to accumulate, and very few solutions emerge.

2.2 Graphic design in VUCA context

The above observations prove that the graphic design profession is subject to a volatile, uncertain, complex, and ambiguous (VUCA) environment, as identified in future studies (Bennett & Lemoine, 2014). The VUCA environment affects the graphic design and all the contexts, including business, economic, political, etc. To meet the external challenges coming from the surrounding environment of an organization, the organization needs to be agile and invest in leadership development, and their employees should have the ability to influence the organizational and relational dynamics (Kolga, 2021). Complex relationships and networking are prioritized over control, standards, and autocracy (Uhl-Bien & Marion, 2009). In the educational environment, this led to a need to promote more active learning approaches that transfer to the students responsibility for learning and entrepreneurial mindset (Fernandes & Afonso, 2021).

Graphic design as a profession obtained its popularity thanks to the Swiss school of typography, which influenced our understanding of what represents a good standard of graphic design. However, the reality of the graphic design profession is associated with a number of delusions related to the negative sides of its working process, such as project-based regimes and work-life disbalance, low wages, and low social protection, prevailing individualism and self-promotion, and the overall uncertainty related to the development of a professional career (Quintela, 2016). What further contributes to the uncertainty of the profession is the frequently changing market trends and consumer preferences that are hard to predict and keep up with.

Secondly, rapidly emerging technologies, and especially the GPT and other AIassistants, have created heavier pressure on the designers and even a sense of competition with AI. In addition to that, the introduction of new software, platforms, and devices constantly reshapes the tools and techniques used by graphic designers, necessitating continuous adaptation of their skills, which may lead to a lack of professional confidence among designers and push them to opt for "junior" positions at work. Additionally, the rise of digital media has led to an increased emphasis on responsive design, motion graphics, and interactive experiences, further contributing to the volatile nature of the profession, changing rapidly and often unpredictably. Thirdly, the graphic design profession is marked by complexity, involving multiple stakeholders, varying requirements, and the need to balance creative vision with technical constraints. The

integration of design with other disciplines, such as marketing, IT, and others, adds to the complexity of the profession. Designers must navigate complex workflows, project management, and team dynamics to deliver design solutions that often become a compromise between the stakeholders rather than a strong, visionary design with an individual style that many designers dream of achieving (Quintela, 2016). The need to work with ambiguous design briefs and mediate the opinions navigating through diverse perspectives of clients, end-users, and design teams characterizes the profession as ambiguous, which completes the VUCA environment description.

2.3 Transferable skills

The volatile, uncertain, complex, and ambiguous nature of the design practice is addressed in the research "AIGA Designer 2025". According to the forecast made in 2017, in 2024, designers should be trained to collaborate among experts in different fields, bridging gaps between related information and activities, bridging physical and digital experiences, searching for new approaches to forecasting change, structuring strategic conversations, innovating business models, and making sense of research data; identifying the social and ethical responsibilities; being responsible for data-aware research methods and systems; adapting methods borrowed from other disciplines to design problems and define acceptable evidence for practical applications in practice e.t.c (AIGA, 2017). To achieve such educational outcomes, design educators have to pay more attention to raising transferable skills, such as problem-solving, analytical reasoning, critical thinking, leadership, adaptability, teamwork, communication, and writing.

Jan Eckert, the head of the Master's Programme in Design at Lucerne University of Applied Sciences and Art, describing the process of revision of the educational approach makes the emphasis on the development of connective competencies (Eckert, 2018). In opposition to the common "Tshaped Skills Model" based on the combination of cross-discipline expertise and deep-discipline expertise (Eckert, 2018), Eckert proposes the YShaped Designer model. The proposed model aims to catalyze "the shift from authorship towards stewardship in design". In order to accomplish these goals, "designers need to be a step ahead to become involved or even lead the conversation" (Eckert, 2018, p.52). This idea corresponds with the increased relevance of co-design approaches, giving the community a major say in the design process. "The most important skills are management and leadership — traditional training in typography, color, form, and materials would be of little or no relevance" (Meyer & Norman, 2021, p. 17).

Afonso Pereira de Matos, design student at the Design Academy Eindhoven, addresses this issue in his graduation project "Who can afford to be critical?" (2022):

"Instead of solving market-defined problems, 'critical designers' produced by institutions like Design Academy choose to address social, political and environmental conditions. Yet, who can afford to continue such a practice after graduation? Why do we ignore the material and socioeconomic constraints that bind us as designers, claiming instead that we are powerful agents of change? Do we really have any political agency through our individual design practices? Could designers' own working conditions be targeted as one immediate site for collective action?"

Interrogating the design educational system and design industry helps students to become more conscious about planning their educational and career paths and to become responsible, future-conscious designers with the ability to be "a step ahead". The methods proposed during the workshop aim to strengthen these capabilities.

3. Methods

3.1 Futures Thinking

To address the questions posed, we have used the methodology of "Futures Thinking" (Balagtas, 2021). This methodology organizes the creative process to envision and visualize the alternative scenarios that may occur in the future. The key idea was to introduce to the students the concept of the plurality of time and the idea that the future is not given but should be created by us, as Elvin Toffler suggested in his book "The Third Wave" (1980). Thus, while going through the methodology, students had to think critically through the bigger-picture effects to project multiple future consequences of the ongoing technological developments and propose relevant solutions.

Students worked in groups, where undergraduate students were guided by the postgraduate students. PG students pre-researched the potential directions that may be of interest to the graphic design profession, and UG students developed these directions further following the "Futures Thinking" methodology. The topics proposed by the PG students were:

- "AI and the future psycho type of the graphic designer."
- "New forms of transdisciplinary communication".
- "Designing with the Big Data".
- "New forms and technologies for sketching and visualizing ideas".

One PG student had led each topic. All students belonged to the educational programme "Graphic Design". Each workshop day would include the briefing and the presentations of each workshop phase. This approach allows students to stay focused

and not postpone the process of design to the last moment. The design process serves to avoid jumping into the first solution and keep the minds open and free from presumptions. The methodology included three analytical steps, such as "Trends research," "Trends analysis," and "Worldbuilding," and the creative step, such as brainstorming and visualization of the ideas. The workshop lasted seven working days and was finalized with the presentations of conceptual installations representing their visions for the future of the graphic design profession.

The first step of the workshop was to research the emerging trends, where students used the method of "Environmental-Scanning". The second step was to analyze the identified trends using the "Probability/Impact Matrix" and "Futures Wheel", and the final step of the analytical phase was to describe alternative scenarios using the "Dator's Four Futures".

The "Environmental-Scanning" method identifies early indicators suggesting emerging alternative futures (Gordon & Glenn, 2009). Students were given instructions to conduct quick internet searches and pick up short phrases that describethe connection between the emerging technology and how it can be used in the given theme, e.g., "personalized AI to co-develop with the designer". The Impact Matrix analyzes the trends in relation to their likelihood of becoming ubiquitous and their impact on the market and society at large to help prioritize them. "Impact" refers to the impact on the Graphic Design profession, and likelihood refers to the possibility of this trend becoming ubiquitous (Fig. 1).

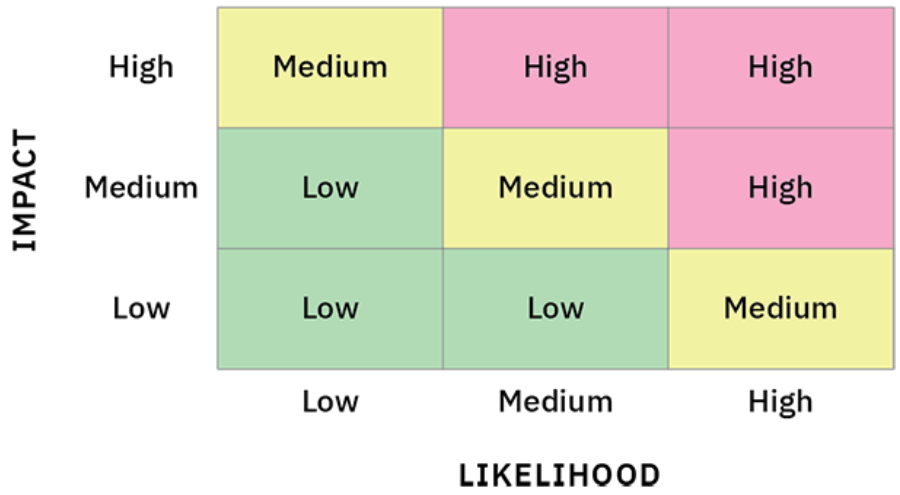


Figure 1. Probability/Impact matrix (Balagtas, 2021).

Students were instructed to discuss in groups which trends that they had identified could become more or less ubiquitous and of impact. This matrix is normally used to assess the risk in the business environment; in our case, we used this matrix as a facilitating tool to help students prioritize the trends. Futures Wheel is a sort of brainstorming analytical technique. Students had to place one of the identified trends at the center of the mind map (wheel) and discuss within groups how it will affect different aspects of the design profession, tools, designers, business, outcomes, etc. (Fig. 2).

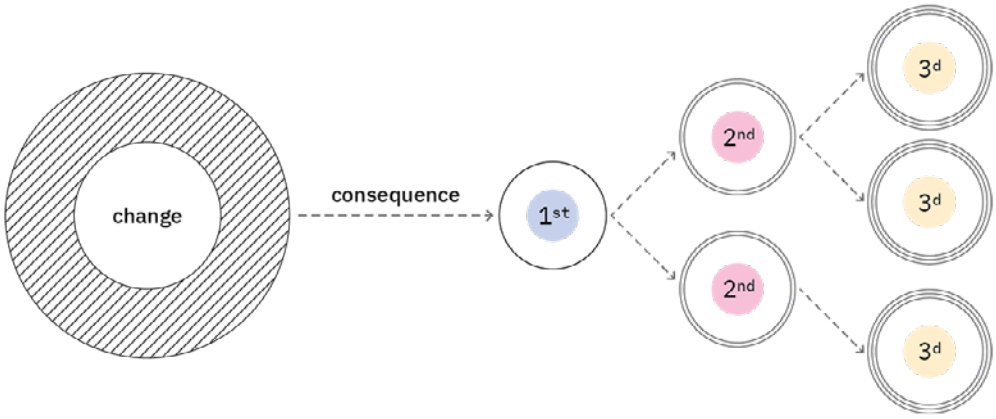


Figure 2. Futures Wheel – logics of brainstorming.

In the workshop, we used Dator's four futures (2009) to describe how a trend might evolve in different scenarios. Scenarios allow designers to see how different consequences may evolve in the future they refer to. According to the methodology, students had to describe the following scenarios: "Continued growth", "Transformation", "Collapse", and "Discipline" (Fig. 3).

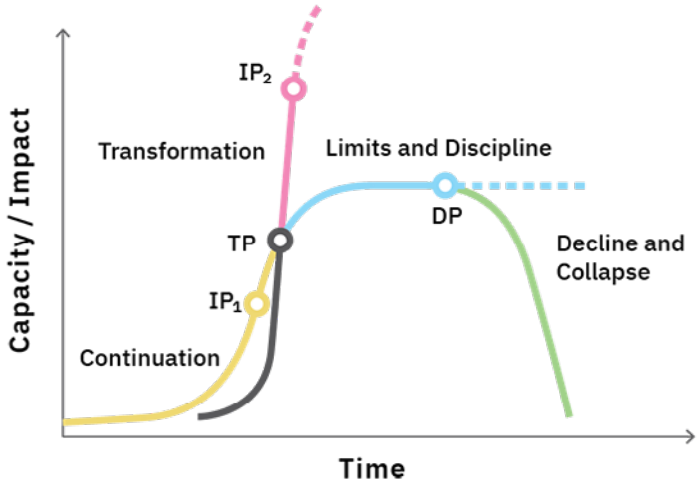


Figure 3. Smart's four futures, adapted from Jim Dator 1979.

"Continued growth" is a future of continuation and intensification of the current trajectory and problems, it is a development of the present. "Transformation" is a breakthrough of the present that leads towards new standards and activates new events. "Collapse" is a dystopic future where the system reaches its limit and breaks down, and a failure of one system triggers failures in the others. "Discipline" is a future of equilibrium, where a certain degree of sustainability is achieved but has limitations, and the growth does not bring transformational evolution. After completing the analytical part, students have brainstormed and visualized their ideas using a free technique, including the suggested forms of visualization, such as sketches, moodboards, and scaled tangible models or renders of their installation.

To further understand the students' perception of their future profession, we have inquired their opinions using the "Ethnographic Futures Research" method (Textor, 1995). This method invites to explore how the target group perceives ongoing trends and possibilities and which related changes they 1) want, 2) fear, and 3) expect. The answers were collected using online forms.

In the paragraph 2.2, when discussing the VUCA environment, it was mentioned that educational institutions tend to promote more active approaches to learning to invite students to own the responsibility for their learning and professional development in order to develop skills needed to adapt to that kind of environment. The "Futures Thinking" workshop and the "Ethnographic Futures Research" method served as means for practicing the responsible approach to students' learning as well as a way to research the potential futures of graphic design as insights for further development and adaptation of the "Graphic design" educational program to the needs of the near future context.

4. Results and Discussions

4.1 Student's work and reflections

In this paragraph, we will discuss the experience of implementation of the above methods by describing the workflow of one of the design teams exploring the theme "New forms of transdisciplinary communication". This theme was selected as exemplary as it fits our research task to rethink the graphic design discipline, at least within the given educational programme: this theme represents the overall trend in modern research approaches to aim at the transformation of ideas, discoveries, and tools and radically change the understanding of existing concepts or lead to the creation of new paradigms and scientific fields (Darbellay & Lubart, 2017). Creative Interdisciplinarity is an innovative approach that intersects with design thinking and aims at solving complex problems from an innovative perspective focusing on human experience, transcending disciplinary boundaries.

In this context, design becomes not just a set of methods and techniques but an important paradigm that facilitates the integration and interaction of various fields of knowledge. It stimulates creative thinking and interdisciplinary collaboration, becoming more of a way of thinking and acting. While the descriptions of the exercises represent a reflection on the nature and possible futures of graphic design, we will also add some reflections below each exercise on how it contributes to the students' take on their future, development of transferable skills, and other aspects.

Environmental Scanning

In the process of Environmental Scanning, special attention was paid to atypical ways of communication, predominantly non-verbal, which can serve as a basis for creating a metalanguage capable of overcoming barriers and limitations arising from differences in terminology and thinking among specialists from various fields. One vivid example of such an approach is the project "Dialogues" by a London photographer and director Lisa Jahovic (2023). In her work, she explores the absurdity of everyday life by filming an abstract ballet with dialogues. The author uses inanimate objects as a means of self-expression, allowing her to reveal life and emotions in their mechanized interaction through a series of kinetic experiments with household items. This approach demonstrates how visual and kinetic means can convey complex emotional and conceptual messages without using traditional verbal language. Besides that, students also considered examples of communication in the plant world. Plants communicate through visual signals, such as light, and through biorhythms, which can be translated into music (Plantwave). These forms of interspecies communication show how natural processes can be used to create new forms of interaction that can be perceived and interpreted by humans. Sign languages, such as dactylology, were also analyzed. Deaf-blind people use teletactors and biomorphic devices that convert information into electrical signals and project it into the brain as simplified pixels (Lewis et al., 2015). These technologies not only expand communication possibilities for people with disabilities but also offer new ways of transmitting information that can be useful in various professional fields, including design. Students also explored modern technologies for visualizing neural connections, which allow communication without words and accelerate the process of mutual understanding (Chen, Qing & Zhou, 2023). The reconstruction of video signals from brain activity can change our understanding of graphic design, opening new possibilities for visual representation of information and interpretation of thoughts and ideas. Thus, students' have summarized this exercise as "neural connection visualization technology" as the key trend to be further explored in the workshop.

In this exercise, students' research identified that the future of communication and design lies in the integration of disciplines and the use of innovative technologies that allow

overcoming traditional barriers and creating new forms of interaction and expression. This finding supports the trend described by AIGA in the introduction paragraph that "designers should be trained for collaborating among experts in different fields". Thanks to this exercise, the trend obtained a more specific shape in the students' eyes and became more credible through examples of the use of new technologies, scientific discoveries, and artistic and design projects that they found during the exercise.

The Probability/Impact Matrix

Following the given methodology, students applied The Probability/Impact Matrix (Figure 4) to assess the impact of neural connection visualization technology in the context of the graphic designer profession. This method allowed them to systematize their ideas and analyze the future of graphic design as affected by the development of these technologies. One of the prioritized findings concerns the likely emergence of mental piracy. The design team discussed that with the development of this technology, there is a danger of ideas and thoughts theft, leading to increased attention to digital security and mental health issues. These changes require new approaches to protecting one's intellectual resources. Additionally, students thought that the visual transmission of brain activity will significantly alter existing formats of graphic media. The emergence of braincomputer interfaces with new types of screens or even their absence will radically change the means of visual communication, requiring the development of a new visual language. This can open new horizons in the field of graphic design, providing designers with tools for more direct and intuitive interaction with the human brain.

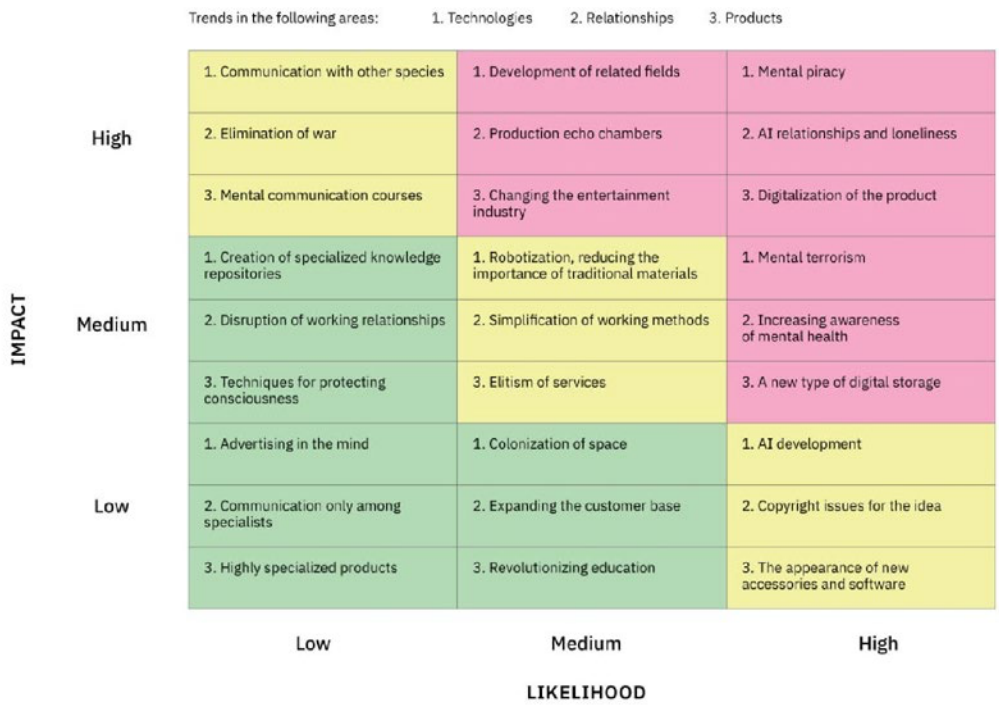


Figure 4. Imact Matrix developed by the design team exploring the theme "New forms of transdisciplinary communication".

Working on The Matrix without access to interviewing the leaders in the field becomes an exercise similar to brainstorming rather than a thorough research activity, as it becomes hard to evaluate the probability and impact of certain events without knowledgeable people in the field. Yet, it helps develop transferable skills of teamwork and analytical reasoning by organizing the discussion and providing some keys for selecting the most prominent ideas thanks to the matrix structure.

Futures Wheel

Using the Futures Wheel, students were able to capture a broader spectrum of influences of neural connection visualization technology beyond graphic design (Figure 5). In analyzing changes in tools and technologies, they noted the need to increase databases and servers for mental communication. This raises risks related to server space shortages and data leakage threats, as well as the possibility of thought interception. However, such changes may foster the creation of specialized knowledge libraries and the revision of copyright laws adapted to new realities. In the context of the impact on consumers of design products, students suggest that neural connection visualization can improve communication between designer and client but also raise user expectations and devalue the designer's work. The introduction of such technology may lead to information overload, where the consumer's consciousness will be unable to process the vast flow of information. From the designer's perspective, neural connection visualization technology can simplify work methods and allow focusing on concept and creativity. This will speed up the process of idea realization, but the increased pace of work and idea flow may contribute to professional burnout. The issue of remuneration remains open: it may increase due to the high cost of technology and shorter project completion times, but it may also decrease due to automation and the accessibility of such tools to a wide audience.

Futures Wheel is an important exercise that can teach students the plurality of consequences of each innovation. Today, we are taught to praise the new technologies and wait with excitement for the new releases of cell phones and other gadgets. However, the technology costs may appear different to different stakeholders, as demonstrated in Moore's first and second laws (Schaller, 1996), where the cost of the computer technology to the consumer gets cheaper, while for the manufacturers it rises. With the Futures Wheel structure, students are invited to explore broader consequences of change and engage into a structured strategic conversation.

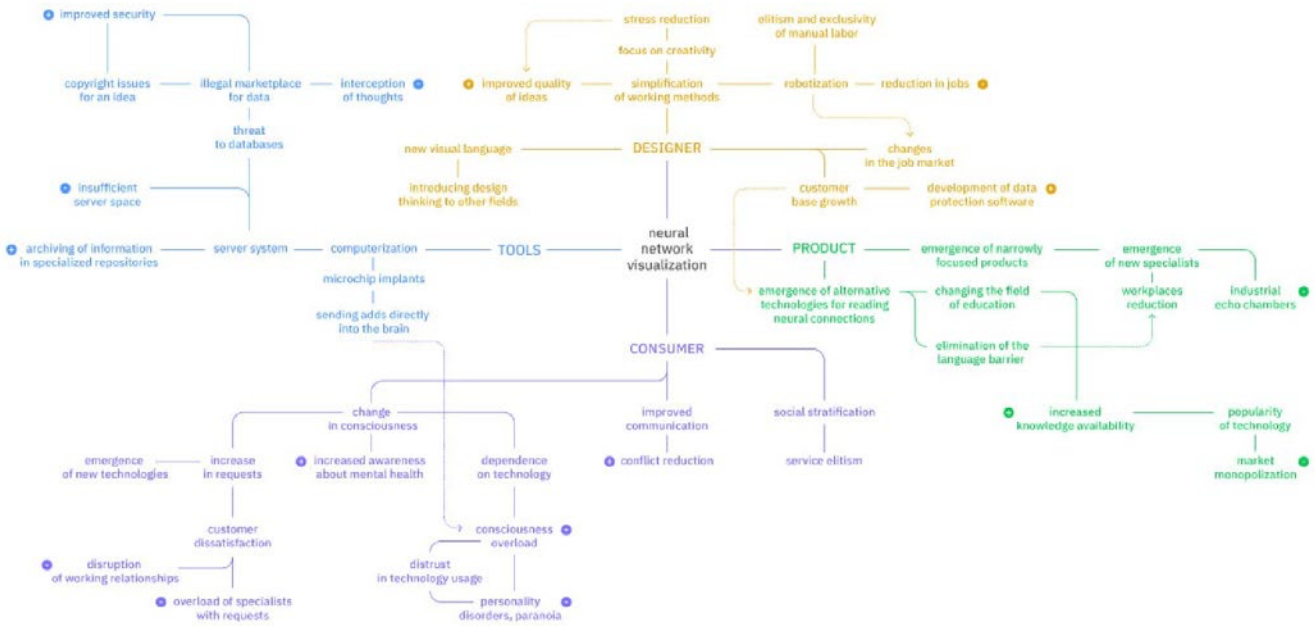


Figure 5. Futures Wheel developed by the design team exploring the theme "New forms of transdisciplinary communication".

Future scenarios

Students imagined possible future scenarios related to the development of mental technologies, reflecting not only potential opportunities for societal transformation but also emerging threats. Here we will discuss two scenarios: transformation and collapse. In the 'transformation scenario', students suggested that with the development of mental advertising, "mental block" programs will emerge, allowing users to limit or block unwanted ads or monetize them by allowing personalized ad broadcasting. Accordingly, strict control over mental advertising is expected, including a ban on such advertising for children, as well as on tobacco, alcohol, and dubious services. Competition and filtering of unscrupulous content will lead to qualitative growth in the advertising market. Moreover, the direct transmission of information to the brain will require enhanced data protection from piracy and negative impacts, stimulating the development of the data protection and intellectual property industry. Additionally, free mental libraries with open access will appear, enabling people to learn regardless of social status and age, significantly transforming educational system.

Considering the 'collapse scenario', students expect significant impacts of neural connection visualization technology on the user's personality, contributing to consciousness exhaustion and anxiety growth. Specialists will face increased idea generation volumes, while ordinary people will be concerned about protecting their

data. Manipulation of academic and personal experience will lead to global knowledge falsification and concept substitution, causing a personality crisis. The manipulative advertising will create dependence on technology. Refusal to subscribe to a secure service will result in the user's data being publicly available, enhancing social inequality and product elitism. Technologies visualizing personal fears and weaknesses will be used as leverage, leading to mental slavery and terror. There may be complete erasure of individual information in lower-class people, followed by their use as production units or cloning data to eliminate dissenters. This will lead to dehumanization and totalitarian control over the individual.

The analyzed future scenarios highlight the profound consequences of mental technology implementation. The transformation scenario demonstrates the radical change in the quality of life and education, while the collapse scenario emphasizes the dangers of consciousness manipulation and social inequality. Such analysis of the future development of mental technologies allows maximizing positive effects and minimizing negative consequences for society and the individual when introducing innovations.

Concept

The final stage of the workshop was the creation of a conceptual installation representing a reflection of the conducted research. Students presented a project to explore non-verbal interdisciplinary multilog through an installation. The experiment created conditions for the emergence of interdisciplinary non-verbal interaction among people by creating a joint design object. With this installation, students plan to observe how specialists not connected to the design world will create artistic compositions from objects, light, and sound, demonstrating their own vision of the world and studying the thinking principles of others. From the 'Environmental Scanning' to the 'Probability/Impact Matrix', to 'Futures Wheel', to 'Scenarios', the whole research and discussion methodology invites students to make their future visions from generic to more and more clear, specific, and researched from different perspectives. Besides, in addition to such transferable skills as analytical reasoning, critical thinking, communication, and teamwork, the 'scenarios' exercise also trains the writing, which is commonly overlooked in the design education. The final step was the visualization that indicates the meanings of the described change and the possible interaction with the technologies in the future.

Overall, the proposed workshop methodology allows, on the one hand, to build the transferable skills and promote responsible learning among students, and on the other hand, it serves as a research tool that allows both the students and the educators to self-reflect through research on design and its future to adapt timely to the change occurring in the discipline and the society. This design team proposed a vision of the future of graphic design as "Meta-communication design" which refers to the strategic

structuring of communication processes to enhance understanding and effectiveness in the context of evolved technologies supporting new forms of communication. It focuses on how messages are conveyed and interpreted beyond the content itself.

4.2 Conclusions and students' expectations, fears, and desires

In the last paragraph, we would like to share the opinions regarding the future of graphic design collected from the participating students. In this workshop-tester, we applied design research methods to reflect on the future of design as an important step of acknowledging the value of design methodologies and processes not only for the business environment but also as part of metacognition: design for the sake of improvement and evolution of the design discipline. Also, by giving to the students the power to self-interpret their skills and future, we recognize that the current programmes to some extent fail to fit the current and future job requirements. In the introduction paragraph, we shared examples of how the programmes change and position designers a "conversation leaders", however, instead, should we listen to how students feel about their profession rather than imposing our idealistic visions? By looking at the students' results in this workshop and in general, throughout the educational practice, we can observe the need and a strong capacity of the designers to be intellectually challenged. Yet, current job requirements do not reflect this capacity.

How can we assist our students and create a path leading them to the world where they apply their intellectual skills at maximum? With this workshop, students interrogated the design industry to project what might change and which skills may still remain constant in this VUCA environment? Even if, "Graphic design" will live a transformation from "Communication design" to "Meta-communication design", we can still observe that both transferrable (e.g., teamwork, analytical reasoning, writing), and professional skills (e.g., visual design) will preserve in the future, e.g., to support visual ad design, information visualization design, etc. Noticing the area of stability is an exercise to be repeated in the intensifying VUCA environment we are experiencing today.

Below are the results collected from the online forms of the survey using the "Ethnographics Futures Research" method applied to grasp students' desires, fears, and overall expectations related to the future of the graphic design profession. Below, we will report the answers students submitted in the forms, indicating their names, corresponding themes, and the role in the project from the who students gave permission to share it.

1. The summary of the realistic view

Daniil Leoshko, the leader of the theme "New forms and technologies for drawing", when sharing the realistic view on the future of the profession highlights the tendency towards the need to personalize the graphic systems, where complex systems will be

more appreciated while the logo will lose its dominating role in the visual identity. 3D and animation will affect the aesthetics, and the Internet will "teach" people to perceive the information through visual-sensory language. Graphic design will find more means and contexts for its implementation, and research will play a more significant role in project development.

Stepan Petrov, the leader of the theme "Designing with the Big Data", shared that 90% of the design will be created for the digital environment; the algorithms and programmable templates in creating a design product will increasingly become more important; the design process will be optimized and the human work may be replaced; in parallel, there will be a tendency to move away from the universality of visual language and search for a new language linked to the local cultural features and return to the artistic origins of design (painting, sculpture, architecture).

2. The summary of the negative view

Daniil Leoshko shared that the most disturbing aspect is the aesthetics of AI becoming mainstream. Also, he mentioned that the rapid development and accessibility of the professional tools blurs the professional identity of a designer. Stepan Petrov also mentioned that the templates availability will lead to eliminating the need in the designer. Also, he is worried about the decreasing value of tangible materials; design losing its creativity and becoming totally subordinated by the market needs; a constant need to adapt to the new programs and algorithms; reduced demand for design services due to economic instability.

Alisa Doroshenko, a design team member, shared her concerns regarding the unstable relationship between graphic design and AI. The problem of the overuse of artificial intelligence is already becoming noticeable when jobs are being cut, the quality of the product deteriorates significantly (e.g., we can see poorly generated posters in the streets). She is concerned regarding the copyright and plagiarism, the depletion of the creative potential of designers due to the intense use of AI and other digital tools. Similarly to the previous student, she fears the impact of the economic crisis on the profession's future.

3. The summary of the positive view

Daniil Leoshko wishes to bring design and creativity closer together, so that design solutions become contextually unique. Also, he mentioned that currently designers lack a clear definition of who they are and what they are valued for in the society, and he would like to see this situation changing. He wishes that there will be more variety in specializations and forms of aesthetical realization in graphic design, and that the project-driven nature of design will transform into a continuous, eventdriven project improvement. Eventually, he mentions the importance of the design community and presence of likeminded people exchanging meaningful thoughts and ideas.

Stepan Petrov shared that he would like to see the growing demand for design services; non-digital design and the return to its artistic origins; the priority given to the uniqueness of the design vision, both individual and geographical, and the end of the era of the International style. He wishes to see the emergence of new technologies and methods for creating digital images mixed with the use of analog equipment in the production process, new media for graphics delivery and distribution (e.g., E-ink screens), and the accessibility of open-source software for designers and artists. Eventually, he shared a hope for overall improvement of the cultural level of designers based on high-quality humanitarian education. Alisa Doroshenko hopes that the need in graphic design will be growing because more people will understand and appreciate what designers can do. Designers will get better equipment, training, healthcare services and as a consequence, they will coexist in a healthy competition; and the AI will only serve to assist in the routine work.

We hope these visions will serve as a source of inspiration for any purposes related to the future of graphic design, such as future design projects, educational programmes naming, identifying future research questions, programme re-design to fit the job requirements, and more. The next step we are going to take is to set up a seminar where students can reflect on which strategic actions they should take in order to prevent or prepare for the future possibilities they have identified. The workshop was held in July 2024, and the seminar "Back-casting discussion" will be held in the beginning of October 2024. The gap between the two activities allows for the continuous reflection on the future career but also for a fresh look at the previous results. Thus, we aim to make this reflective practice become a habit and part of the design skillset.

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DESIGN FOR CHILDREN'S ACTIVE SCHOOL COMMUTING ENVIRONMENTAL SAFETY EMPOWERED BY ARTIFICIAL INTELLIGENCE AND AUGMENTED REALITY.

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ABSTRACT | Background: It is critical for the improvement of urban living conditions to enhance the safety of active school commuting environments for children. However, social innovation design interventions are absent from current designs for children's active school commuting safety, which primarily concentrate on stability indicators such as hardware, infrastructure and social management. Methods: The environmental safety elements are classified into a fourdimensional model in this study, which consists of physical, social, cognitive response, and infringement prevention. To investigate abundant media accident texts that may be applicable to our four-dimensional model analysis, we cluster 607 media text samples using NLP technology, identify the eleven primary clusters, and perform further quantitative calibration for other components. Finally, we provide a summary of the assignment and classification criteria for four dimensions, nine categories and seventeen factors. Result: To resolve the deficiencies in children's safety responses, a design strategy identified as "strengthened perception and graded intervention" was proposed subsequent to an examination of safety response action chains and established safety design interventions. Machine learning algorithms train models to analyse accident causes and outcomes, enabling intelligent security observation and prediction. Light devices, projectors and augmented reality are combined to assist in the development of intervention components that cater to the cognitive experiences and interests of children. Conclusion: The AI and AR co-empowered dual-chain design framework is developed. We effectively communicate comprehensive and accurate safety cognition and response measures to children, enhancing the specificity and effectiveness of children's active school commuting environment safety design.

KEYWORDS | ARTIFICIAL INTELLIGENCE, AUGMENTED REALITY, CHILDREN'S ACTIVE SCHOOL COMMUTE, ENVIRONMENTAL DESIGN

1. Introduction

The spatial quality and environmental structure of urban residential areas play a crucial role in children's growth and development (Visser & Van Aalst, 2022). A large amount of school-age children's activity time is devoted to school commuting, and the school commuting environment and school commuting behavior are crucial to children's growth (Kaseva et al., 2023). school commuting behavior has a clear destination and chain of activities (Hoelscher et al., 2022). Active school commuting is defined when commuting behavior is based on walking and promotes developmental dimensions including independence and sociality (Morris & Hardman, 1997; Tudorlocke et al., 2001). It is particularly effective for static lifestyles such as childhood obesity (Martin-Moraleda et al., 2022) . It also allows children to wander periodically through community life circles and develop social communication and behavior (Ding et al., 2023). Therefore, it is advisable to advocate Children 's Active School Commuting.

However, complex commuting environments are also dangerous for children (Jansson et al., 2022). Most of the existing safety solutions for children's school commuting are passive and static, relying mainly on human activities and top-down policymaking, and lack real-time performance. The government of the United States implemented the SRTS program in New York by improving the environment and facilities around the campus (Boarnet et al., 2005). The Dutch government created the Kindlint Children's Walking Network (Liangwa, 2017). A "walking school bus" pilot project was implemented in northeastern Ontario (Scharoun Benson et al., 2020). The Japanese government has promoted the safety of specific groups such as children, to the design of architectural streets that limit access to pedestrian areas, to the environment of natural surveillance, and to the community atmosphere that has a sense of domain (Hino et al., 2021). The design that excessively prioritises physical change requires a significant amount of time to execute and lacks relevance.

The aim of this study is to analyse media texts and identify the factors that influence the safety of children's school commute. By using a large sample size and data analysis algorithms, we will investigate how these factors impact children's safety. The ultimate goal is to develop design methods and intervention strategies to enhance the safety of children's school commute in urban areas.

2. Literature review

Security means both safe and stable, which is the most basic need for human survival. Environmental safety planning and design refers to the use of scientific methods and technologies in environmental design, with the goal of ensuring the safety needs of human survival, from macro to micro, from the whole population to specific users, comprehensively considering various factors such as the natural environment, social environment and humanistic environment. This section compares the safety of Children's Active School Commuting environment with that of urban scale environmental design, safety in road traffic, and safety in children's activity environment, and distinguishes the characteristic factors of the safety of Children's Active School Commuting environment, so as to better study and conclude the conceptual model of influencing factors.

2.1 Safety influencing factors at urban and community scales

The research on urban and community security focuses on the improvement of urban resilience and the level of public security. The European Union carried out the MOVE program from 2008 to 2011 to encourage and promote a lot of research and practice on urban disaster prevention and reduction, economic and social sustainability (David & Jörn, 2013). The London Development Plan 2021 highlights cooperation between government and relevant actors to deal with climate disasters (Greater London Authority, n.d.). In 2020, the United Nations Office for Disaster Risk Reduction (UNDRR) launched the "Creating Resilient Cities (MCR2023) Initiative", which will include disaster prevention and mitigation and urban resilience in the mainstream assessment of urban sustainability levels, advocating collaboration across municipal agencies and city functions to integrate resilience and sustainability in urban development. Many evaluation indicators and tools, such as City Resilience Profiling Program, Disaster Resilience Scorecard for Cities Scorecard and Enhanced Vulnerability and Capacity Assessment, guide city managers from two aspects: risk assessment and emergency response.

2.2 Safety influencing factors at street scales

However, compared with urban communities, children's school commuting is a special space with mobility, relatively fixed functions and behavioral purposes. Therefore, the planning and design theories, models and tools of road traffic environment safety will also provide inspiration for the safety and planning of Children's Active School Commuting environment. The Highway Safety Strategic plan of the United States distinguishes the nine causes of traffic accidents, expounds the complexity of pedestrians' road traffic safety, and defines the safety and applicability of pedestrians' use of road systems as Walkability (Hughes et al., 2016). Neighborhood Environment Walkability Scale was used to measure walkability using six indicators: land diversity, road connectivity, walking infrastructure and walking safety, aesthetics, traffic safety and crime (Cerin et al., 2006). Ewing and Cervero define a "5D framework" of factors that influence walkability in the built environment, including density, diversity, streetscape design, destination accessibility and public transport systems (Ewing & Cervero, 2010). According to the theory of "Streetscape Skeleton", elements such as buildings and trees are regarded as the skeleton variables of streetscape. Based on the principle of human-oriented design, the relationship between streetscape from human perspective and walkability is discussed (Harvey et al., 2015).

2.3 Safety influencing factors at children's outdoor activity space

From the research on the safety of children's activity environment, this paper seeks the cognitive and behavioral design thinking for children as a special group, summarizes the types and characteristics of children's daily activity environment, and understands how the design of children's activity space provides an effective guarantee for children's safety. The vulnerability of children's bodies lies in the weak and small impact resistance of children's bodies, but the vulnerability of children is not only related to the safety risks brought by physiological abilities such as grasping and balance, but also the vulnerability in cognitive judgment and perceived response is also an important risk factor for children's safety. At the environmental system level, the spatial layout of the activity venue also affects the perception of safety by children and the community. Transparent enclosure, familiar signs, neat ground, safe facilities, friendly atmosphere and accessible space are children's images of public space safety (Horelli, 1998).

2.4 Safety influencing factors of human encroachment

Human encroachment includes intentional crime and unintentional injury. According to the Defensible Space theory, the natural supervision of the community will greatly improve the exposure of residents to potential hazards while moving in the urban

space (Perkins et al., 1993). Both social and physical elements are integral components of a successful defense space. At the theoretical and methodological levels, the population, economy, facilities and other data of the community have been linked to the community man-made crime through CPTED theory in different studies. Oscar Newman summarized the four core elements of sense of domain, natural supervision, environmental image and neighborhood environment into the security design model of defense space (Newman et al., 1976). By constructing the relationship between socio-economic characteristics and victimization behavior according to CPTED principle, we can explore how different spatial types, community socioeconomic variables (length of residence and family income) and residents' victimization experience affect community safety (Hedayati Marzbali et al., 2012). In her book, Vania Ceccato describes the impact of the characteristics of nodes in urban infrastructure networks on crime in surrounding communities (Ceccato, 2014).

3. Concept Framework of children's active school commuting environmental safety

The previous section conducted a thorough examination of safety in urban community intervention, road traffic, children's activity environmental safety, and environmental design against human infringement. This examination was done through literature review and case research. The section defined safety and evaluated its dimensions. It also identified and categorised the main theories, models, methods, and tools related to safety. Additionally, the section compiled and analysed data on the factors involved in environmental safety. The sufficiency and necessity concept of safety planning and design reveals the binary opposition categorisation logic of subject and object, as well as internal and external factors. To adhere to the principle of safety planning and design, the evaluation dimensions are defined by dividing the two-dimensional coordinate system into four quadrants. A conceptual framework is then established to represent the element model in four aspects: material space, social space, cognitive response, and assault prevention.

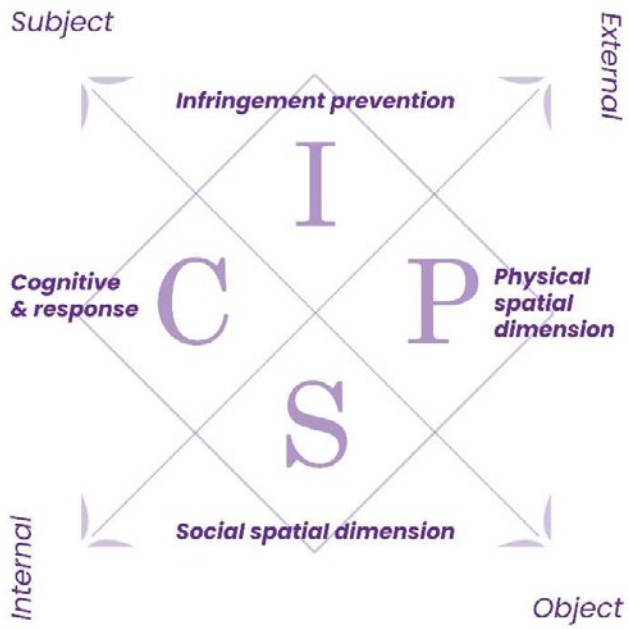


Figure 1. A four-dimensional framework of influencing factors of Children's Active School Commuting environmental safety.

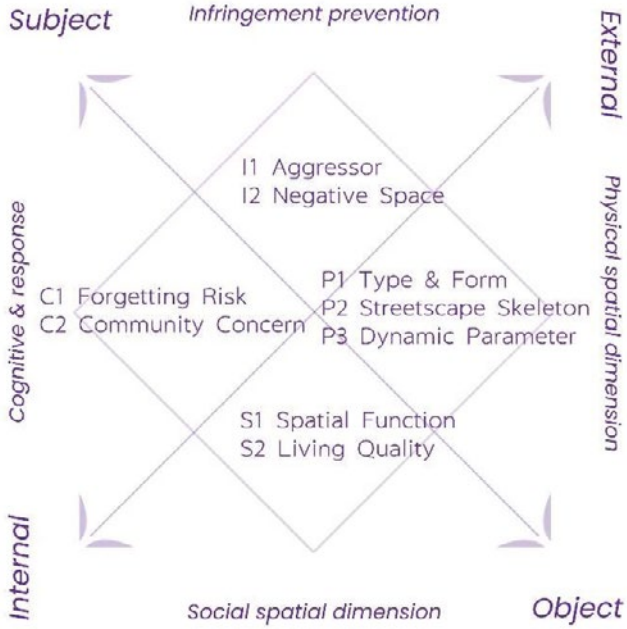


Figure 2. The zonal relationship of nine security impact factors.

This led to a summary of 9 factors that can be used to evaluate the safety of a child's active school commute setting. The physical dimensions of space are categorised into three aspects: spatial type and form, streetscape skeleton, and spatial dynamic parameters. The social dimensions of space are categorised into spatial function and living quality. The cognitive and

response dimensions are forgetting risk and community concern. The measures to prevent infringement are aggressor and negative space. The next chapter outlines methods for discerning various components based on this conceptual map.

4. Methods

When it comes to ensuring the environmental safety of children's school commuting, one of the challenges faced in conducting empirical research is the limited number of witnesses to safety accidents. This makes it difficult for researchers to gather first-hand information about accidents using traditional research methods. This study examines accidents as a result of the impact of many elements and can aid in determining the safety conditions by consolidating environmental safety factors and accident patterns. Initially, a substantial quantity of data on kid safety accidents is gathered through media research. Subsequently, the four-dimensional safety model of Children's Active School Commuting environment is employed as the catalogue framework to augment other components.

4.1 Data collection

We extracted media information from different types of news websites, including social media platforms, news portals, and professional websites focusing on production safety and emergency management, and grabs a total of 730 raw data. Because the basic data structure and parameters of each platform are different, there are old, duplicate or irrelevant data, this paper determines 617 valid data through manual screening, and carries out basic standardized cleaning of the data set.

Table 1. Media accident text data source information

Data source	Data type	Raw data	Valid data
Sina Weibo	Social media	127	107
Security management network	Professional website	284	252
Toutiao	News portal	175	161
China news network	News portal	144	97

4.2 Data analysis

In order to examine a significant amount of media accident texts that may be appropriate for our four-dimensional model analysis, we employ NLP algorithms to group these samples of media texts. This process allows us to identify 11 main clusters and carry out additional quantitative calibration of other components. In conclusion, we provide an overview of the distribution and classification criteria for four dimensions, nine categories, and seventeen variables.

Table 2. Cluster analysis results

Cluster	Content description	Samples
1	Peripheral area	Elevator, fountain, water, park, railway, parking lot, pool, construction site, curve...
2	Streetscape skeleton	Buildings, windows, traffic lights, sidewalks, lighting, garbage cans, greenery...
3	Core object	Children, primary schools, kindergartens, teenagers...
4	Relevant group	Parents, staff, elderly, adults, guardians, lifeguards, medical staff, passers-by...
5	Commercial form	Canteens, libraries, parks, residences, shops, business districts...
6	Aggressor specification	Motorcycles, cars, electric cars, vans, bikes, scooters, gangs, assaults, buses, tricycles...
7	Accident result type	Drowning, falling, electrocution, trapped, heat, suffocation, crevices, poisoning, burns...
8	Accident result severity	Fracture, death, injury, casualty, death toll, trauma...
9	Safety education	School, parents, education, reminder, psychology, publicity, teaching quality...
10	Community governance	Police, public security, jurisdiction, police station, Public Security Bureau...
11	Basic news information	Time of incident, time of publication, media source...

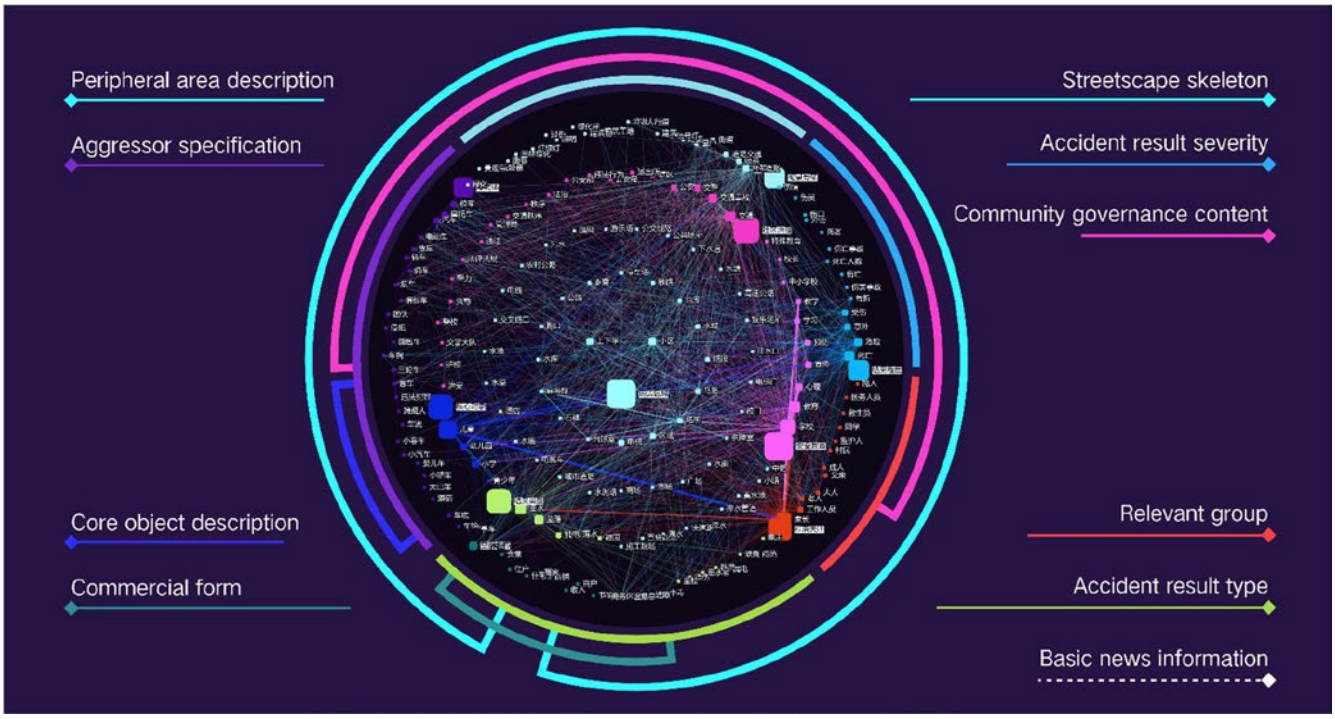


Figure 3. Media text lexical network diagram.

After word frequency cluster analysis and visualization of 617 media texts using Latent Dirichlet allocation (LDA), this paper finds that the following 11 types of information are fully covered in media texts, as shown in Table 2. The result type and result degree are accident dependent variables. Community governance and safety education have nothing to do with the focus of this study, but are related variables. The remaining six clusters belong to accident independent variables. Therefore, the relationship between these 6 types of independent variables and accident type and severity can be obtained through media investigation.

5. Result

5.1 Output factor of security situation judgment

By combing through the media texts, this paper identifies the six most important and common types of children's outdoor space activities, and the clear definition of the types of hazards provides an important basis for further safety research and preventive measures, see Table 3.

Table 3. Common outcome factors of children's outdoor activities safety accidents.

	Factor	From cluster	Classify	Introduction
Y1	Accident type	7	6	Falling or falling from a height
			5	Mechanical injuries, such as collisions, beatings, car accidents
			4	Falling into the water or choking
			3	Electrical injury
			2	scald
			1	Biological damage such as poisoning
Y2	Accident severity	8	3	Cause death
			2	Cause non-fatal injuries
			1	No casualties

5.2 Input factor of security situation judgment

Ideally, we want to be able to take full advantage of big data technology and integrate information from all the independent and dependent variables to build a model that can predict the dependent variables. However, after conducting media research, we found that these elements need to be grouped into two categories based on their source. The first category is elements taken directly from the news text that can be used directly to build relationships between elements and event outcomes, classified by enumeration in this section.

Table 4. Influencing factors of Children's Active School Commuting environmental safety based on media text.

	Factor	From cluster	Classify	Introduction
P1	Road type	1	3	Highways, traffic hubs, parking lots and other vehicle gathering places
			2	Special or non-standard roads such as mountain roads, village roads, bridge
			1	Standard urban street
			0	Not urban road accidents
P1	Prominent features of surrounding area	2	4	Crowded places such as downtown, urban center area and business districts
			3	Water bodies such as swimming pools, rivers, ponds and surrounding areas
			2	Site with roof, slope, high wall, fencing, or deep holes
			1	Isolated or enclosed spaces
			0	Not mentioned
P2	Time	11	2	Daytime (7:00-19:00)
			1	Night (19:00-7:00 the next day)
S1	Commercial form	5	5	Comprehensive function area
			4	Industrial functional areas such as chemical factory
			3	Commercial function area
			2	Green area
			1	Residential community and campus area
			0	Not mentioned
C1	Age	3	4	Adult (over 18 years old)
			3	Youth (13-17 years old)
			2	Children (7-12 years old)
			1	Infant (0-6 years old)
			0	Multiple ages included
C2	Connection type	4	1	Accompanied or supervised
			0	Unaccompanied or unsupervised
I1	Aggressor	6	4	Motor vehicle
			3	Non-motor vehicle
			2	criminal
			1	Natural object
			0	Not mentioned

Although there is a lot of information in media texts about many different types of events that can be used as useful examples for safety study, they are still not able to fully explain what causes crashes. according to the four-dimensional model, it is not possible to conduct a comprehensive quantitative analysis merely on the types of components included in media

material. We utilised safety research models and tools to accurately measure the influence of element information on safety that is not addressed in media texts. It adopts an affirmative approach to reference this data and proposes a comprehensive three-level classification system to assess the severity of these factors on the safety of children's active school commuting (Y2). Thus, the components of the four-dimensional model are transformed using a consistent and measurable conversion.

Table 5. Additional factors added according to the four-dimensional model.

	Factor	Assignment grading	Data source	Assignment basis
P2	Pavement quality	1-3	Street image	STA-YOLOv7 algorithm
P3	Real-time distance	1-3	GPS data	Spatial familiarity/spatial distance
P3	Environmental disturbance	1-3	Street noise	Noise exposure dose-response relation
S2	Quality of residents	1-3	Statistical survey	Educational level
S2	Community economic level	1-3	Statistical survey	Per capita disposable monthly income
S2	Living convenience	1-3	POI data	Ease of living index
C1	Safety education	1-3	Statistical survey	Completion of safety education
C1	Coping ability	1-3	Statistical survey/test	Measurement of motor coordination
I2	Negative space probability	1-3	Statistical survey	Spatial vitality evaluation

5.3 Design strategy

In the natural process of handling danger, the effective completion of the risk response process depends on the seamless progression of the four linkages, see Figure 4. Children have a high probability of not being able to complete the action chain of the coping period by themselves, and parents or companions cannot help children through external forces, which is why children accidents will occur even if they are accompanied by parents.

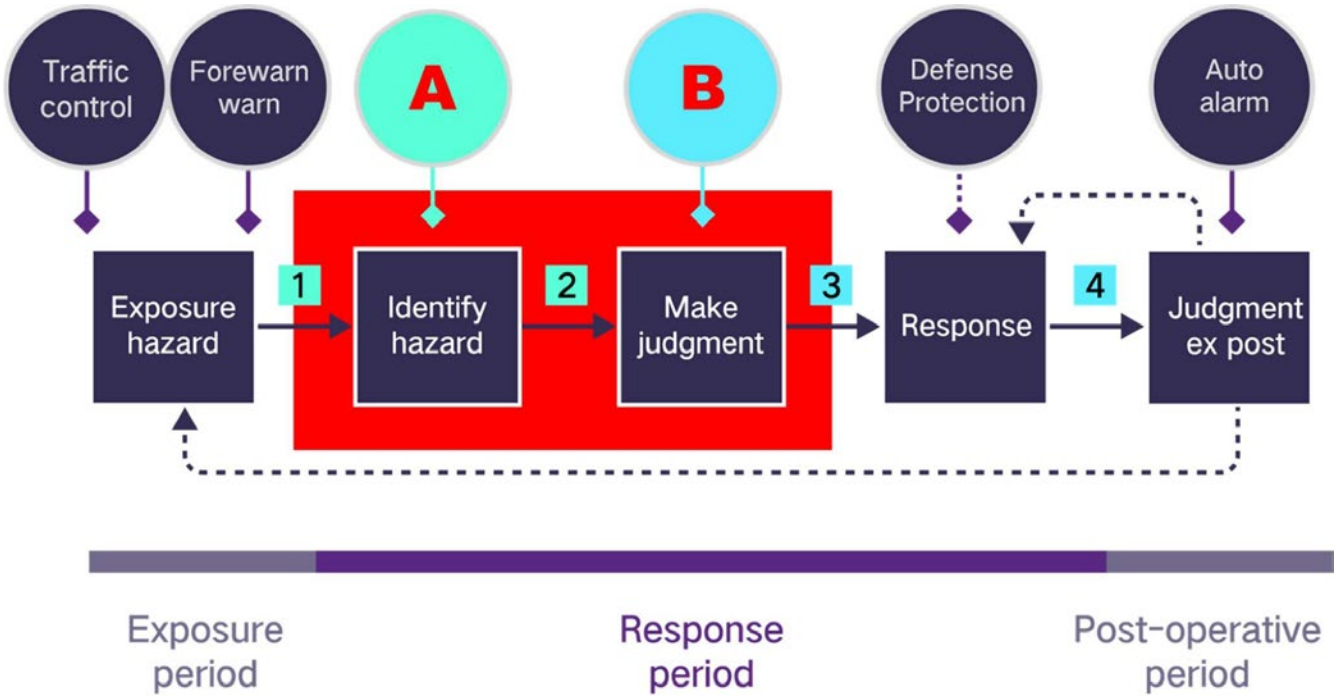


Figure 4. Design strategy derivation process.

Children, due to their limited experience and abilities, may encounter situations where they either overreact or fail to respond adequately. Hence, it is crucial to prioritise enhancing children's receptiveness to design intervention and their understanding of the objective world when designing kid safety measures. Hence, the objective of the design is to provide an intervention that can provide unambiguous action directives.

5.4 Intelligent perception

In order to improve children's safety reactions, a design method called "enhanced perception and graded intervention" was suggested after analysing the safety response action chain and existing safety design interventions. This study utilises the Python programming language, namely the Pandas and TensorFlow libraries. The training data is read and then the input variables and output results are separated. A basic neural network model is employed for

training, consisting of two hidden layers with a Rectified Linear Unit (ReLU) activation function, as well as an output layer. The model was compiled using the mean square error loss function and the Adam optimizer, and nine epoches were trained on the training set. In this paper, 504 pieces of data with complete and standardized media text structure are divided into training sets and verification sets. After the model is obtained, the segmented test set data is imported to verify the effect of the model. The X variable of these validation data points was input into the model to generate the corresponding predicted values of Y1 and Y2. By comparing with the actual values of Y1 and Y2, the performance of the model was preliminarily evaluated using the indicators of Accuracy, Precision and Recall.

Table 6. Model evaluation result.

Index	Value	Index	Value	Index	Value
Y1 accuracy	0.37	Y2 accuracy	0.66	Comprehensive accuracy	0.54
Y1 accuracy rate	0.52	Y2 accuracy rate	0.70	Overall accuracy	0.62
Y1 recall rate	0.44	Y2 recall rate	0.64	Combined recall rate	0.56

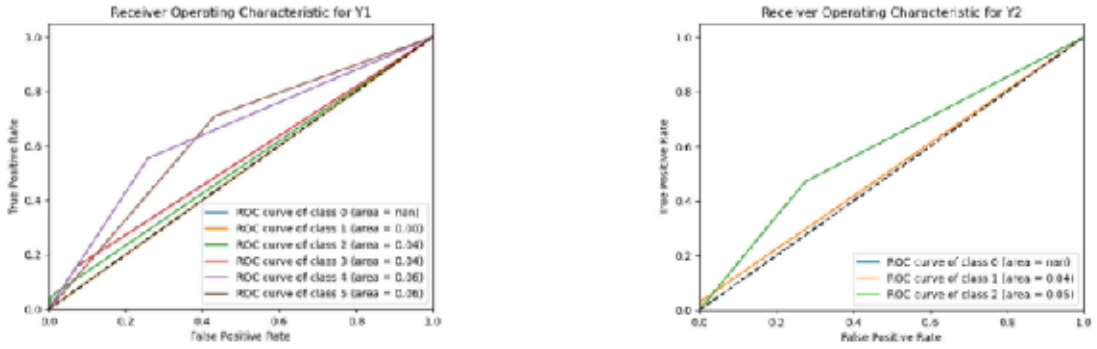


Figure 5. Receiver operating characteristic curve result.

However, the prediction effect of this model for different types of results is quite different, which may be due to the limited sample of valid media reports and the significantly higher proportion of mechanical injury (Y1=5) and high fall (Y1=6) accident types.

Table 7. Training set data classification frequency statistics.

Category	Frequency	Percent	Category	Frequency	Percent	Category	Frequency	Percent
Y_1=1	9	2.23%	Y_1=3	24	5.96%	Y_1=5	215	53.35%
Y_1=2	29	7.20%	Y_1=4	62	15.38%	Y_1=6	64	15.88%
Y_2=1	44	10.92%	Y_2=2	50	12.41%	Y_2=3	309	76.67%

Therefore, the prediction results of mechanical damage (Y1=5) with the largest amount of accident data in the training set were statistically analyzed in this paper. The prediction deviation was only 0.17, and the average deviation of Y2 was 0.22. The performance effect of accuracy, accuracy and recall rate was also better than the comprehensive evaluation effect of all types of accidents in the test set.

5. 5 Design implement

Based on the different levels of security posture, this study defines three levels of design intervention, aiming to provide different levels of protection and intervention for children's school commuting environment according to the degree and urgency of the security threat. Through the setting of these three design intervention functions, the design intervention can be accurately and effectively delivered based on intelligent perception, and effectively protect the safety of Children's Active School Commuting environment.



Figure 6. Design prototype of safety intervention in Children's Active School Commuting environment.

In the upper left corner of the field of view are the main functional areas, including mood artboards, volume and voice input control buttons, and contact functions, triggered by gesture clicks and voice interaction. The center of the visual field is the danger indication area. Under normal conditions, the danger indication area does not superimpose any content to ensure that children's users have a clear vision of the real environment. However, when a hazard occurs, the design content related to the hazard type, hazard labeling and action instructions will be displayed in this area. The information is located at the child's normal eye height, ensuring that the child can quickly receive the intervention information and directly observe the correspondence with the source of danger.

6. Discussion

The paper presents a conceptual framework consisting of four dimensions to identify the aspects that influence the safety of Children's Active School Commuting environment. The influential factors are categorised based on the binary opposition logic of subject and object, internal and external, which accurately and comprehensively represents the essence of ensuring the

safety of children's active school commuting environment. There might still be constraints in categorising the nine items within the four-dimensional model. The division of the nine elements preserves independence, while there is still a link between distinct elements. Nevertheless, appropriateness is the paramount factor in security prevention. While there may be a link in the analysis of individual aspects, it is important to examine the many directions of prevention and completely evaluate the reasons of risk from various perspectives in order to accomplish comprehensive and targeted security prevention objectives.

On the other hand, the drawback lies in the fact that the training data used to establish the association model between accident causes and accident outcomes in this study is derived solely from media accident reports. While this approach guarantees a substantial number of accident samples, it may have some limitations. Yet, the media accident data only covers a restricted range of variables. Therefore, this study provides a temporary summary of the safety situation by manually classifying and calculating parameters that are not included in the media data. Future research should incorporate additional urban data, gather more extensive and detailed information on safety factors in accident statistics, develop comprehensive datasets that link factors to accident outcomes, construct a comprehensive database of urban children accidents based on the four-dimensional safety framework, and refine a more precise safety situational awareness model through training.

7. Conclusion

The paper explores the concept of environmental safety planning and design in the context of the Children's Active School Commuting environment. The purpose is to outline the primary goals of planning and designing for environmental safety, along with the related fields of study. Then, by employing the notion of sufficiency and necessity in safety planning and design, the logic of categorising subjects and objects, as well as internal and external elements, is determined. To evaluate the adequacy of dimensions, the four quadrants of the two-dimensional coordinate system are defined, following the principles of safety planning and design. The conceptual foundation of the element model is originally built inside a two-dimensional coordinate system. In addition, a comprehensive set of nine components has been established for evaluating the safety of the Children's Active School Commuting environment.

This paper develops a theoretical foundation for a model that incorporates established theories and methods from relevant research domains in a comprehensive manner. This framework enhances the ability to precisely define the safety of Children's Active School Commuting environment. The fourdimensional framework establishes a basic relationship between the factors that contribute to and the consequences of guaranteeing the safety of children's active school commuting environment. The paper examines the use of new technologies to improve environmental space planning and design. The aim is to improve comprehension of child-friendly city principle, undertake thorough research on the safety of Children's Active School Commuting, and help for the planning and construction of safe community. Promote the development of unified and safe communities, while providing specialised knowledge in improving community governance skills and developing the creation of intelligent communities. We recognise the significance of precisely sensing ambient information and user state during the design process. This enables us to establish accurate assessments of security issues and systematically guide the development of intervention elements in the design. By taking this step, we guarantee that security interventions are adequate and effective.

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“ENSURANCE” ENVIRONMENTAL INSURANCE: RESEARCH AND PRACTICE BASED ON SOCIAL INNOVATION DESIGN

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ABSTRACT | “Carbon Peaking” represents a significant challenge for developing countries in balancing economic development with environmental issues. The lack of well-defined laws and regulations creates new creative spaces for financial services and sustainable development needs. This paper explores how financial insurance services can construct relationships between government regulation, corporate rights, and sustainable environmental development, thereby encouraging industrial enterprises to proactively implement green transformations. Through desktop research, in-depth interviews, and field surveys, this study comprehensively understands the main types of environmental pollution and the current state of protection in the region, and proposes new service models in conjunction with commercial market insurance behaviors. A named “ENSURANCE” environmental liability insurance service system platform was designed to facilitate a multi-win situation among residents, industrial enterprises, governments, and insurance companies. “ENSURANCE” promotes green technological innovation in industrial production through citizen oversight, government regulatory measures, and economic incentives, particularly via carbon trading, enhancing market competitiveness and environmental responsibility; simultaneously reducing pollution risks and improving regional environmental quality. “ENSURANCE” offers new approaches for policymakers and insurance practitioners entering the field of environmental protection, providing more possibilities for global environmental conservation.

KEYWORDS | DEVELOPING COUNTRIES, ENVIRONMENTAL PROTECTION, SUSTAINABLE DESIGN, ENVIRONMENTAL INSURANCE, SOCIAL INNOVATION

1. Introduction

With the escalating severity of climate change, global attention on environmental protection has intensified. The Paris Agreement, adopted in December 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), aims to limit global temperature rise to well below 2°C above pre-industrial levels and strives to keep the increase to 1.5°C. The Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC, 2021) highlights the urgent need to significantly reduce greenhouse gas emissions over the next decade to achieve carbon peaking by 2030 and carbon neutrality by 2050.

Developing countries face unique challenges and opportunities in meeting these goals (Sumiani et al., 2007). Key challenges include reducing emissions while sustaining economic growth, transitioning from fossil fuels to green energy, and closing technological gaps in low-carbon and zero-emission technologies (Yu et al., 2022). Additionally, efforts to achieve carbon neutrality are complicated by the degradation of natural carbon sinks due to deforestation, agricultural expansion, and coastal development. In recent years, with economic development and technological advancements, developing countries have made a series of improvements in environmental governance and regulatory measures, including industrial upgrades, public disclosure of environmental information, and civil society participation in decision-making. Despite some progress, there is still a lack of efficient coordination among different actors in society, as well as between different levels of government and local authorities (Li et al., 2021), in addressing the increasingly severe global environmental challenges (Rogelj et al., 2016).

This paper explores the potential of innovative financial services in supporting environmentally sustainable development in developing countries. Specifically, we examine how the "ENSURANCE" environmental liability insurance platform can bridge gaps between government regulation, corporate responsibility, citizen participation, and environmental sustainability, thereby promoting the green transformation of industrial enterprises.

2. Literature Review

Early economic theories generally posited that economic growth was inextricably linked to environmental degradation, particularly during the rapid development phase of industrialization. This perspective has been supported by numerous empirical studies, primarily based on the severe environmental pollution experienced by developing countries (Grossman and Krueger, 1995). The Environmental Kuznets Curve (EKC) hypothesis further refines this theory, suggesting that environmental pollution increases during the initial stages of economic development but decreases after reaching a certain income level, forming an inverted U-shaped curve (Stern, 2004). However, in recent years, scholars have proposed the theory of sustainable development, arguing that economic growth and environmental protection can achieve a win-win situation through green technologies and policy interventions (Wang and Feng, 2021). This theory emphasizes that innovative technologies and effective policies can significantly reduce pollution while promoting both environmental protection and economic development.

Environmental pollution liability insurance (or pollution insurance) emerged as a product of comprehensive liability insurance in the 1960s in industrialized countries, particularly in the United States, France, and Germany. Currently, there are two main types of pollution insurance worldwide: mandatory pollution insurance and voluntary pollution insurance (Feng et al., 2014). Many scholars believe that pollution insurance has significant advantages as an environmental regulatory tool (Krutova et al., 2021). Firstly, pollution insurance ensures that victims of pollution can receive compensation, even if the polluting company goes bankrupt. Secondly, pollution insurance can mitigate environmental risks by offering lower premiums to those who invest in risk reduction and preventive measures (Freeman and Kunreuther, 2003). Thirdly, as an insurance tool, pollution insurance spreads the risk and cost of environmental pollution across a group of polluters, protecting individual insured companies from bankruptcy (Yang and Zhang, 2022). In summary, pollution insurance serves two key functions: risk transfer and incentive mechanisms. By transferring potential environmental risks to insurance companies, it reduces the financial burden on enterprises. Additionally, by lowering premiums, it incentivizes companies to comply with environmental regulations, take preventive measures, and reduce the occurrence of environmental incidents (Shi et al., 2023). In contemporary China, studies have shown that the implementation of mandatory environmental liability insurance, compared to voluntary insurance, helps local governments quickly establish relatively mature pollution insurance systems (Feng et al., 2014;).

Social innovation design combines design thinking with social needs, proposing solutions to complex social problems through interdisciplinary collaboration and

innovative methods. Manzini (2015) studied several social innovation projects and found that incorporating design thinking and community participation can effectively enhance public environmental awareness and promote sustainable behavior. Mulgan et al. (2007) showed that through design thinking and social innovation, communities can better respond to environmental changes, improving disaster response and resilience. In recent years, social innovation design has demonstrated unique advantages in the field of environmental protection and sustainable development, driving social change and solving environmental problems (Batle et al., 2018).

3. Research Methods

This study employs a mixed-methods approach, including desktop research, in-depth interviews, and field investigations, to comprehensively understand the current state of environmental pollution in Ningde, a city in southeastern coastal China, along with its control measures, main types of environmental pollution, and existing protection measures. Data on water pollution, air pollution, soil pollution, and marine pollution were collected by searching academic databases and government reports, including the "China Environment Yearbook" and environmental quality reports published by the Fujian Provincial Environmental Protection Bureau.

In-depth interviews were conducted with 15 respondents, including environmental protection department staff, industrial enterprise representatives, insurance practitioners, and residents living around the industrial areas. These interviews were carried out face-to-face and via telephone, with the content recorded and transcribed to ensure data accuracy and completeness. Additionally, major industrial zones and coastal areas in Ningde were selected for field investigations to verify the actual situation of environmental pollution and the effectiveness of control measures, with on-site photographs taken for documentation.

Finally, qualitative analysis was conducted to code and perform thematic analysis on the text and image information obtained from the interviews and field investigations.



Figure 1. Tall chimneys emit industrial waste gas



Figure 2. Rivers around CATL electric vehicle factory

4. Research Findings

The study identifies four main types of environmental pollution in the Ningde area: water pollution, air pollution, soil pollution, and marine pollution (Zhou et al., 2018). Despite the implementation of existing policies and regulations, several challenges remain in effectively protecting the environment.

4.1 Water Pollution

Industrial wastewater, domestic sewage, and agricultural runoff are the primary sources of pollution. Due to insufficient treatment facilities, untreated or improperly treated wastewater is discharged into rivers and coastal areas. This leads to water quality degradation, posing significant risks to aquatic ecosystems and public health, affecting drinking water safety, and reducing biodiversity.

4.2 Air Pollution

The main sources of air pollution include industrial emissions, motor vehicle exhaust, and construction dust. The burning of fossil fuels in industrial activities and the increasing volume of motor vehicles significantly contribute to air pollution. Poor air quality has led to higher incidences of respiratory and cardiovascular diseases among residents, especially during peak industrial activity periods and traffic congestion.

4.3 Soil Pollution

Soil pollution is caused by the disposal of industrial waste, agricultural chemicals, and improper waste management. Heavy metals and persistent organic pollutants released during industrial activities accumulate in the soil. Contaminated soil adversely affects agricultural productivity and food safety, posing long-term risks to human health through the food chain.

4.4 Marine Pollution

Marine pollution results from land-based pollutants, maritime transportation, and fishing activities.
Industrial and domestic sewage discharged into coastal waters deteriorates the marine environment. Marine pollution disrupts coastal ecosystems, reduces fishery resources, and threatens the livelihoods of local communities.

4.5 Environmental Protection Measures

The Ningde municipal government has implemented several initiatives, including the construction of sewage treatment plants, waste management facilities, and air quality monitoring stations. Advanced technologies such as bioremediation and physicochemical treatment have been introduced. While these measures have improved environmental quality to some extent, challenges remain in facility management and maintenance.

Insufficient treatment capacity and weak enforcement of regulations hinder overall effectiveness. Strengthening regulatory enforcement, increasing public awareness and participation, investing in advanced pollution control technologies, and improving infrastructure management are essential to ensure long-term sustainability.

5."ENSURANCE" Environmental Liability Insurance Service System

To enhance overall environmental awareness among residents and ensure the sustainability of environmental protection, all stakeholders related to environmental interests are integrated into the "ENSURANCE" platform: promoting a rules-based approach to public participation (Johnson, 2010). This platform leverages resident supervision, government regulatory measures, and economic incentives— particularly through carbon trading—to guide industrial enterprises in green technological innovation, boosting market competitiveness and environmental responsibility. It aims to reduce pollution risks and improve regional environmental quality. The specific stakeholders, user journey map, and service blueprint design and analysis are as follows

5.1 Stakeholder Analysis

· **Government Departments:** Responsible for the formulation and implementation of regional environmental policies. Support the development of environmental liability insurance business and the carbon trading market through specific regulations.

· **Regulatory Agencies:** Oversee the insurance market to ensure that insurance products comply with industry standards and regulatory requirements.

· **Environmental Protection Organizations:** Act as policy advocates and disseminators of environmental knowledge. Promote higher awareness of environmental risks and guide public and corporate demand for environmental liability insurance.

· **Insurance Companies:** Direct providers of environmental liability insurance. Design and sell insurance products tailored to environmental risks.

· **Insured Enterprises:** Purchase corresponding environmental liability insurance as required by mandatory policies from relevant government departments. Manage environmental responsibility and risks.

· **General Public:** Beneficiaries of environmental liability insurance or those affected by environmental issues. Their demand for environmental policies and measures can indirectly influence the environmental insurance market.



Figure 3. "ENSURANCE" Service system stakeholders

5.2 User Journey Map

· **Opening the Application:** Users open the application to view the surrounding environmental conditions based on real-time monitoring data.

· **Viewing Environmental Data:** The application provides data displays for the current location, including air quality index and water quality indicators, allowing users to understand the current environmental situation promptly. Users can input an address or use GPS to locate and search for nearby chemical and other polluting enterprises. The platform displays the environmental protection measures and emission information of these enterprises.

· **Reporting Pollution:** When users detect pollution, they can use the application to take photos and record the pollution source. The system automatically identifies the type of pollution and provides corresponding pollution control toolkits, guiding users on preliminary handling. Users submit the pollution report through the application, including detailed pollution data and photo evidence. The platform system sends the report to relevant departments, initiating the treatment process.

· **Tracking Rectification Information:** Users can track the progress of pollution reports within the application, learning about the implementation of corrective measures. The platform provides updates on rectification information, ensuring that users are informed of every step in problem resolution.

· **Submitting Environmental Credit Applications:** Enterprises and individuals can submit environmental credit applications through the application. The system evaluates their environmental behavior and credit status. Based on the evaluation results, the platform grants environmental credit ratings and offers related benefits and rewards, such as loan discounts and policy support.

Through these features and processes, the service system not only improves the efficiency of environmental monitoring and management but also enhances user engagement and responsibility through interaction and incentive mechanisms, promoting sustainable environmental development.

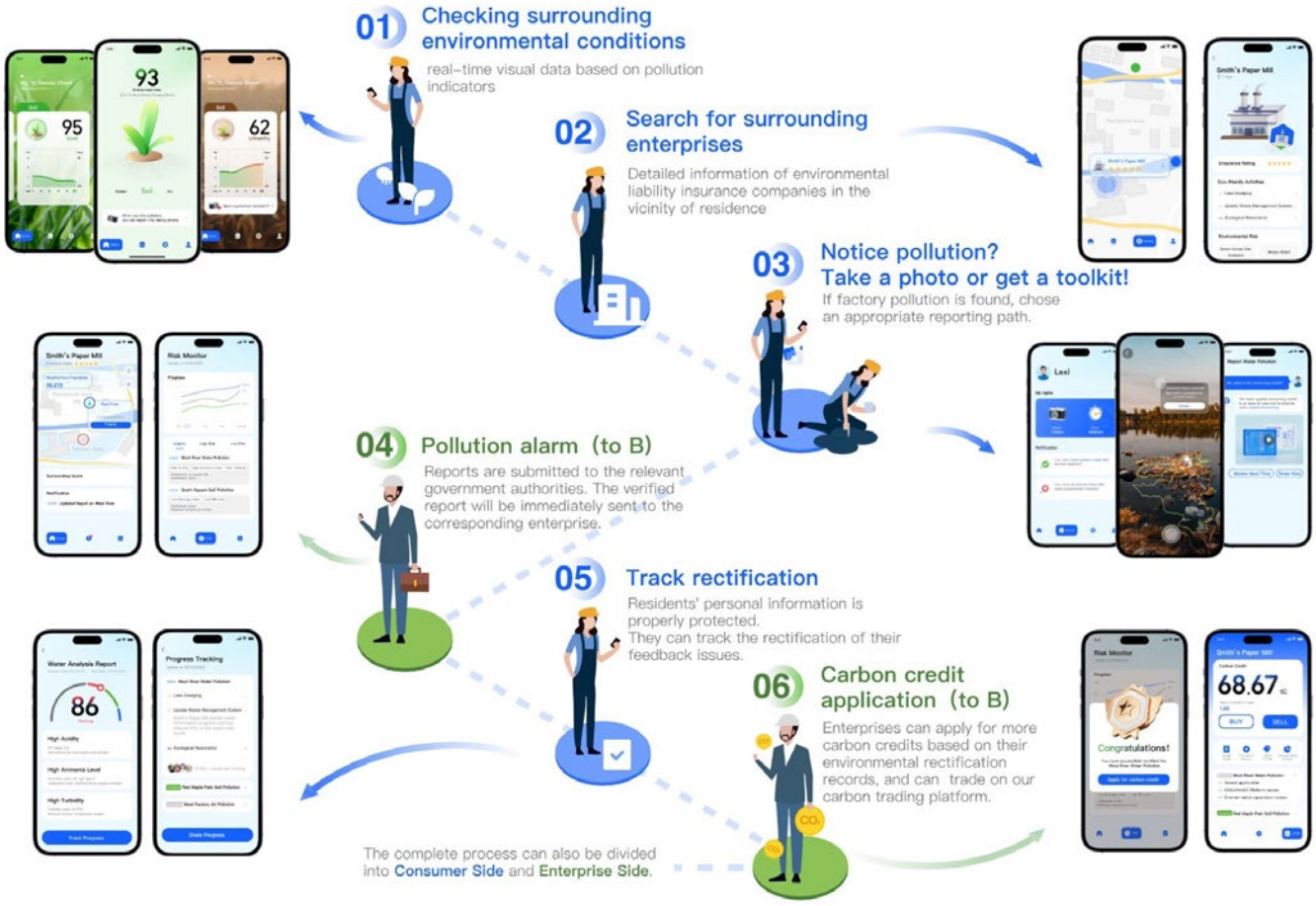


Figure 4. "ENSURANCE" User Journey Map



Figure 5. "ENSURANCE" User Guide for System Usage

5.3 Service System Blueprint

The "ENSURANCE" Environmental Liability Insurance Service System comprises three main service stages: Information Acquisition, Basic Services, and Advanced Services. Each stage encompasses five levels: User Journey, Front-End Interaction, Technical Support, Back-End Interaction, and Policy Support.

Information Acquisition Stage

- **User Journey:** Users access the system to learn about the surrounding environment and nearby enterprises' insurance information.
- **Front-End Interaction:** The system uses environmental information visualization technology to provide daily environmental risk reports.
- **Technical Support:** The system collects and processes environmental data, ensuring up-to-date information is available to users and enterprises.
- **Back-End Interaction:** Coordination between the system and environmental data sources to deliver accurate reports.
- **Policy Support:** Government regulations and guidelines ensure the system delivers necessary environmental information and supports awareness.

Basic Services Stage

- **User Journey:** Users detect pollution, take photos, and upload them to the system along with a submitted toolkit for initial response.
- **Front-End Interaction:** Users use image recognition technology and professional environmental sample analysis to report pollution.
- **Technical Support:** The system identifies pollution types, collects information on surrounding enterprises, and processes user submissions.
- **Back-End Interaction:** The platform pushes daily rectification progress reports from enterprises, ensuring users are informed about the implementation of corrective measures.
- **Policy Support:** Policies enforce transparency in environmental management, requiring enterprises to provide rectification progress reports.

Advanced Services Stage

- **User Journey:** Users achieve personal carbon neutrality through environmental public welfare activities, and enterprises benefit from carbon trading incentives.
- **Front-End Interaction:** The system facilitates user participation in public welfare activities and provides access to the carbon trading platform.
- **Technical Support:** The system conducts environmental impact analyses and supports financial consulting and trading for enterprises on the carbon trading platform.
- **Back-End Interaction:** Continuous analysis and reporting on the effectiveness of environmental protection measures and carbon trading activities.
- **Policy Support:** Carbon trading incentive policies support enterprises in their green transformation efforts, providing financial and regulatory backing.

Through these stages, the "ENSURANCE" system not only enhances the efficiency of environmental monitoring and management but also promotes user engagement and accountability. This comprehensive approach ensures sustainable environmental development by integrating real-time data, user interaction, and policy support.

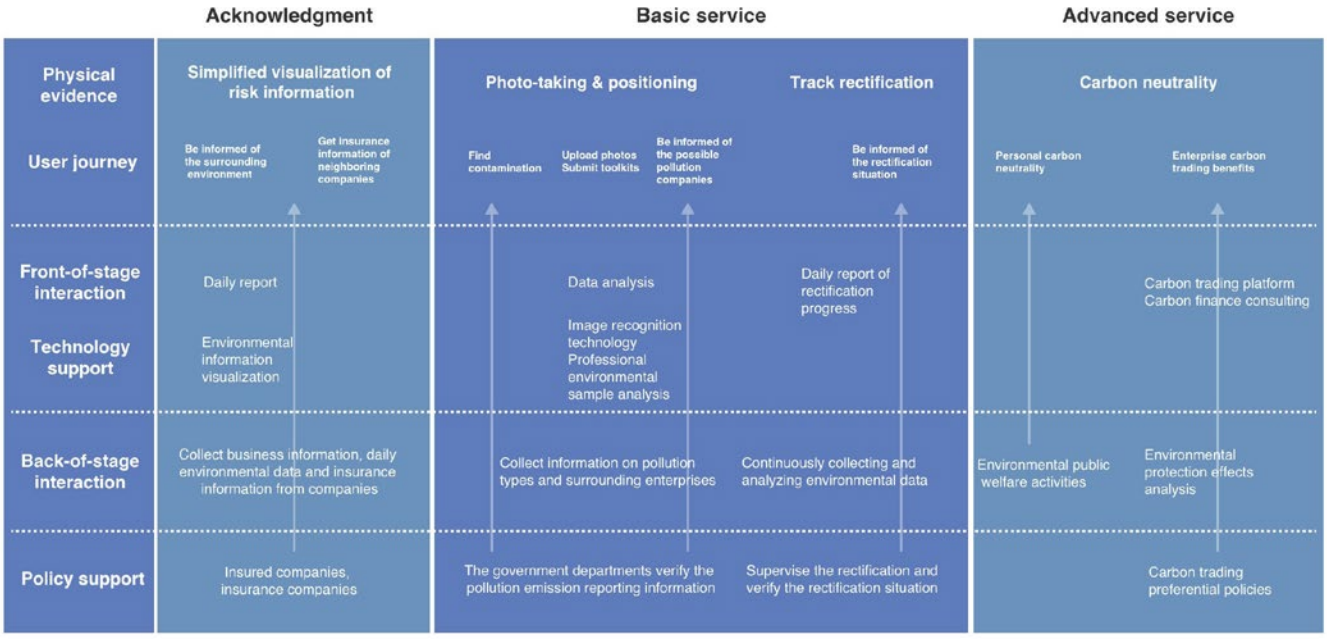


Figure 6. "ENSURANCE" Service System Blueprint

6. Conclusion

This study highlights the major environmental challenges faced by regions in developing countries like China, including water pollution, air pollution, soil pollution, and marine pollution. Despite existing policies and measures, there is still room for improvement in effective regulatory enforcement, public participation, and technological innovation.

The "ENSURANCE" environmental liability insurance platform offers an innovative approach by bridging the gap between government regulation, corporate responsibility, and environmental sustainability. By leveraging resident supervision, government incentives, and carbon trading mechanisms, "ENSURANCE" has, to some extent, promoted green technological innovation and enhanced overall public environmental responsibility.

Future research should focus on improving the "ENSURANCE" model, exploring its applicability in other regions, and evaluating its long-term impact on environmental sustainability. Policymakers and practitioners can benefit from the insights provided by this study to develop more comprehensive and effective environmental management strategies.

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RESEARCH ON HEALTH DETECTION PRODUCT DESIGN BASED ON AFFORDANCE AND TRADITIONAL CHINESE MEDICINE (TCM) WELLNESS CONCEPTS

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ABSTRACT | This study explores the dynamic interactions among individuals, health monitoring products, and the environment under the backdrop of Traditional Chinese Medicine (TCM) preventive healthcare. The main goal is to analyze user experience components related to health monitoring products influenced by TCM wellness trends, exploring subconscious interaction methods to deepen the connection between users and products. Methodologically, this research uses the TCM Four Diagnostics Device and TCM Thermal CT as examples, relying on sample records and user interviews to identify operational challenges and user expectations during the health monitoring and wellness process, thereby clarifying users' experience needs. To achieve this goal, the study integrates TCM wellness concepts to deeply explore the affordance design strategies of health monitoring products, covering aspects such as form, interaction experience, and service innovation, culminating in the practical design of TCM wellness health monitoring products.

KEYWORDS | THEORY OF AFFORDANCE, TRADITIONAL CHINESE MEDICINE WELLNESS CONCEPTS, HEALTH DETECTION PRODUCT DESIGN

1. Introduction

Over time, Traditional Chinese Medicine (TCM) wellness has seen significant advancements in its concepts, usability, and human-computer interaction, expanding its role beyond traditional healthcare in contemporary Chinese society. Today, TCM wellness has evolved into an integrated health management approach that combines personal health monitoring with lifestyle adjustments, leading to the concept of "lifestyle-based health management." Due to the complex individual differences inherent in TCM diagnostic and treatment processes, health monitoring products must provide more personalized and precise services.

This paper introduces the concept of "affordance" from the perspective of ecological psychology to explore the user experience elements in the design of health monitoring products based on TCM wellness principles.

2. The Role of Affordance in User Experience Systems

Donald Norman redefined the concept of affordance in his series of books on design psychology, thereby introducing the concept into the design field (Norman, 1990). In subsequent research, Norman further explained that the reciprocity of affordance in product design is manifested as "physical constraints," which facilitate or inhibit certain user behaviors to inspire user needs. Based on Norman's research, Rex Hartson extended the classification of affordances, defining and using four types: cognitive affordance, physical affordance, sensory affordance, and functional affordance (Hartson, 2003, p.315). Many scholars have further elaborated on these classifications:

- Cognitive affordance helps users recognize and understand the design features of a product, providing cues on how to use it.

- Sensory affordance refers to design features that can be perceived by users through senses such as sight and hearing.

· Physical affordance helps users perform actions within the interface.

· Functional affordance involves design features that assist users in completing actions, representing purposeful action design.

Jordi Vallverdu introduced the concept of emotional affordance in the study of humancomputer interaction, suggesting that users experience emotional responses when perceiving the affordance characteristics of a product. Therefore, emotional affordance refers to design features that provide emotional satisfaction to users during interaction (Vallverdu, et al, 2018, p.78).

In the field of communication studies, Leonardi and other scholars view affordance as the potential for technology to influence daily life, such as the various functions provided by the internet and the potential characteristics of using technology to conduct actions (Leonardi, 2011, p.147). Therefore, in the design field, technological affordance can refer to design features that rely on technology, such as user experiences generated through the application of new technologies.

In user experience research, it is widely accepted that user experience should focus on three aspects: the user, the product, and the interactive environment. Among the definitions, ISO 9241-210 provides the most influential one: it describes user experience as the reactions and outcomes that individuals have when using, or anticipating the use of, a product, system, or service. The user experience process is influenced by a variety of factors, such as the user's psychological state and the context, making the process inherently uncertain due to the diversity and complexity of these factors. This uncertainty often leads to user experience being perceived as a subjective sensation that is challenging to design directly.

Therefore, this paper introduces the concept of "affordance" into the analysis of user experience. The core of the affordance concept focuses on the relationship between people and objects in specific contexts. By incorporating affordance theory, there is an opportunity to translate subjective user experiences into objective elements within the product or environment. This approach provides valuable design strategy guidance for enhancing product interaction and improving user experience.

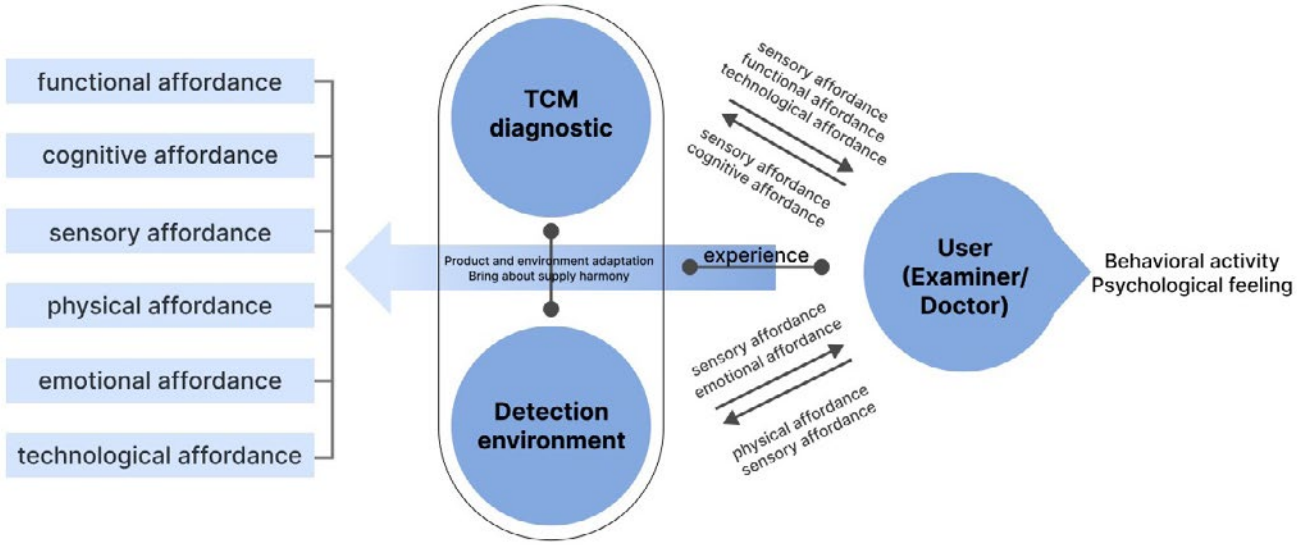


Figure 1. Affordance theory in user experience

3. The Role of Traditional Chinese Medicine (TCM) Wellness Concepts in Health Management

With the accelerated pace of modern life and increased work stress, sub-health conditions have become a common issue affecting many people today. The TCM concept of "preventing disease before it occurs" (治未病) utilizes body constitution identification to understand an individual's current health status. If a person is in a sub-health state, personalized adjustments and optimization based on their constitution can help prevent diseases and maintain or improve health. This approach supports individualized health improvement and enhances quality of life.

In 2009, the China Association of Chinese Medicine established the "Standard for Classification and Determination of TCM Body Constitutions" (ZYYXH/T157.2009), which was implemented on April 9 of the same year. As illustrated in Figure 2, this standard, based on Wang Qi's nine-type classification method, divides body constitutions into nine categories and specifies the characteristics and determination rules for each type (Wang Qi, 2005, p.5). The development and implementation of this standard have laid the foundation for the development of TCM health assessment products.

Currently, TCM body constitution identification is widely applied in clinical settings, epidemiological surveys, health management, and public health. Yang Lingling et al. "added TCM body constitution identification to routine physical examinations for 207 individuals, finding that it increased the detection rate of sub-health conditions and potential health risks, effectively addressing the shortcomings of routine check-ups" (Yang Lingling, et al, 2018, p.4595).

Jia Danbing et al. "discussed the characteristics of body constitutions in patients with impaired glucose regulation, fatty liver, hepatitis B, hyperthyroidism, and hypothyroidism, discovering that body constitution identification can provide insights into the balance of Qi, blood, Yin, and Yang, offering new perspectives for clinical diagnosis and treatment" (Jia Danbing, et al, 2014, p.2037).

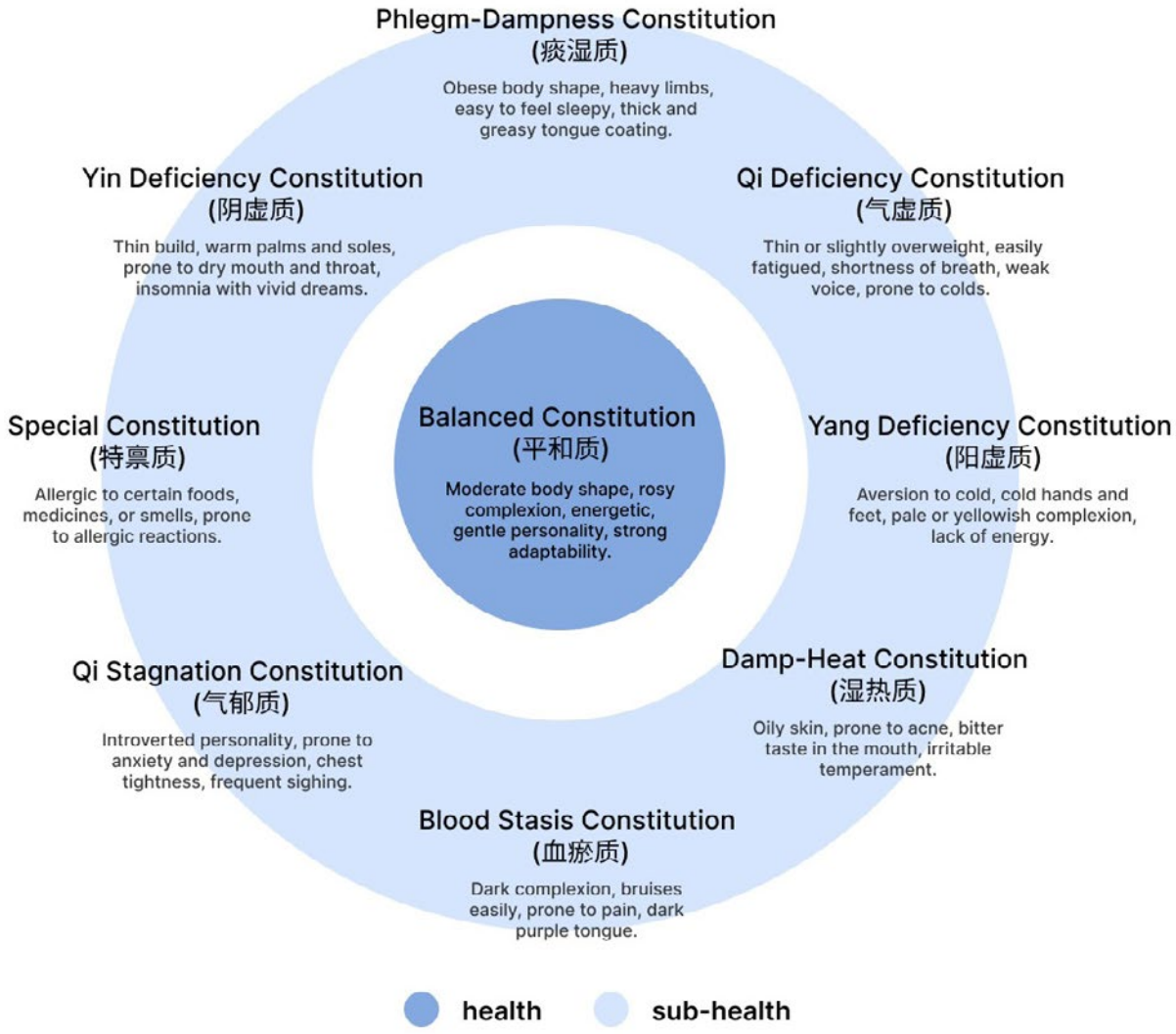


Figure 2. Classification of the constitutions of TCM

4. Current State of User Experience with TCM Health Monitoring Products

Traditional Chinese Medicine (TCM) diagnostic methods encompass observation (望), listening and smelling (闻), inquiry (问), and palpation (切诊), collectively known as the Four Diagnostic Methods (四诊合参). Health monitoring products developed based on TCM diagnostic principles act as a bridge between traditional medicine and modern technology. These products integrate TCM concepts with contemporary health assessment technologies, aiming to help users better understand and manage their health conditions, as shown in Figure 3.

TCM diagnostic	Specific expression	Health testing product	Extent of application
Inspection	This involves observing the patient's general appearance, including their facial complexion, body shape, posture, and behavior. The practitioner also examines the tongue and its coating.	**Facial Diagnosis Device:** It classifies physical signs by objectively and intelligently analyzing facial complexion, facial luster, and lip color.	Commercial and Clinical Applications: Integrated into the Four Diagnostics Device in a modular format.
		Tongue Diagnosis Device: It diagnoses TCM syndromes based on the characteristics of tongue color, tongue shape, and tongue coating.	Commercial and Clinical Applications: Integrated into the Four Diagnostics Device in a modular format.
		Ocular Diagnosis Device: It performs intelligent analysis and completes health assessments based on the characteristics of spots and blood vessels in the scleral area of the eyes.	Academic Research Phase
		TCM Thermal CT: Using infrared thermal imaging technology, it captures infrared thermal images formed by the metabolic heat sources of the user's body tissues and cells. These images assist in TCM constitution classification based on the body's cold, heat, deficiency, and excess characteristics.	Commercial and Clinical Applications
Listening and Smelling	This involves listening to the patient's voice, breathing, and coughing sounds, as well as smelling any body odors or breath odors that might indicate certain conditions.	**Voice Diagnosis Device:** The subject vocalizes specified sentences or syllables in a low-noise environment (below 30 or 45 decibels). The experimenter collects these sound signals with professional recording equipment. The data is then denoised, sampled, and audio features are extracted. Consistent low-noise sound information is obtained, and pathological diagnosis is conducted through modeling and analysis.	Academic Research Phase
		Olfactory Diagnosis Device: It analyzes the patient's exhaled breath. The process primarily includes three steps: gas sampling, gas composition analysis, and disease diagnosis.	Academic Research Phase
Inquiry	This involves asking the patient about their medical history, symptoms, lifestyle, diet, emotional state, sleep patterns, and other relevant information.	**Constitution Identification Questionnaire:** It uses a standardized syndrome diagnosis questionnaire to collect health information from users through a Q&A format. Based on data analysis, it identifies the user's TCM constitution.	Commercial and Clinical Applications: Integrated into the Four Diagnostics Device in a modular format.
Palpation	This involves feeling the patient's pulse at various points on the wrist and palpating specific areas of the body to detect any abnormalities in temperature, texture, tenderness, and masses.	**Pulse Diagnosis Device:** Sensors are placed on the measured area to collect pulse signals and convert them into electrical signals. These signals are amplified and recoded, or converted into digital form for computer processing. The data is then analyzed for pulse wave characteristics and used for diagnosis.	Commercial and Clinical Applications: Integrated into the Four Diagnostics Device in a modular format.
Four Diagnostics Device	Four diagnostic methods of Inspection, Listening and smelling, Inquiry and Palpation were performed at the same time.	**Four Diagnostics Device:** This device operates through various modules, capturing tongue images with a camera, conducting inquiries through a constitution identification questionnaire, and measuring the pulse with sensors. All data is analyzed by the system, and a report is generated to assist doctors in making diagnoses.	Commercial and Clinical Applications

Figure 3. Health testing products combined with traditional Chinese medicine

In China, a variety of TCM body constitution identification systems and products are available, primarily used in hospital preventive medicine departments and TCM wellness centers to assess users' constitutions and provide corresponding health services. However, due to limited public awareness and design shortcomings that overlook users' cognitive load and emotional needs, these products often fail to meet user requirements accurately, resulting in unsatisfactory user experiences.

To assess and optimize the user experience of TCM health monitoring products, this study utilized methods including user interviews, field observations, and sample recordings. In-depth interviews were conducted with 13 experienced users and 10 TCM practitioners, and observational data was collected from 59 participants across various cities such as Xi'an, Shanghai, Nanjing, and Changsha. The study tracked users' interactions with TCM health monitoring activities, as depicted in Figure 4.

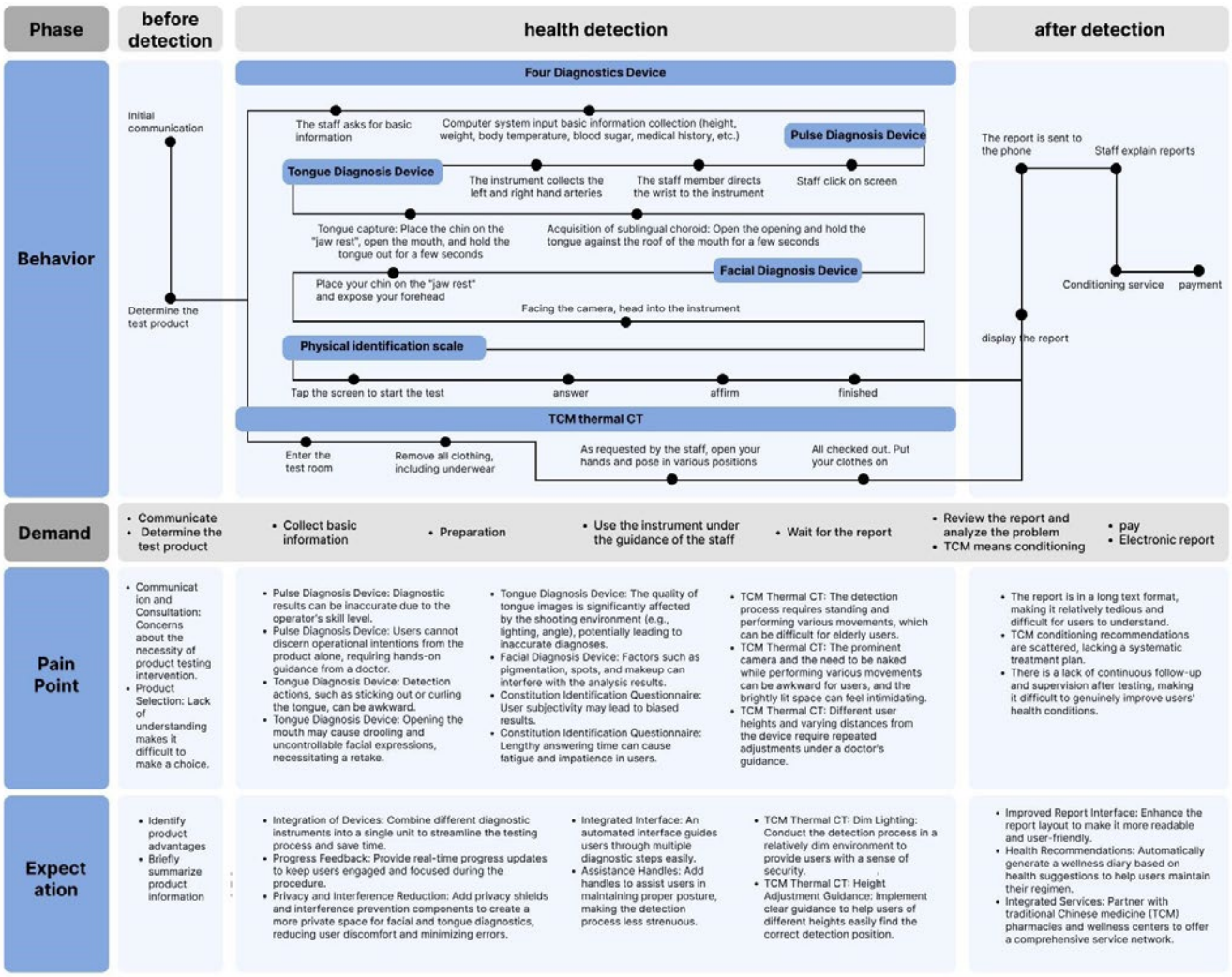


Figure 4. TCM health testing user journey map

The personal TCM health monitoring process primarily involves information inquiry, data recording, constitution analysis, and lifestyle adjustment recommendations. Through a comprehensive analysis of subjective feedback and both conscious and subconscious user behaviors, the user experience was examined from six affordance perspectives: functional affordance, cognitive affordance, physical affordance, sensory affordance, emotional affordance, and technological affordance.

· Functional Affordance: While the devices generally offer a complete set of features, the complexity of some functions may lead to operational difficulties, reducing ease of use and practicality. Many devices are used independently and lack integration, making it challenging to form an efficient and streamlined detection process.

· Cognitive Affordance: Users often lack an intuitive understanding of device operation logic and result interpretation. For instance, the lack of direct operational guidance

for adjusting the pulse diagnostic device and TCM thermal CT can lead users to frequently seek external help, affecting the efficiency of the detection process and user autonomy.

· Physical Affordance: Devices such as facial diagnostic instruments and TCM thermal CT fail to accommodate diverse body sizes, requiring users to make multiple adjustments to fit, which increases operational difficulty and affects the smoothness and comfort of the user experience.

· Sensory Affordance: The devices lack adequate auditory or visual feedback during operation. For example, the pulse diagnostic device lacks progress feedback, and the operation instructions for the TCM thermal CT are not sufficiently clear. This deficiency makes it difficult for users to determine whether they have completed the operation correctly, leading to a lack of confidence, anxiety, and confusion.

· Emotional Affordance: Devices like the tongue diagnostic instrument and pulse diagnostic device can cause discomfort due to awkward positioning or prolonged fixed stances. The TCM thermal CT, which requires users to expose themselves, can induce anxiety and discomfort due to overly bright environments and visible cameras, increasing psychological burden.

· Technological Affordance: The technical accuracy and stability of devices such as the facial diagnostic instrument, tongue diagnostic instrument, and TCM thermal CT are limited. Variations in lighting conditions can impact result accuracy, decreasing user trust in the results. Additionally, the current inability of TCM thermal CT technology to perform non-invasive clothed assessments increases users' psychological burden. Advances in this area could reduce this burden and enhance user experience.

5. Affordance Design Strategies for TCM Health Monitoring Products

Based on user surveys, we have identified key pain points and expectations related to TCM health monitoring products. To align with affordance design principles and better reflect the tenets of traditional Chinese health management, we have re-evaluated and refined the design strategies for these products as follows:

· Functional Affordance: Integrate diagnostic functions into a unified system that combines tongue, facial, and pulse diagnostics. This approach reduces the number of steps required and simplifies the operational complexity for healthcare providers. Additionally, optimize the functionality of components such as facial and tongue diagnostic devices to minimize the impact of external conditions on diagnostic accuracy.

· Cognitive Affordance: Provide clear cognitive guidance and feedback to ensure users can intuitively understand how to use the product and its functions, thereby reducing cognitive load. Utilize clear icons, color coding, and animations

on the interface to guide users, ensuring that information is presented in an easily comprehensible manner to minimize learning curves and operational errors.

· Physical Affordance: Design an intuitive user interface and enhance ergonomic features to simplify product use. This will make the devices accessible to elderly users and those unfamiliar with technology, ensuring ease of operation and comfort throughout the diagnostic process.

· Sensory Affordance: Incorporate visual and auditory feedback to enhance multi-modal sensory interactions. This will boost user confidence and make the diagnostic process more engaging and interactive.

· Emotional Affordance: Integrate elements of TCM culture into the design to strengthen emotional and cultural connections. Provide interactive prompts that reflect TCM philosophy and create a warm, relaxing environment through thoughtful spatial design and interaction methods. This will help users feel comfortable, secure, and culturally validated during the diagnostic process.

· Technological Affordance: Reduce errors caused by user operations and environmental conditions through well-considered design, thereby improving diagnostic accuracy. Additionally, offer multilingual support and interfaces tailored to various user proficiency levels, including guided operations for beginners and customizable options for advanced users.

5.1 Integration of Product Functions and Unconscious Design to Optimize User Experience

To minimize cognitive and physical burdens for users of TCM health monitoring products, we have integrated the functionalities of pulse diagnostic instruments, tongue diagnostic devices, facial diagnostic tools, and TCM constitution assessment scales into a unified design. This integration streamlines the operational steps and enhances the overall fluidity of the diagnostic process. By reimagining the product's appearance and structure, we enable users to complete multiple tests through simple actions, thereby mitigating result deviations caused by improper use. For example, in the TCM thermal CT, we have designed various handles to physically guide users into the correct posture; similarly, the TCM Four-Diagnosis Instrument includes humansized features to assist users in performing tests with greater accuracy and comfort. These design enhancements aim to reduce cognitive load, improve overall user-friendliness, and simplify operation for elderly users.

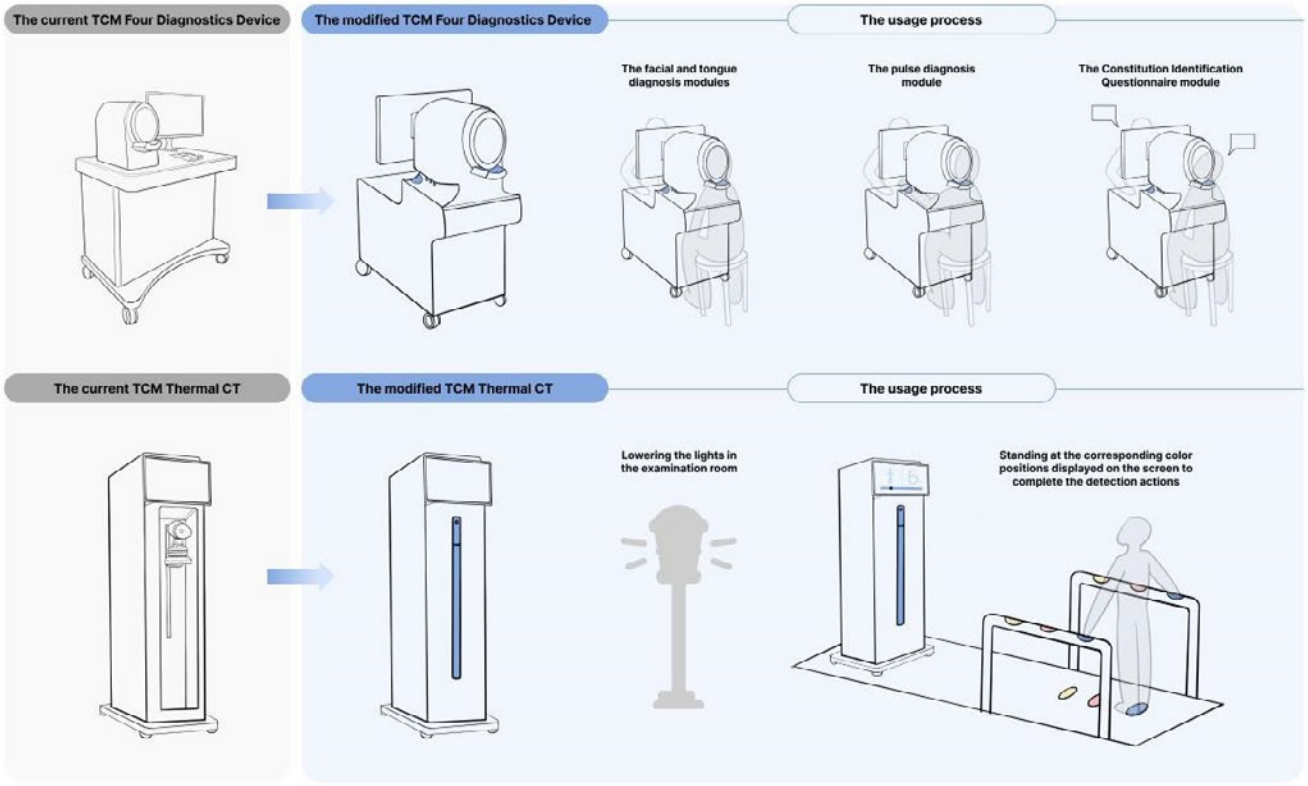


Figure 5. Design of TCM health monitoring products based on affordance design strategies.

5.2 Enhancing Sensory and Emotional Affordance to Strengthen Emotional and Cultural Connections

Enhance multimodal sensory interaction to improve user confidence and satisfaction. Increase the sound of successful operation and error warnings during the testing process to instantly correct operational errors and improve the accuracy of testing. The interface is equipped with clear signs and operating guidelines, using simple and clear language and diagrams to help users easily understand the upcoming operation steps and reduce the anxiety caused by uncertainty. The testing environment incorporates TCM cultural elements, such as the use of traditional patterns and colours, as well as the provision of interactive prompts rich in TCM philosophy, to enhance the user's emotional experience and sense of cultural identity. In addition, the camera of the TCM Thermal CT is hidden to ensure that the testing process is dimly lit to alleviate the embarrassment of naked testing and enhance the user's sense of security when using the product.

5.3 Improve service links to promote sustainable user experience

By integrating intelligent algorithms, user health testing data is automatically transformed into personalized wellness

advice and recorded in an easily accessible and manageable digital wellness diary. This approach helps users track their health status and wellness progress while increasing their engagement and sustainability in health management activities. The wellness diary provides a timeline view that displays trends in the user's health indicators, implementation of wellness recommendations, and assessment of their effectiveness. Additionally, establishing partnerships with Chinese herbal medicine and wellness centers can offer users a complete service chain from testing to healthcare. For instance, based on health test results, the system can recommend nearby Chinese herbal medicine halls or wellness centers and facilitate appointment scheduling. This cooperation not only helps users implement and follow up on healthcare recommendations but also brings potential customers to partner organizations, forming a mutually beneficial and win-win business model.

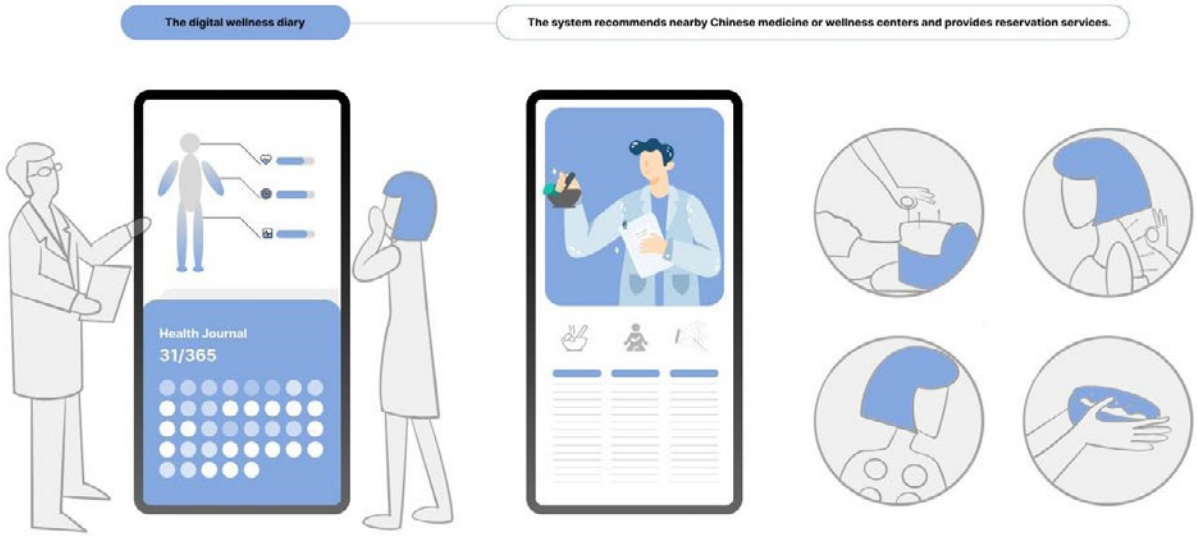


Figure 6. Extended services of TCM health monitoring products based on affordance design strategies.

6. Conclusion

Health testing products have evolved into multifunctional centers for personal health management, encompassing health testing, lifestyle adjustment, and cultural heritage, thereby providing diverse experiences. The emergence of health testing products based on the principles of Chinese medicine and health maintenance aligns with societal and lifestyle changes. From the perspective of ecopsychology's affordance theory, we derive design strategies to enhance the experience of health testing products across multiple dimensions, including functional, cognitive, physical, sensory, emotional, and technological aspects.

These strategies support the development of Traditional Chinese Medicine (TCM) health testing products in several key areas: integrated functional design, simple and accurate user interaction, multimodal sensory feedback, continuous service link experience, and the deep integration of emotion and culture. This approach emphasizes optimizing human-computer interaction, deepening the emotional connection between the user and the product, and promoting a greater understanding and practice of TCM health culture. Consequently, users not only enjoy an enhanced health testing experience but also deepen their identification with and appreciation of TCM culture through the product's use, achieving a harmonious integration of technology and traditional medicine.

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CROSS-CULTURAL DESIGN INNOVATION THROUGH TECHNOLOGY AND CREATIVITY.

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ABSTRACT | Over the past 15 years, a research collaboration has been established between several universities within the Latin Design Network as a Process, involving numerous academic exchanges and participation in international forums on topics such as design, biodiversity, territory, and emergencies. This collaboration culminated in the eighth forum in Bologna in 2022, focusing on "Disrupting Geographies in the Design World." The project explores innovation at the intersection of design, technology, and traditional craft across Colombia, Brazil, and Italy. Its primary aim is to bridge cultural gaps by incorporating modern technology to breathe new life into traditional art forms, focusing on transformative design practices and cross-border collaboration.

The project reflects the evolution of co-design from user-centered methodologies to co-creation, showing how contemporary technologies such as artificial intelligence, data visualization, and biocreativity can redefine traditional craftsmanship and educational practices. Designers act as mediators between knowledge, emphasizing interdisciplinary contamination to add complexity and developing collaborative and cross-disciplinary skills that foster creative innovation based on cultural diversity.

Through “Design Experience” modules, participants gain hands-on experience with innovative tools and methodologies. These workshops explore the potential of these technologies to enhance traditional crafts and foster new modes of artistic expression. The use of AI allows for unprecedented levels of data-driven creativity, while bio-creativity emphasizes sustainability through circular and local materials.

The outcomes of the workshops indicate a broader potential for AI and technology to reshape design and art fields, fostering unique design practices and creative exploration. The project emphasizes cross-cultural collaboration, uniting students, researchers, and artisans from different countries in shared learning and experimentation, leading to a comprehensive understanding of traditional crafts and innovative design processes.

KEYWORDS | CROSS-CULTURAL DESIGN, AI DESIGN, TECHNOLOGY, INNOVATION, TRADITIONAL CRAFT

1. Introduction

Over the past fifteen years, a partnership between the research team Advanced Design Unit of the University of Bologna and the Universidad Nacional de Colombia and University of Vale do Rio dos Sinos in Brazil has been consolidated through the Latin Network of Design as Process. This partnership has generated a shared research reflection, characterised by a strong link with the local territorial capital. This territorial capital is defined as a systemic set of material and immaterial factors and resources, including communities, entrepreneurs, landscapes, innovation capacity, traditions, technologies, infrastructures and skills.

For example, the network, through forums such as "Disrupting Geographies in the Design World" (https://www.forumdesignprocess.org/dgdw22/), has opened the space for design communities to share design perspectives and transitions, to imagine and create the future of design in accordance with the cultural diversity that characterizes communities around the world.

From this reasoning, a shared reflection has developed in recent years focused on the need to understand how new technologies can support design skills, promoting and enhancing local knowledge with a future vision. The research led to the collaboration of universities in the project "Frontier Design Innovation and traditional craft": an exploration, in the form of an educational format of a workshop and multidisciplinary nature, of the potential of the innovation process at the intersection of design, technology and traditional craftsmanship applied in Colombia, Brazil and Italy.

The exploration took the form of an international workshop, held between February and July 2023 in Italy and Colombia. The objective was to bridge cultural divides by incorporating technology to breathe new life into traditional art forms. Furthermore, the aim was to explore the potential of these technologies to improve traditional crafts in the three countries and promote new modes of artistic expression and design. In this process, we saw the integration of, on the

one hand, artificial intelligence as enabling unprecedented levels of data-driven creativity, and on the other, biocreativity to emphasise the importance of sustainability using circular and local materials.

The paper aims to reflect on the potential of artificial intelligence technologies through a critical analysis of the results that emerged from the workshop in order to identify which transformative design practices emerge through an approach based on cross-border collaboration. After an indepth review of the literature with respect to the evolution of co-design practices in processes of interdisciplinary contamination and characterised by design cultural diversity, the article presents the methodology applied in the workshop and analyses the results in a punctual manner, highlighting useful design directions to outline design practices, implications and challenges of the introduction of artificial intelligence technologies to reshape the design and the arts fields.

2. Literature review

2.1 Co-design evolution

The evolution of co-design reflects a shift from user-centered methodologies to co-creation. Over the years, co-design has incorporated various theories and models, such as design thinking and the user-centered design approach. This has led to a greater emphasis on collaboration and participatory innovation (Brown, 2008; Sanders & Stappers, 2014).

Recently, co-design has seen greater integration with digital technologies and expansion into sectors such as healthcare, education, and urban development. Sustainability and inclusivity have become central themes, with particular attention to the participation of marginalized communities (Bason, 2010; Björgvinsson, Ehn & Hillgren, 2012). As an approach that involves stakeholders in the design process, it fosters listening and responsive interactions between stakeholders and the design team, ensuring outcomes in line with community needs (Interaction Design Foundation - IxDF, 2023).

Co-design practices include collaborative workshops, brainstorming sessions, rapid prototyping, and the use of digital tools to facilitate remote collaboration. These methodologies have evolved to adapt to different contexts, such as the design of services, products, and public policies (Steen, Manschot & De Koning, 2011).

This evolution demonstrates how the integration of contemporary technologies, such as artificial intelligence, data visualization, and bio-creativity, can redefine traditional craftsmanship and educational practices (Davis et al., 2021; Light et al., 2022; Sanders & Stappers, 2008, Singh et al., 2018).

The evolution of co-design reflects a growing awareness of the importance of collaboration and user participation in the design process. Co-design practices and methodologies will continue to evolve, influenced by new technologies and the emerging needs of society.

2.2 Interdisciplinary Contamination: Importance of cross-disciplinary skills and cultural diversity in design

Interdisciplinary contamination emphasizes the importance of cross-disciplinary skills and cultural diversity in design. It involves the blending of knowledge from various disciplines to foster innovation and creativity. This approach is particularly valuable in design, where different perspectives can lead to more comprehensive and innovative solutions. The literature highlights several successful examples of interdisciplinary contamination, where the integration of diverse skills and cultural insights has led to groundbreaking design solutions (Augsburg, 2014). Thompson (2014) raises the concept as a possibility to transcend from reliable scientific knowledge to socially robust knowledge, through alliances between different stakeholders.

The paper aims to address precisely how new technologies can help implement cross-cultural processes in order to practise inclusive non-discriminatory analyses.

2.3 Technology in Design: overview of AI in enhancing traditional craftsmanship

The integration of Artificial Intelligence (AI) into traditional craftsmanship represents a transformative intersection between advanced technology and age-old artisanal techniques (Eglash et al., 2020). This fusion not only preserves but also enhances the unique characteristics of handmade goods, providing a contemporary edge while maintaining cultural authenticity. In recent years, AI has been leveraged across various facets of design and craftsmanship, from initial conceptualization to the final production stages.

Applications of AI in traditional craftsmanship ranges from the realm of design optimization for functionality and aesthetics (Wang et al., 2024) to the customization process, making personalized craftsmanship more accessible (Deng et al., 2024), passing through the preservation and documentation of traditional skills and knowledge (Ghaith et al., 2024).

Hence, the incorporation of AI into traditional craftsmanship is not about replacing human artisans but augmenting their capabilities (Buš, 2024). It offers a bridge between the past and the future, ensuring that the essence of craftsmanship is preserved while embracing the efficiencies and possibilities of modern technology (Garvin et al, 2023).

As AI continues to evolve, its role in the craftsmanship sector is likely to expand, offering new tools and techniques that further enhance the artistry and precision of handmade goods.

3. Methodology

The project's methodology was developed through three main phases: Design Modules, Cultural Probes and context mapping, and Technological Integration. Each phase was designed to maximize participation and interaction between Italian and Colombian students, fostering an environment of co-design and mutual learning.

The Design Modules were conducted before the trip to Colombia, during a series of initial workshops designed to prepare participants and select the best projects for the next phase. The structure of the Design Modules included:

- Workshop Structure: Each day was divided into theoretical and practical sessions, with specific objectives for each session. The theoretical sessions included lectures on key co-design concepts, artificial intelligence techniques applied to design, and prototyping methodologies. The practical sessions allowed students to apply this knowledge by developing concrete projects;
- Participants: Italian and Colombian students were divided into mixed groups to promote intercultural collaboration. Each group worked on a specific project, using a combination of digital and analog tools, such as interactive whiteboards, design software, rapid prototyping materials, and brainstorming kits;
- Winner Selection: At the end of the Design Modules, a panel of experts evaluated the projects developed by the students. Evaluation criteria included innovation, feasibility, technology integration, and social impact potential. The project evaluation was conducted by averaging the individual assessments provided by the professors and lecturers, ensuring a balanced and comprehensive review of the participants' work.
- The best projects were selected, and the respective teams had the opportunity to participate in the next phase in Colombia.

3.1 Cultural Probes and context mapping

An important component of our methodology was the implementation of Cultural Probes and context mapping. This phase was conducted directly in the field in Colombia and included:

- Data Collection: Using surveys, interviews, and direct observations to collect qualitative and quantitative data on local practices and stakeholders' perceptions. Use of field guides (see Figure 1) in order to record gestures, smells, sounds, tastes and scenes at some points along the route;

· Context Mapping: Site visits and immersive experiences in cultural identity locations and with local artisans, to gain an in-depth understanding of the local cultural and artisanal dynamics. A route was established in the context by places associated with these dynamics with the use of Google Maps;

· AI Analysis: The collected data were analyzed using artificial intelligence tools. A database was built from a Google Forms survey where responses were entered based on field guides. AI was fundamental in processing a large amount of data and conducting research, eliminating biases from co-designing between two different cultures. Additionally, AI helped break down linguistic and creative barriers, thus improving the quality and effectiveness of the co-design process.

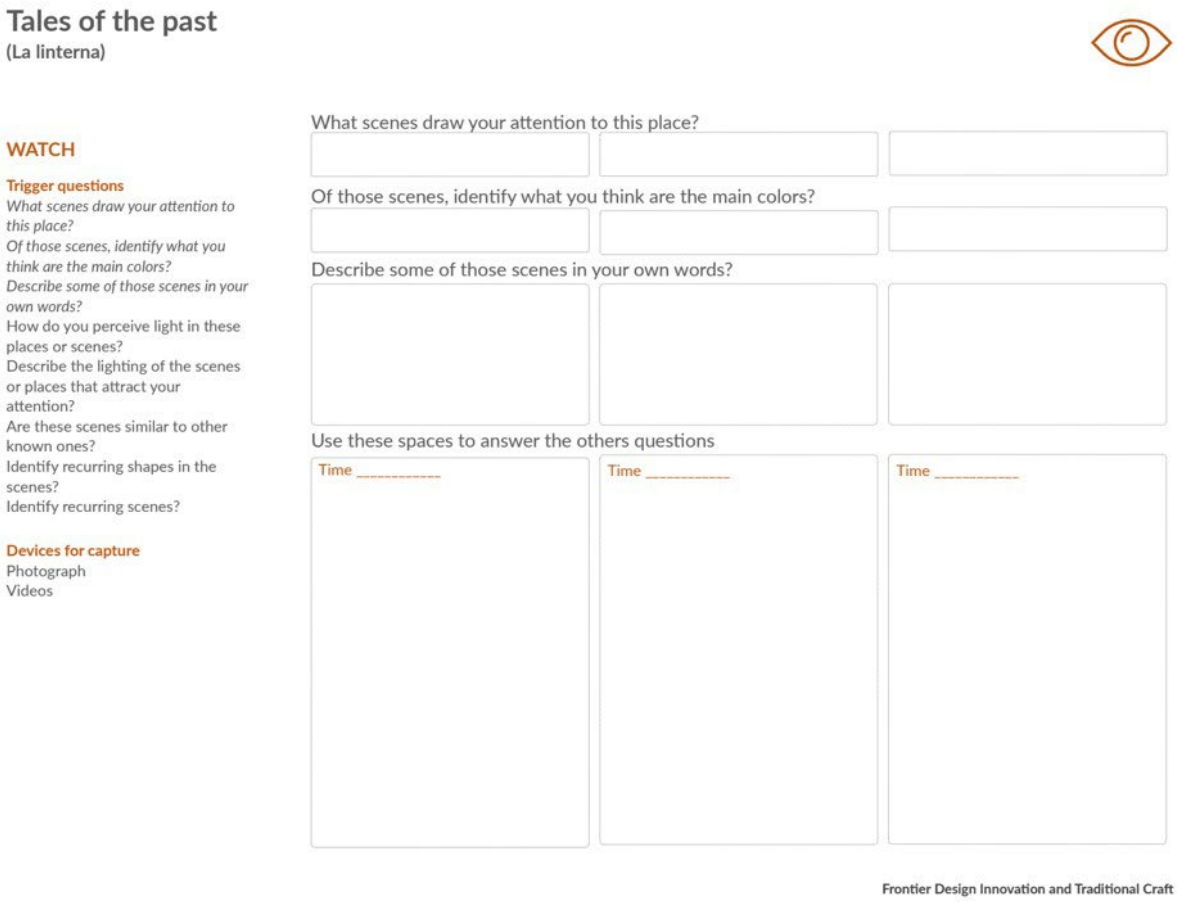


Figure 1. Observation sheet "Tales of the Past" used to collect visual data during the project. Participants respond to trigger questions about scenes that draw their attention, identify main colors, describe lighting and recurring shapes, and note similarities to other known scenes. Responses are recorded in designated spaces to capture visual and narrative characteristics of the observed location. Devices used for capture include photographs and videos.

3.2 The integration of technologies

The integration of technologies, particularly artificial intelligence, was crucial for our project. The main aspects of this phase included:

- AI Integration: Implementing AI tools to support data-driven creativity, facilitating idea generation, prototyping, and concept evaluation. AI played a key role in breaking down linguistic and creative barriers, enabling smoother collaboration between participants from different cultures. Moreover, Data collected in various languages were provided as input to a Large Language Model, which democratized access to the information. This allowed all participants, regardless of their spoken language, to have a uniform knowledge base, enabling deeper engagement and idea exchange; Use of Digital Technologies: In addition to AI, other technologies such as data visualization and bio-creativity were used, allowing for the exploration of new forms of sustainable craftsmanship and design;

- Remote Collaboration: Using digital tools such as video conferencing platforms and online collaborative tools to facilitate continuous communication and collaboration among participants, even after the in-person workshop concluded.

The adopted methodological approach allowed us to achieve significant results in terms of innovation and intercultural collaboration. The integration of contemporary technologies demonstrated the potential to redefine traditional practices and promote new forms of artistic and design expression. Reflecting on the outcomes of the workshops, we were able to identify transformative design practices that develop through a cross-border collaborative approach.

3.3 Generative Reasoning and Systemic Mapping in Cross-Cultural Design Innovation

Systemic mapping is a valuable tool in the analysis and development of complex design projects, especially those involving cross-cultural collaboration. The systemic map created during our project (see Figure 2) illustrates the intricate relationships between various elements of traditional craftsmanship and modern technology. This map served as a generative tool, merging AI-driven analysis with group creativity to drive innovation and deeper understanding in our cross-cultural design workshops.

Systemic mapping facilitated the identification of connections between cultural elements and modern design practices, highlighting potential areas of innovation. The visual nature of the map helped bridge language and cultural barriers, making it easier for participants from different backgrounds to contribute equally. By visualizing the design ecosystem, participants could see new possibilities and intersections that were not immediately obvious.

The systemic map created in our project is a rich tapestry of post-it notes and images, each representing a critical component of the design process. Various traditional crafts and local practices were mapped to show their relevance and potential for modernization. Points where AI and other technologies could enhance or preserve traditional methods were highlighted, and central points where cross-cultural interactions were most effective were identified, showcasing successful collaboration.

Post-analysis of the systemic map involved several steps: gathering qualitative data from participants' experiences and insights during the workshops, using AI tools to identify patterns and recurring themes in the data collected, and generating new design concepts based on the identified patterns. This integration of AI analysis and group creativity yielded significant insights and innovations, such as hybrid designs combining traditional craftsmanship with modern design principles, leveraging local materials and sustainable practices, and developing new educational modules that incorporate systemic mapping and AI tools to teach design students about crosscultural collaboration. Several case studies emerged from the workshops, demonstrating the practical application of insights gained from the systemic map. For example, a project that combined traditional Colombian weaving techniques with Italian design aesthetics created a sustainable product line, directly informed by the systemic map. Another project used AI to analyze and map community data in a Colombian village, providing deeper insights into local needs and cultural practices. A third case study explored the use of bio-based materials in design, driven by insights from the systemic map about local resources and sustainable practices.

While the systemic map provided numerous benefits, several challenges were encountered, such as managing the complexity of the map, ensuring cultural sensitivity, and overcoming technological barriers. Solutions included conducting interactive sessions to help participants become familiar with the systemic map, holding workshops focused on cultural sensitivity and the respectful integration of technology, and providing additional technical training and support to participants less familiar with the digital tools used.

The integration of systemic mapping into our cross-cultural design project proved to be a transformative approach, enabling generative reasoning that drove innovation and deeper cultural understanding. By visualizing complex relationships and facilitating collaborative creativity, systemic mapping bridged the gap between traditional craftsmanship and modern technology, paving the way for future cross-cultural design endeavors. This section outlines how systemic mapping and generative reasoning can be effectively utilized in design innovation projects, providing a robustframework for future research and practice in cross-cultural design.



Figure 2. Systemic map from cross-cultural design workshops, illustrating connections between cultural heritage, technological integration, and collaborative nodes to identify potential innovation areas.

4. Case studies and results

The results reflect the impact of this comprehensive approach, as evidenced by the diverse range of innovative projects and the mutual learning experiences of the participants.

4.1 Intercultural design collaboration

In one of the standout projects, Italian and Colombian students collaborated to develop a sustainable product line that blends traditional Colombian craftsmanship with modern Italian design aesthetics. This project exemplified how cross-cultural collaboration can lead to the creation of products that respect and innovate upon cultural heritage. The team used digital prototyping tools and AI-driven data analysis to refine their designs, ensuring both cultural authenticity and contemporary appeal.

Image	Where	Archive name	Extracted objects
	Cali - Mercado	iimg2332.jpg	letters
	Cali - gatos	imgen3633566.jpg	cat bag
	Cali - Linterna	la linterna 1 - Anny Gicela Guerrero Chapal.jpg	person (3) bottle (3) cup (3) bowl (1)

Table 1. AI image analysis

4.2 AI-Enhanced Community Mapping

Another significant project involved the use of AI for community mapping in a Colombian village. Participants collected data through interviews and observations, which were then processed using AI tools to identify key cultural and social patterns. This project demonstrated the power of AI in enhancing understanding and visualization of complex cultural contexts, leading to more informed and culturally sensitive design solutions.



Figure 2. Image labelling examples

4.3 Bio-Creativity in Sustainable Design

A third case study focused on the integration of bio-creativity techniques with local materials. Italian and Colombian students worked with local artisans to create sustainable design prototypes using bio-based materials and techniques. This project not only highlighted innovative uses of local resources but also provided new economic opportunities for the artisans involved.
The outcomes of these collaborative efforts were multifaceted, showcasing the potential of blending traditional and modern practices through advanced technology and intercultural teamwork.

4.4 Innovation in Design

The collaborative process resulted in several innovative products and design solutions that were both culturally relevant and technologically advanced. For instance, the sustainable product line project combined traditional weaving techniques with modern materials, creating a unique blend of old and new that appealed to both local and international markets.

4.5 Enhanced Understanding through AI

The use of AI tools in data collection and analysis proved to be highly effective. AI helped break down language barriers and provided deep insights into cultural nuances that would have been difficult to discern through manual methods alone. This led to more accurate context mapping and betterinformed design decisions.

The projects not only fostered innovation but also emphasized sustainability. The use of biomaterials and the focus on local craftsmanship helped promote environmentally friendly practices. Additionally, the economic impact on local communities was significant, as the projects opened up new avenues for income generation and skill development.

4.6 Digital tools and AI technologies

Throughout these projects, various digital tools and AI technologies were employed to enhance the participants' perceptions and capabilities. Digital tools were used to generate new information from the collected elements in the systemic map, such as identifying key concepts from text documents, transforming audio interviews into text, recognizing entities in images, converting ambient sounds into numerical data, and generating images from text using tools like DALL-E.

Text processing involved using AI, in particular ChatGPT, for topic modeling to reveal the main topics in extensive texts, identifying entities such as people, objects, and places mentioned in the texts, and performing keyword extraction to list all keywords and create co-occurrence tables of keywords found in the same sentences or paragraphs.

Image processing was conducted using YOLO (Redmon et al., 2016), where images were analyzed to label and identify key elements. This process included uploading images, running scripts to process them, and obtaining labeled outputs.

Interview transcription was facilitated by Otter.ai (Corrente et al., 2022), which transcribed audio files into text, making it easier to analyze and identify keywords. Sound processing involved converting sounds into numerical representations, similar to the image labeling process but using audio-specific tools.

Ethical considerations were paramount in the use of AI tools. All AI applications complied with ethical standards, ensuring the transparency of training databases and using local languages to avoid cultural biases. This integration of digital tools and AI technologies enabled a more comprehensive, inclusive, and non-discriminatory approach to design, significantly enhancing the quality and impact of the collaborative projects.

By leveraging these advanced technologies, we were able to achieve a deeper understanding of cultural contexts, foster innovation, and promote sustainable practices. This comprehensive and inclusive

approach has shown how modern technology can be harnessed to support and enhance traditional craftsmanship and intercultural collaboration in design.

5. Learnings from the Workshop: key insights and challenges faced during the project.

The workshops showed the strong potential of combining new technologies with traditional craftsmanship in a cross-cultural setting. We found that technology, when used carefully, can connect different cultural expressions rather than separate them. Using AI and digital tools highlighted the importance of preserving the essence of traditional methods while enhancing them with modern innovation. This balance was achieved through ongoing discussions and iterative design processes, promoting a sense of shared ownership and mutual respect among participants from different cultural backgrounds.

However, the process was not without its challenges. Working with diverse cultures required sensitivity and adaptability. Language barriers and different levels of comfort with technology among participants sometimes slowed progress. Yet, these challenges also became opportunities for growth, as they required the development of new communication strategies and teaching methods that could accommodate various learning styles and cultural perspectives. The workshops underscored the value of patience and the need for flexible, inclusive approaches in co-design projects.

5.1 Comparison with existing literature: how the findings extend or challenge current understanding of cross-cultural design and AI integration.

Our findings provide a detailed perspective that both supports and extends current discussions on cross-cultural design and AI integration. While existing literature often emphasizes the theoretical benefits of interdisciplinary and cross-cultural collaboration (Augsburg, 2014; Thompson, 2014), our project offers concrete evidence of these benefits in practice. The use of AI tools not only facilitated more inclusive and unbiased design processes but also revealed new dimensions of cultural synthesis and innovation that had not been fully explored before.

Moreover, our project challenges some prevailing assumptions about the role of technology in design. Contrary to the view that technology might overshadow traditional practices, we found that AI and digital tools can enhance and preserve cultural heritage when used thoughtfully. This finding prompts a re-evaluation of the perceived divide between tradition and innovation, suggesting instead a mutually beneficial relationship where each can enrich the other.

5.2 Broader Implications: potential for AI and technology to reshape the design and art fields.

The broader implications of our project are significant, suggesting that the strategic integration of AI and technology can change the fields of design and art. By facilitating deeper cultural understanding and fostering innovative practices, these technologies have the potential to transform how we approach creativity and craftsmanship.

AI proved to be a powerful tool in this transformation. Its ability to process and analyze large amounts of data quickly and accurately provided insights that were previously unattainable, enhancing the design process's depth and precision. Additionally, the use of digital platforms for remote collaboration broke down geographical barriers, enabling continuous and dynamic interaction between participants from different parts of the world.

Furthermore, the project highlighted the potential for AI and technology to support sustainable practices. By optimizing resource use and promoting eco-friendly materials, these tools can help designers and artists create works that are not only beautiful and culturally significant but also environmentally responsible.

However, the reliance on technology also introduced certain drawbacks. For instance, the need for continuous access to digital tools and platforms could create disparities among participants with varying levels of technological access and expertise. Additionally, the integration of AI raised ethical concerns regarding data privacy and the potential for algorithmic biases, which require careful consideration and ongoing oversight.

5.3 Conclusion

This research underscores the transformative potential of integrating contemporary technologies, particularly artificial intelligence (AI), with traditional craftsmanship in a cross-cultural context. The project's methodology, which combined design modules, cultural probes, context mapping, and technological integration, facilitated a dynamic and inclusive environment for co-creation and innovation. Through this approach, we observed significant advancements in design practices, fostering an environment where modern technology and traditional craftsmanship synergistically enhance each other.

The findings highlight several key insights. First, AI and digital tools are not merely adjuncts to traditional methods but can actively preserve and amplify cultural heritage. By providing unprecedented levels of data-driven creativity and sustainability-focused innovations, these technologies bridge the gap between the old and the new, ensuring the continuity of cultural narratives in contemporary design contexts.

Second, cross-cultural collaboration, as evidenced by the diverse and innovative projects generated through this initiative, is pivotal in enriching the design process. The integration of different cultural perspectives and expertise led to the development of products and solutions that are both culturally resonant and technologically advanced. This collaboration not only fostered mutual learning and respect but also unveiled new dimensions of cultural synthesis and innovation, challenging prevailing assumptions about the role of technology in design.

However, the project also illuminated the challenges inherent in such interdisciplinary and intercultural endeavors. Language barriers, varying levels of technological proficiency, and the need for adaptive communication strategies emerged as critical factors requiring careful navigation. These challenges, while significant, also offered opportunities for growth and the development of new, more inclusive methodologies.

The broader implications of this research suggest that the strategic integration of AI and technology in design can profoundly reshape the fields of art and craftsmanship. By enabling deeper cultural understanding and fostering innovative, sustainable practices, these technologies can transform traditional design processes, making them more inclusive, precise, and environmentally responsible. Nonetheless, it is essential to address the ethical considerations associated with AI, such as data privacy and algorithmic biases, to ensure that technological advancements do not perpetuate inequalities or cultural insensitivity.

In conclusion, the project's outcomes reaffirm the value of blending traditional craftsmanship with contemporary technology within a cross-cultural framework. This fusion not only enhances the creative process but also promotes a richer, more inclusive understanding of design. The insights gained from this research provide a robust foundation for future explorations into the integration of AI and other advanced technologies in design, advocating for a balanced approach that respects and leverages cultural diversity to foster innovative and sustainable design practices.

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RESEARCH ON THE EXPERIENCE PRODUCT DESIGN OF INTANGIBLE CULTURAL HERITAGE "SONG DYNASTY KITES" BASED ON THE PERSPECTIVE OF USER NEEDS

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ABSTRACT | Intangible Cultural Heritage (ICH) is an important symbol of the historical and cultural achievements of a country and a nation, and in recent years, as the awareness of ICH protection has been raised, Experiential ICH Products are gradually attracting wide public attention. The purpose of this paper is to explore how to design experiential ICH products based on the user needs perspective, using China's Song Dynasty Kites (SDK) as an example. According to Donald A. Norman's Emotional Design Theory, semi-structured interviews and observation methods are used to obtain users' initial needs. And by building the KANO-AHPQFD integrated model, the user needs are weighted and transformed into design elements. The result is a completed experiential product design solution for SDK based on the first 10 design elements derived from building the House Of Quality. The combination research method of this study deeply mines user requirements and applies them to ICH experience products, which can effectively improve satisfaction and thus user stickiness, promote the living inheritance of ICH, and also provide an innovative path and reference model for the design of other ICH experience products.

KEYWORDS | INTANGIBLE CULTURAL HERITAGE, SONG DYNASTY KITES, KANO, AHP, QFD

1. Introduction

Since the 1990s, global academics have paid great attention to the relationship between globalization and cultural diversity. The protection and transmission of ICH has become one of the key issues, and in 2003, UNESCO promulgated the Convention for the Safeguarding of the Intangible Cultural Heritage. The safeguarding of ICH is an important factor in maintaining social coherence and cultural diversity, but it is also a challenge in modern society (Pistola et al., 2021). Overall, the safeguarding of ICH of all peoples of the world is not only a consensus of all countries in the world, but also a universal demand of all peoples. As a cultural power with five thousand years of inheritance, as of May 2024, China has 43 items inscribed on the UNESCO ICH list and register, which is the highest number in the world. In the diversified and integrated pattern of China's civilization, the Central Plains culture plays a central and dominant role (Fan Yuchou, 2006). As an important carrier of the Central Plains culture, Henan has not only preserved rich historical relics and cultural heritages, but also nurtured many ICHs with local characteristics.

Among them, Song Dynasty Kites (SDK) is one of the outstanding representatives. SDK comes from the royal family in the Northern Song Dynasty. According to legend, the kite flew out of the palace when the emperor of the Northern Song Dynasty was playing with a kite, and it flowed into the people until now. The Song family also developed a unique double-headed shape in the process of being passed down from generation to generation. SDK, as an important part of Chinese kite culture, carries rich historical information and cultural connotation. The evolution of kites has witnessed the social and cultural changes and development as well as highlighted the spirit of Chinese art and philosophical thinking of the unity of heaven and man. SDK have become a bright pearl in Chinese kite culture with its unique kite style and kite making skills.

Given that kites have been developed so far, they are mostly used as recreational toys. Therefore, the design of experiential products for SDK can not only help more people understand and love SDK, but also inherit and promote ICH.

2. Status of research

In recent years, under the guidance of China's policy of supporting the innovative development of ICH, experiential products related to ICH have attracted much attention from the public, and along with the rapid development of cultural tourism and study education (Ma, Yunlin & Zhang, Fang, 2023), they have become one of the most important ways of ICH inheritance and preservation. The cultural connotation of ICH is embedded in the production and creation process of "non-materials", and experiential products can maximize the user's understanding of the unique production techniques of ICH. He Jia et al. suggested that expanding the multichannel public participation system by means of handmade experience would be a way to help ICH dissemination (He Jia & Ben Zhang, 2022). Lu, Zhicong et al. successfully stimulated students' interest in ICH by engaging them in an ICH-oriented experience design (Lu, Tan, Ji, & Ma, 2022). Yue Zhang's team made it easier for children to acquire knowledge of ICH embroidery through a gamified interactive experience design, allowing for better transmission and popularization of today's ICH skills (Zhang, Xu, Wang, Yang, & He, 2023). Zhu Junjie's team developed an experiential game product of ICH "Bu hu Hunting" through an experiential educational game model (Zhu, Li, Zheng, & Sun, 2024). Dong Chaonan et al. improved the design process and methodology of ICH bamboo weaving handicraft experience products by using the double diamond model through design thinking research (Dong, Chaonan, Chen, Ruoru, Xia, Zhiyuan, & Wu, Jue, 2022). Tingting Ma explored the users' demand for ICH cultural products in Shanxi under the perspective of service design by establishing a KANO model, and analyzed the strengths and weaknesses of ICH cultural and creative products in Shanxi in combination with SWOT (Tingting Ma, 2022). However, with the promotion of ICH experiential products, the lack of demand side has become a key issue in ICH product development. Although current research on ICH experiential products has reached a certain scale, there are still many flaws and deficiencies. On the one hand, there is a lack of in-depth and precise analysis of user needs, a lack of systematic methods and models, and a lack of integration of multiple effective design tools and methods in the design process of experience products. On the other hand, under the background of experience economy, consumers pay more attention to the emotion carried by the products and the humanized experience, which is also an important factor restricting the further development of ICH experience products.

In order to try to make a solution to the above problems and to design ICH experience products based on the perspective of user needs, the "SDK" is used as an example for research in practice. In order to further inherit and promote SDK, and to combine it with cultural tourism and study tour, this paper is based on the user needs perspective. This paper is guided by Donald A. Norman's

Emotional Design Theory, and uses both qualitative and quantitative research methods to construct a KANO-AHP-QFD integrated model to guide the development of the SDK experience product. We explored an innovative and effective path for the design of ICH experience products, promoted the inheritance and development of ICH culture in contemporary society, and scientifically optimized the user experience.

3. Research method

In user needs-based design research, commonly used design models include the KANO model, Analytic Hierarchy Process (AHP), Quality Function Deployment (QFD), Axiomatic Design (AD), Kansei Engineering (KE), etc. In recent years, researchers have constructed complementary integrated models based on the differences of the design models to guide their practice. For example, Ruo-Mei Tang et al. used the KANO-AHP-AD theoretical model to develop the design practice of a pediatrics dental chair (Ruo-Mei Tang, Junjie Li, Qiong Luo, Dadi Lin, & Xiangbin Peng, 2023). Jia Li and KieSu Kim used an integrated Kano-QFD model to design an app for ICH crafts so that users can quickly and easily perceive ICH culture through mobile devices (Li & Kim, 2023). Shi Yuanwu and Han Shan used QFD and KANO models to analyses the users' styling design requirements for medical service robots and proposed effective design solutions accordingly (Shi Yuanwu & Han Shan, 2017). Chen Xu et al. completed the interaction design of age-appropriate smart home products through QFD-TRIZ integrated model (Chen Xu & Xue Biao, 2019).

The KANO model, originally proposed by Japanese scholar Noriaki Kano in 1984, is a tool used to categories and priorities users' needs, and is designed to help companies better understand their customers' needs and improve their products or services accordingly to increase customer satisfaction (Barsalou, 2023). It classifies user needs into five types, namely Must-be Quality (M), One-dimensional Quality (O), Attractive Quality (A), Indifferent Quality (I) and Reverse Quality (R). KANO model can reveal the non-linear relationship between product performance and user satisfaction, but KANO model can only achieve the effect of qualitative analysis in acquiring user needs, and it cannot judge and analyze the degree of importance between each user need, and there is a certain degree of subjective error, so it needs to be combined with other quantitative methods in order to ensure the scientific nature of the design strategy.

AHP was proposed by Thomas L. Saaty, a famous American operations researcher and professor at the University of Pittsburgh, in the mid-1970s. The model combines qualitative and quantitative analysis methods, and its core lies in constructing a hierarchical model to decompose the decision-making problem into Goal Layer, Criterion layer, and Alternative layer, and determining the relative importance or priority of each factor by comparing them two by two to provide a basis for the optimal choice of alternatives

(Liu, Eckert, & Earl, 2020). AHP is able to determine the weighting factors for each user requirement, but it is unable to convert user requirements into specific design requirements.

QFD is a systematic approach proposed by Japanese scholars Yoji Akao and Shigeru Mizuno in the 1960s. The method is a user demand orientated quality management tool that translates user demand into design parameters and completes the mapping from demand to design strategy to ensure that the product design and production matches the user demand, thus ensuring that the final product meets or exceeds the customer's expectations. However, this method is unable to obtain important user requirements indicators.

Based on the analysis of the above model, this study proposes a product design process that integrates KANO, AHP and QFD, as shown in Figure 1. This design process is orientated to the user needs of SDK non-heritage experience products, combining both qualitative and quantitative research methods, and mapping out specific design elements through a scientific research process while considering user needs.

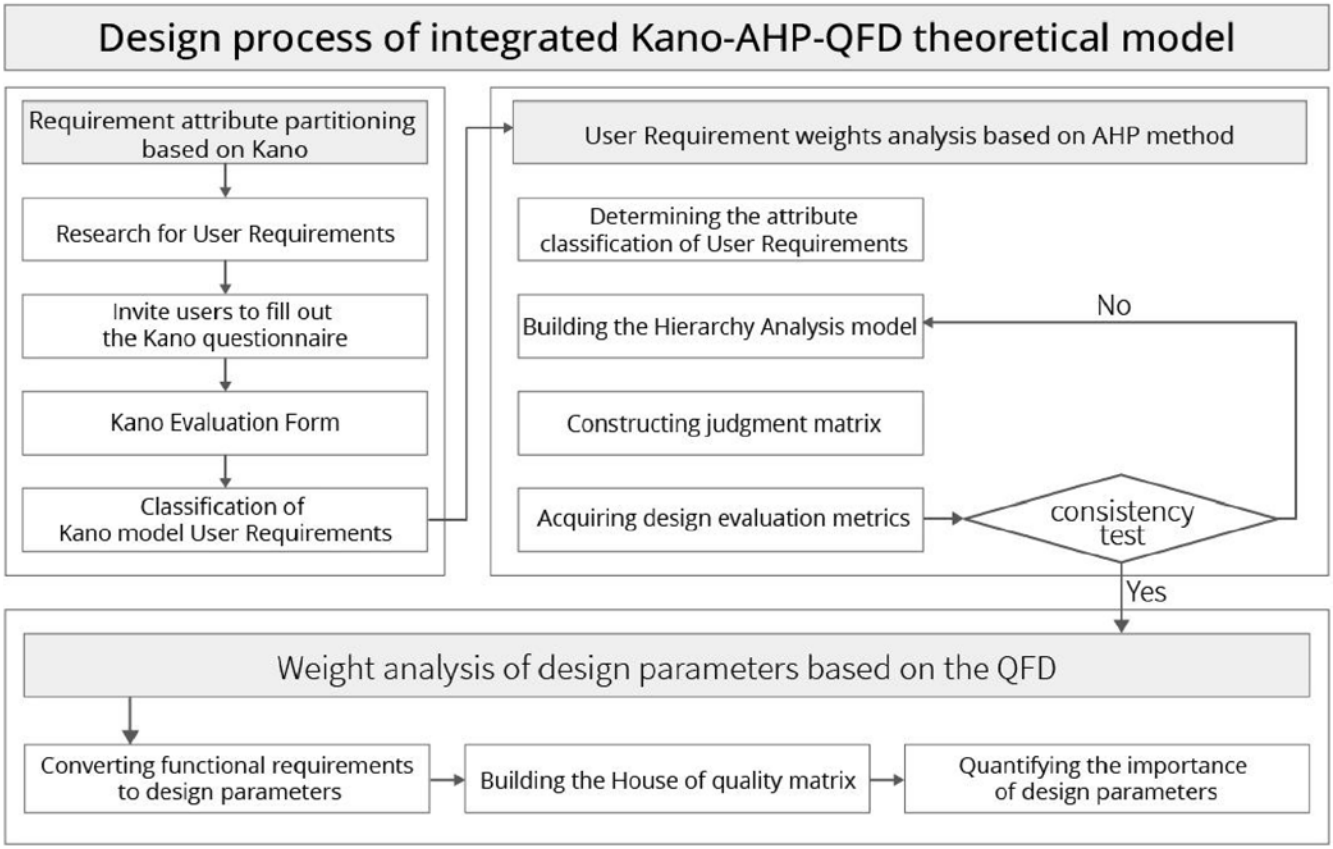


Figure 1. Design process of integrated Kano-AHP-QFD theoretical model

4. KANO-AHP-QFD integrated modelling of SDK experience product design process

4.1 User experience element acquisition

Regarding the user's experience needs, the Emotional Design Theory proposed by Donald A. Norman in Emotional Design systematically divides people's emotional needs into Instinct layer, Behavior layer and Reflection layer, and stresses that no kind of design can be completely independent of these three levels. Instinct layer design is the law of nature, in this level plays a leading role in people's five senses of experience, for example, traditional cultural books using antique paper can be from the sense of touch to bring direct feelings. Behavior layer is the user's experience of the product in terms of functionality, utility and ease of use (Lu, Chunfu, Xiao, Zihao, & Fu, 2020). Products with a Reflection layer create a mood that establishes an emotional connection with the user, evoking a deep-seated response based on personal values, such as pride, satisfaction, and happiness.

This paper maps Emotional Design Theory to the design of ICH experience products, corresponding to the refinement of the Sensory experience, Interaction experience and Emotional experience three experience elements, as in Figure 2, only when all of them are satisfied, users can get the best experience.

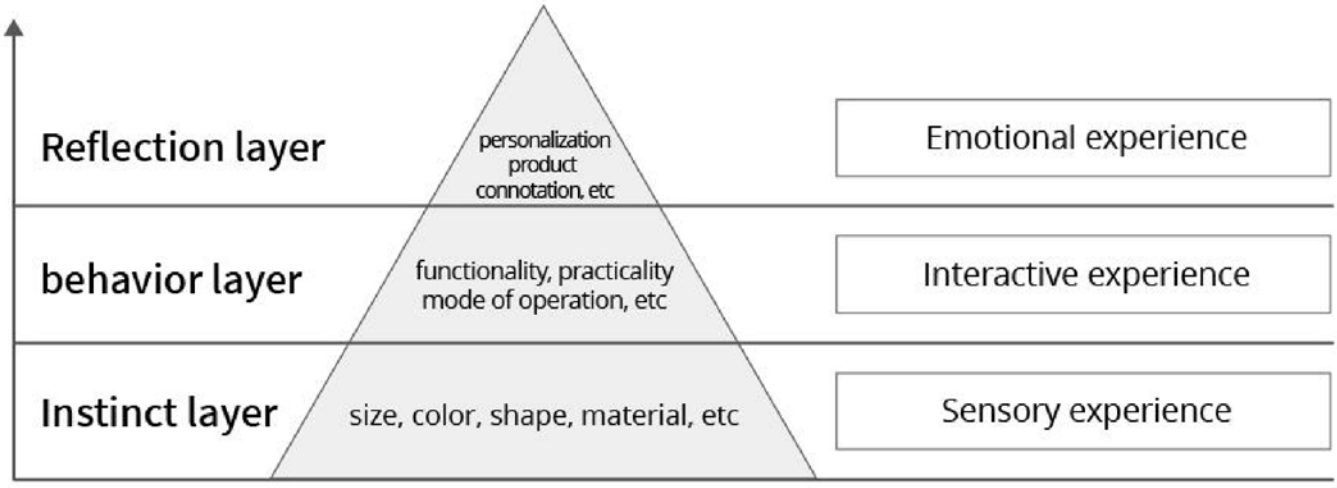


Figure 2. Mapping Emotional Design Elements for Experience Products

The author cooperated with the inheritor of SDK and conducted a research and analysis based on the current study and visit experience groups of SDK. It is found that the users interested in SDK experience products are mostly young people aged 15-25, who are mostly in the stage of education, full of curiosity about new things, with strong learning ability and hands-on desire. Among them, students are interested in SDK experience products due to the guidance of various

cultural activities organised by schools, their own desire for traditional culture and the characteristics of experience products. Therefore, this paper chooses the student group aged 15-25 as the target group of SDK experience product design.

In order to make the research more targeted, semi-structured in-depth interviews and observation methods were firstly adopted to obtain explicit and implicit needs around the target group. Secondly, the primitive descriptions of the experiencers were transformed into clear user needs, and finally, the card analysis method was used to classify and merge them into three categories and 16 preliminary user needs vocabularies in accordance with the Emotional Design Theory. As shown in Table 1.

Table 1. User need extraction

Experience elements	Requirement number	User needs
Sensory experience	1	Ancient colors
	2	Representative kite shape
	3	The material presents a simple and ancient texture
Interaction experience	4	Clear instructions
	5	Timely operation feedback
	6	Complete set of tools
	7	Estimation of experience time
	8	Moderately difficult to operate
	9	Lightweight materials to ensure flight
	10	Display and storage of the finished product
	11	Material safety
	12	Spare materials are available
	13	Long-term storage of the finished product
Emotional experience	14	Cultural stories
	15	A certain sense of modern design
	16	Personalization

4.2 Classification of User Requirement Attributes Based on the Kano Model

In this study, based on the KANO model and the 16 acquired user experience requirements, a KANO questionnaire in the form of a Five-point Likert scale was constructed by designing standardized positive and negative questions with the aim of exploring the requirements attributes in depth. The questionnaire answer options

were like, necessary, irrelevant, tolerable and dislike as shown in Table II. A total of 100 questionnaires were distributed to students aged between 15 and 25 years old, and all of them were validly returned. The results of the questionnaires were then consolidated and analyzed. According to the answers of the questionsanswered by the users, based on the demand codes in the Comparison table for the classification of KANO evaluation results in Table 3, the number of demand codes for each question was counted. The number of demand codes for each question was counted and converted into a percentage.

According to the outcome attributes that accounted for the largest share of the results attributed them to Must-be Quality (M), One-dimensional Quality (O), Attractive Quality (A), Indifferent Quality (I) and Reverse Quality (R).

Table 2. KANO model Five-point Likert scale

Serial number	Concern	Like (5)	Necessary (4)	Irrelevant (3)	Tolerable (2)	Dislike (1)
1	How do you feel if the experience product has ancient colors?					
2	How do you feel if the product does not have ancient colors?					

Table 3. Comparison table for the classification of KANO evaluation results

Positive	Negative				
	Like(5)	Necessary(4)	Irrelevant(3)	Tolerable(2)	Dislike(1)
Like(5)	Q	A	A	A	O
Necessary(4)	R	I	I	I	M
Irrelevant(3)	R	I	I	I	M
Tolerable(2)	R	I	I	I	M
Dislike(1)	R	R	R	R	Q

And the importance level of this need is obtained by calculating the satisfaction index (SI) and dissatisfaction index (DSI) (Chaudha, Jain, Singh, & Mishra, 2011), which ultimately results in Table 4

$$\text{Satisfaction index}(SI) = \frac{(A_i + O_i)}{(A_i + O_i + M_i + I_i)}$$
$$\text{Dissatisfaction index}(DI) = -1 * \frac{(M_i + O_i)}{(A_i + O_i + M_i + I_i)} \quad (1)$$

Table 4. Results of KANO questionnaire analysis

Requirement number	M	O	A	I	R	Q	KANO Positioning	SI	DI
1	31.00%	4.00%	29.00%	22.00%	2.00%	12.00%	M	0.38	-0.41
4	31.00%	19.00%	18.00%	18.00%	2.00%	12.00%	M	0.43	-0.58
6	32.00%	17.00%	17.00%	20.00%	1.00%	13.00%	M	0.40	-0.57
9	6.00%	33.00%	17.00%	26.00%	1.00%	17.00%	O	0.61	-0.48
11	16.00%	38.00%	15.00%	15.00%	0.00%	16.00%	O	0.63	-0.64
13	5.00%	37.00%	25.00%	14.00%	2.00%	17.00%	O	0.77	-0.52
2	6.00%	7.00%	49.00%	25.00%	1.00%	12.00%	A	0.64	-0.15
3	3.00%	8.00%	52.00%	24.00%	1.00%	12.00%	A	0.69	-0.13
10	2.00%	9.00%	46.00%	23.00%	2.00%	18.00%	A	0.69	-0.14
14	2.00%	9.00%	47.00%	22.00%	3.00%	17.00%	A	0.70	-0.14
15	3.00%	6.00%	50.00%	23.00%	1.00%	17.00%	A	0.68	-0.11
16	3.00%	7.00%	52.00%	19.00%	2.00%	17.00%	A	0.73	-0.12
5	5.00%	14.00%	20.00%	46.00%	3.00%	12.00%	I	0.40	-0.22
7	4.00%	8.00%	27.00%	48.00%	0.00%	13.00%	I	0.40	-0.14
8	3.00%	11.00%	21.00%	49.00%	4.00%	12.00%	I	0.38	-0.17
12	10.00%	12.00%	22.00%	42.00%	1.00%	13.00%	I	0.40	-0.26

As can be seen in Table 4, four types of KANO requirement attributes appear in the 16 user requirements. In the table, 1, 4, and 6 are Must-be Quality (M) These types of needs are essential points for SDK experience products, and if they are met, user satisfaction will not increase significantly, and if they are not met, user satisfaction will decrease significantly. Since all of these needs have been largely satisfied in the current ICH experience products, they should continue to be provided. Serial numbers 9, 11, and 13 are One-dimensional Quality (O) The better such needs are considered in the design of the SDK experience product, the higher the user satisfaction will be. On the contrary, it will cause user dissatisfaction. Therefore, such needs need to be satisfied as much as possible. Attractive Quality (A) is 2, 3, 10, 14, 15, 16, when this kind of demand is satisfied, it will bring some surprises beyond the expectations of the users, which can greatly improve the user satisfaction, so it should be considered in the design of SDK experience products. The remaining 4 items are Indifferent Quality (I), i.e., these needs will not affect user satisfaction no matter whether they are satisfied or not, so these 4 user needs will be excluded and will not appear in the subsequent design process.

4.3 AHP-based weighting analysis of user requirements

In this study, the user requirements of SDK experience products were first classified using the KANO model. In order to further clarify the focus of the subsequent product design, this paper will apply the AHP Analytic Hierarchy Process to construct a hierarchical analysis model after the analysis of the KANO model, and to clarify the weights of the user requirements, so as to enhance the accuracy and objectivity of the analysis of user requirements. According to the user requirements and design objectives of SDK experience products, the AHP model is divided into Goal Layer, Criterion Layer and Sub-Criterion Layer.

The Goal Layer is the SDK experience product design solution. The Criterion layer (Primary Indicator) is based on Donald A. Norman's emotional design theory of Sensory experience, Interaction experience and Emotional experience.

The Sub-criterion layer (Secondary Indicator) is the 12 design elements filtered out by the Kano model in the previous section, and these 12 elements are corresponded and recoded according to the Criterion layer, which are: ancient colors M1, representative kite shape A1, The material presents a simple and ancient texture A2, clear instructions M2, complete set of tools M3, lightweight materials to ensure flight O1, material safety O2, long-term storage of the finished product O3, Display and storage of the finished product A3, Cultural stories A4, Certain sense of modern design A5, Personalization A6. as shown in Figure 3.

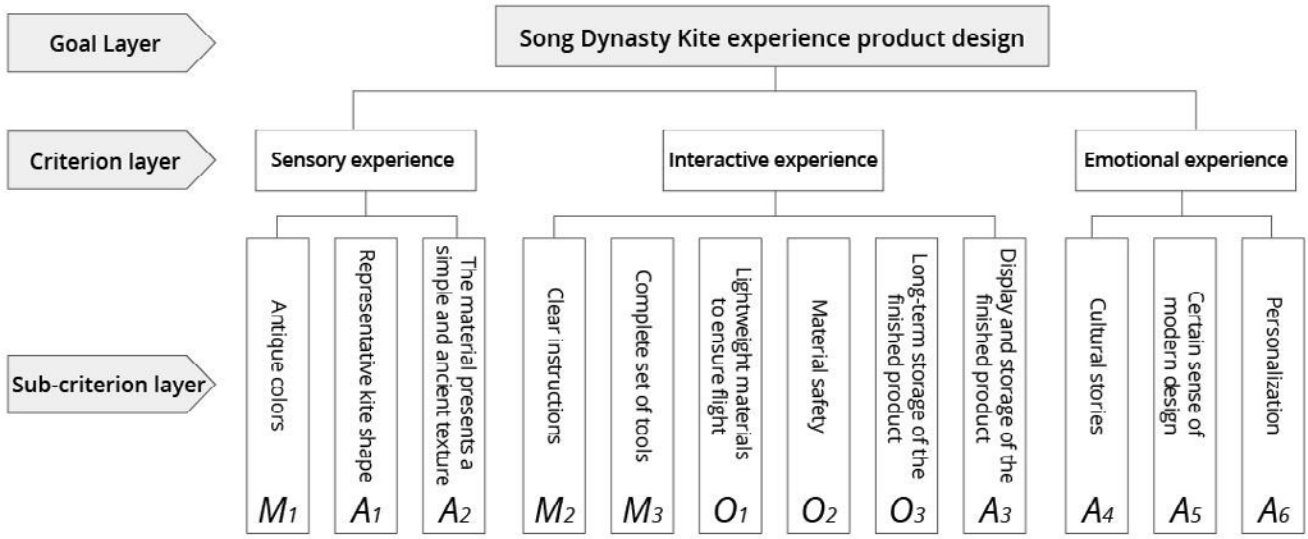


Figure 3. SDK Experience Product Design AHP Model

In order to ensure the scientific and objectivity of the results of user requirements weighting, this study invites 15 researchers related to the product design of SDK experience, including five non-geneticists, four doctoral students of product design, two professors of visual communication design, and four postgraduate students related to the study of ICH. They were invited to compare and rate the importance of the needs of each level of SDK experience products two by two according to the 1-9 scale method, and the arithmetic mean was used as the basis for weight calculation to derive the judgement matrix of each level. And then the geometric mean method was applied to calculate the weighting results to derive the weighting values of user requirements of SDK experience products, and the consistency test was conducted on the matrix scoring, and the arithmetic process was as follows, and the results are shown in Table 5 and Table 6.

1）Construct the judgment matrix, in the formula, $a_j \cdot a_{ji} = 1$，$i \neq j = 1, 2, \cdots, n$.

$$S = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & \cdots & a \end{bmatrix} \quad (2)$$

2）According to the judgment matrix, the mean value is obtained by geometric average method V_i.

$$V_i = \sqrt[n]{\prod_{j}^{n} S_{ij}} \quad (3)$$

The results are normalized, and the average weight W_1 and weight vector W are obtained.

$$W_1 = \frac{\sqrt[n]{\prod_{j}^{n} S_{ij}}}{\sum_{i=1}^{n} \sqrt[n]{\prod_{j}^{n} S_{ij}}} \quad (4)$$

$$W = (w_1 w_{2,\cdots} w_n)^T \quad (5)$$

3）Computing the Maximum Eigenvalue (λ_{max}) :

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{S_{wi}}{W_i} \quad (6)$$

In the formula, S_{wi} represents the i-th component of vector S_w , n represents the order of the matrix.

4）Conducting a consistency check on the results. (I_{CI}) :

$$I_{CI} = \frac{\lambda_{max} - n}{n-1} \quad (7)$$

$$I_{CR} = \frac{I_{CR}}{I_{RI}} \quad (8)$$

In the formula: n represents the order of the judgment matrix, IRI stands for the Index of Random Consistency, ICR denotes the Consistency Ratio.

Table 5. Criterion layer weights

Primary Indicator	Sensory experience	Interaction experience	Emotional experience	weight value	I_{CR}
Sensory experience	1	1/2	3	0.3090	
Interaction experience	2	1	5	0.5816	0.0036
Emotional experience	1/3	1/5	1	0.1095	

Table 6. Sub-criterion layer weights

Primary Indicator	Secondary Indicator	Judgment Matrix						weight value	ICR
Sensory experience	M1	1	1/2	2	×	×	×	0.2970	0.0088
	A1	2	1	3	×	×	×	0.5396	
	A2	1/2	1/3	1	×	×	×	0.1634	
Interaction experience	M2	1	3	7	2	5	4	0.3817	0.0198
	M3	1/3	1	5	1/2	3	2	0.1625	
	O1	1/7	1/5	1	1/6	1/2	1/4	0.0360	
	O2	1/2	2	6	1	4	3	0.2535	
	O3	1/5	1/3	2	1/4	1	1/2	0.0628	
	A3	1/4	1/2	4	1/3	2	1	0.1035	
Emotional experience	A4	1	2	4	×	×	×	0.5584	0.0176
	A5	1/2	1	3	×	×	×	0.3196	
	A6	1/4	1/3	1	×	×	×	0.1220	

When the I_{CR} (Inconsistency Rate) $\leqq$ 0.1 in the consistency test result, it is usually considered to have high consistency and reliability. The ICR of the Criterion layer is 0.0036, and the subCriterion layers are 0.0088, 0.0198, and 0.0176 are all less than 0.1, passing the consistency test. It was obtained to multiply the weight value of Primary Indicator by the weight value of the corresponding Secondary Indicator to calculate and rank the relative weights in the whole model, as shown in Table 7.

Table 7. Relative Weight Calculation Ranking

Number	M1	A1	A2	M2	M3	O1	O2	O3	A3	A4	A5	A6
Relative Weight	0.092	0.167	0.051	0.222	0.095	0.021	0.147	0.037	0.060	0.061	0.035	0.013
Ordering	5	2	8	1	4	11	3	9	7	6	10	12

4.4 Analysis of design elements of SDK experience product based on QFD

The core purpose of QFD is to transform customer needs and preferences into product design features (Wang Genxin, 1998). After clarifying the priority of user needs of SDK experience products through AHP in the previous section, it is necessary to map user needs into design elements through QFD and complete the weight calculation of design parameters by establishing House Of Quality (HOQ). When converting user requirements into design elements, firstly, the initial acquisition was made through literature research method, secondly, 10 ICH experience products currently on the market were selected for analysis through case study method, and finally, Table 8 User Requirements-Design Elements Conversion Table of SDK Experience Products was obtained by summarizing and combing through group discussion method.

Table 8. User Requirements-Design Elements Conversion Table of SDK

Goal Layer	Criterion layer	User needs	Design elements
SDK experience product design	Sensory experience	M1	D1 Traditional color combinations of cinnabar red, stone green and rattan yellow
		A1	D2 The representative two-headed parrot kite
		A2	D3 Using natural bamboo, rice paper, silk cloth, etc.
	Interaction experience	M2	D4 Demonstrate the steps of making the kite with drawings
		M3	D5 Provide special scissors, glue, brushes, paints and other tools.
		O1	D6 Bamboo is as light as possible
		O2	D7 Materials are non-toxic and harmless, especially paints and glues
		O3	D8 Provide anti-oxidation treatment and design moisture-proof packaging.
		A3	D9 Design display space inside the package
	Emotional experience	A4	D10 Tell the story of the history of kites/SDK
		A5	D11 Design incorporating modern elements such as simplicity, geometry and abstraction
		A6	D12 Add your own name, logo or favorite pattern on the kite

HOQ is a graphical method for determining the link between customer needs and corresponding product or service performance. Using HOQ, core user needs can be filtered out (Yueqian Yang, Yushan Zhu, & Wei Xu, 2022), user needs and their corresponding Relative Weights are imported into the left wall, and design elements are imported as ceilings. Five professors and PhDs in product design where invited to score the relevance of user needs and design elements. Strong correlation is denoted by ● , general correlation by ◎ , and weak correlation by △ , with ● , ◎ , and △ corresponding to weight values of 1.5, 1.2, and 1.0, respectively.The sum of the products of all user requirements and their corresponding Relative Weights under the Design Element is the final weight of the element (Qiang Wei, 2022). The results are shown in Table 9.

Table 9 . House Of Quality and Design Element Weightings

User needs		Design elements											
User needs	Weight value	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
M1	0.092	●											
A1	0.167		●										
A2	0.051	◎	△	◎		◎	△				△		
M2	0.222				●							△	
M3	0.095			◎	△	●			△				
O1	0.021			△			△						
O2	0.147			△		◎		●					
O3	0.037		△						◎	△			△
A3	0.060		◎		△			△	◎	◎	◎		△
A4	0.061	△	●	△							●		
A5	0.035											△	
A6	0.013					△							◎
Final weight		0.259	0.501	0.403	0.488	0.393	0.071	0.281	0.211	0.109	0.214	0.257	0.113
Rank		6	1	3	2	4	12	5	9	11	8	7	10

5. SDK experience product design

Based on the comprehensive model of Kano-AHP-QFD in the previous section, the transformed design elements were finally ranked, and the top ten items with high weighting were focused on in the process of design practice, and a SDK experience product that can optimize the user experience was designed from the three aspects of Norman's Emotional Design Theory, namely, Behavior layer (Instinctive experience), Behavior layer (Interaction experience), and Reflection layer (Emotional experience). As shown in Figure 4, The specific features of the product are as follows.



Figure 4. SDK Product Photograph

The SDK experience product consists of eight parts: a production instruction card, a kite ID card, and six kits of materials related to SDK production. Through this experience product, users are able to make a SDK that carries the essence of ICH culture. As shown in Figure 5.

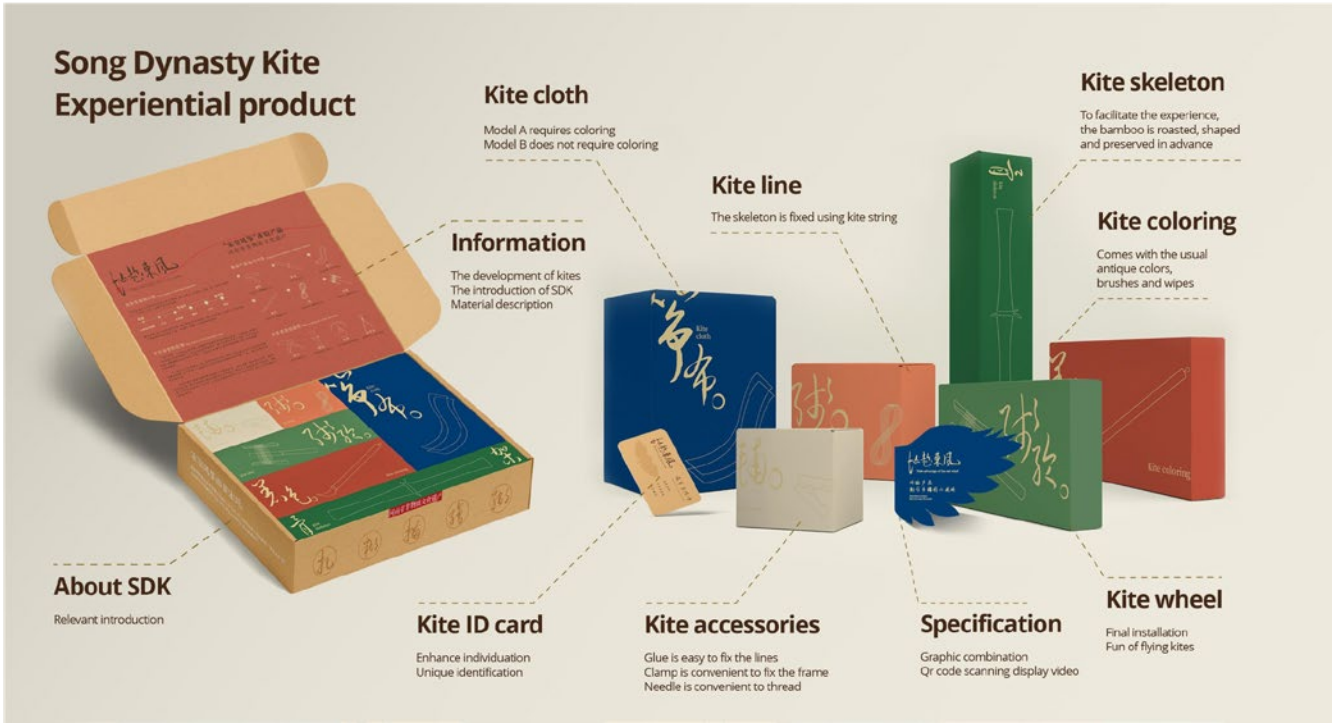


Figure 5. SDK Experience Product Composition Description

In the design of Sensory experience, the overall shape of SDK experience product skillfully integrates ancient style elements and simple design concept. The traditional Chinese brush characters and colors were used to show the deep traditional charm, and the packaging material was chosen to be special paper with texture, so that users could have a special experience in terms of tactile sensation. The most representative SDK, the two-headed parrot kite, which symbolizes the wise and heroic, and a hundred-year happiness, was used as the type of SDK for the experience (Lin Lin & Chen Hui-Ling, 2023), which further highlights the product's cultural connotation and characteristics.
In terms of Interaction experience design, in order to ensure that users have a high-quality production experience, an illustration of the production instructions is designed, and a production video that can be viewed by scanning the QR code is equipped, so that users can intuitively and clearly understand the production process. In addition, a full range of tools, such as glue, needles, brushes, paints, etc., are provided, and the materials used are strictly ensured to be safe and non-toxic. Especially worth mentioning is the antiseptic treatment of the bamboo in the material kit, which effectively enhances the shelf life and durability of the product. In terms of Emotional experience design, not only the long history of Chinese kites as well as the origins of SDK are detailed inside and outside the box, but also a kite identity card is carefully designed. Users are able to give a unique name to their handmade kites and solemnly record the date of production, thus deeply integrating their personal emotions into the production process and enhancing the emotional connection with the product.

6. Conclusions

At present, ICH is not only a remarkable manifestation of national cultural confidence, but also an important symbol of cultural diversity and creativity. This paper focuses on the design of ICH experience products from the perspective of user needs, taking the SDK as an example of Henan's non-heritage. Based on Norman's Emotional Design Theory, the three experience elements of Sensory experience, Interaction experience and Emotional experience are refined, and the integrated model of KANO-AHP-QFD is explored and constructed. The KANO model is used to classify and prioritize the original user needs, and the weight of the needs is further refined with the AHP, to ensure the scientificity and accuracy of the design decision. The user requirements were transformed into specific design elements through QFD, and the experience elements of SDK were finally completed according to the first ten design elements transformed. The design solution not only considers the practicality and aesthetics of the product, but also emphasizes the transmission of cultural inheritance and Emotional experience value, thus realizing the living inheritance of ICH culture, and at the same time, its combination of research methods also provides an innovative path and reference model for the design of other ICH experience products.

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RESEARCH ON ENVIRONMENTAL REGULATION DESIGN OF SUSTAINABLE COMMUNITY FROM THE PERSPECTIVE OF THERMODYNAMIC SYSTEM.

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ABSTRACT | With the rapid growth of urban population density and calls for energy conservation and carbon reduction, the sustainability of the built environment in communities is a growing concern. While there are many studies on the physical environment of urban blocks and building units, the research that considers the performance of community environments from a systems perspective and design behavior remains notably limited. The community serves as the fundamental system for human life, integrating diverse energy flows, including acoustic, light, electrical, and thermal energies. These flows are not limited to individual buildings but typically consider the community environment as the primary unit of energy circulation. Moreover, the human comfort level in the community is closely related to their energy consumption.

This paper, based on Lou's Four Systems framework ,explains the interactions among the four systems—Nature, Human Beings, Artificial Systems, and Cyber Systems—from a thermodynamic perspective within a community, viewing the microclimate, the built environment, the inhabitants, with energy, information, matter flowing within the system. It analyzes how to improve human comfort in the environment through design, thereby improving the community's energy use and carbon emissions and ultimately leading to a more sustainable community environment.

This paper reviews historical research and analyzes and compares cases to summarize several strategies for environmental regulation of community from a thermodynamic perspective. It also provides an analysis and explanation of the interactions among these systems, aiming to offer a reference for the design of sustainable communities in the future.

KEYWORDS | ENVIRONMENTAL REGULATION, THERMODYNAMIC SYSTEM, HUMAN COMFORT, SUSTAINABLE COMMUNITY, DESIGN

1. Introduction

Systematic considerations of the living environment can be traced back to B.C., where it was already recognized that the location, orientation, building materials, and forms of housing significantly influenced people's lifestyles. Two thousand years ago, Vitruvius highlighted in "De Architectura" the importance of considering tangible and intangible resources in the environment, such as water, wind, food, sunlight, and sound, when constructing residential areas to ensure the physical and mental well-being of the inhabitants.

Communities, as collections of architectures and products of design, bear a significant social responsibility to ensure the well-being of residents and the ecological health of urban environments. Yongqi Lou pointed out that communities are composed of the interactions between the Four Systems that constitute human activities: nature, human beings, cyber system, and artificial system (Figure 1). Different disciplines often focus on one of these themes, while the interactions among them are realized through design practice (Lou, 2018). Designers play a crucial role in dissolving the opposing relationships between these systems.

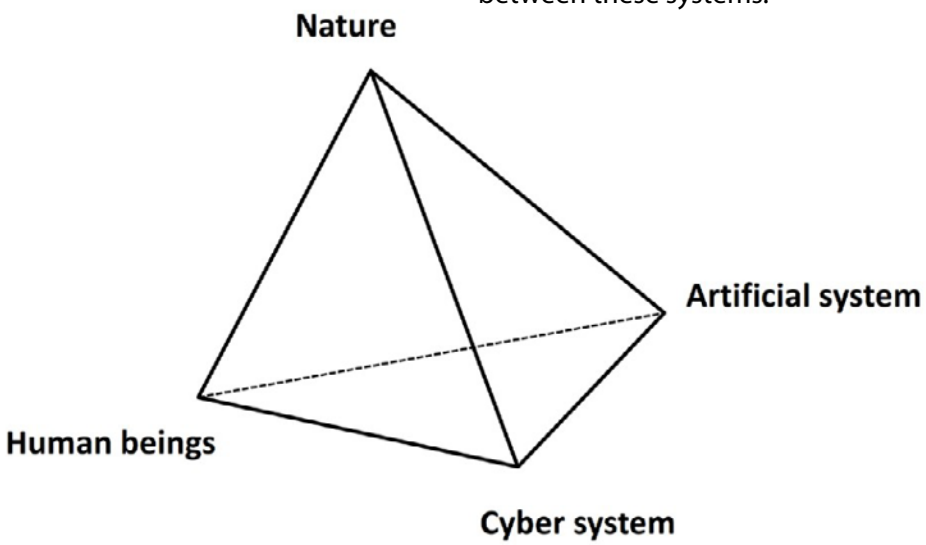


Figure 1. The interactions of the Four (nature, human, cyber, and artificial) Systems (image source: Lou, 2018).

According to China's seventh national census, the urban population has reached 63.89%, an increase of 14.21% over the past decade(Chen, 2021). As more people migrate to cities, extensive efforts are being made in community development and the renovation of old neighborhoods. The World Commission on Environment and Development (WCED) highlighted in the 1987 Brundtland Report that energy, economy, and environment are the three pillars of sustainable development(Federal Office for Spatial Development ARE, 1987). However, according to a review of sustainable development policies and interventions by Mamudu et al., 80% of publications on sustainable development in academia focus on science and technology, including environmental science, energy, agriculture, engineering, and chemistry. Research in the fields of social sciences and economics accounts for only 20% (Akudugu & Ogwu, 2024).

In the fields of architecture and design, the advancement of science and technology has led to the quantification of all quantifiable aspects of the construction process. In 1964, Reyner Banham criticized in "The Architecture of the Well-Tempered Environment" that architects were becoming accustomed to delegating all environmental control work, except for structural concerns, to engineers, HVAC specialists, telecommunication experts, and other technical personnel. He considered this a severe dereliction of duty (Banham, 1964). He also mentioned that an overreliance on quantification can lead to a neglect of human comfort and sensory stimulation. William W. Braham also noted that when people talk about energy, their focus tends to be limited to listing efficient equipment and applying high-energy fuels. He argued that energy flows in natural, technological, and social environments should all be considered (Braham, 2015).

With the advancement of information technology, information as a new form of energy is influencing community living patterns. The internet has given rise to remote work and digital nomad, altering the composition and consumption patterns of community residents (Jiwasiddi et al., 2024). New electronic products and appliances bring new energy consumption demands. People can achieve a balance between energy consumption and comfort through remote operation or centralized control by power companies (Kim et al., 2023). These energy flows shape people's lifestyles and work patterns.

However, even with such dramatic social changes, designers still lack a voice in the construction process regarding the development of energy systems. To improve this situation, it is crucial to create a universal tool for designers in community design. This paper will explore the following question from the perspective of energy flows: How can design work achieve a positive interaction between humans, machines, and the environment when designing sustainable communities?

Research Methodology:

1. Conduct extensive literature research to delineate the boundaries of community energy and human perception, analyzing their constituent elements and characteristics.

2. Perform case analyses of related works grounded in Yongqi Lou's "Four Systems" theory, explaining the role of design in resolving conflicts among the elements within the Four Systems in these projects.

3. Construct a foundational knowledge framework for low-carbon community design based on case analysis, aimed at enhancing designers' understanding and application.

2. Literature Review

2.1 Start From Architecture

The theoretical origins of habitat environment regulation stem from the field of architecture. Initially, it was observed that the chosen environment for constructing residential areas significantly impacts the physical health of the inhabitants. Around 250 BCE, the ancient writing "Mozi: Ci Guo" records:

"In ancient times, when people did not know how to build houses, they lived on hills and in caves. The dampness from below harmed the people, so the wise king created palaces and houses. The method for building houses was as follows: the rooms should be high enough to avoid dampness, the four sides should be sufficient to protect against wind and cold, and the roof should be adequate to withstand snow, frost, rain, and dew." (J. Li, 1925)

Vitruvius also mentioned in his renowned work, "Ten Books on Architecture," that houses in the north and south should have different designs due to the varying effects of sunlight(Hawkes et al., 2002, p. 3). At that time, people primarily considered the relationship between the environment and human comfort. Architecture, as an intermediary, mainly served the function of being a "dwelling," providing a healthy living environment for people.

By the 1920s, with the post-war population boom and housing shortages, mass production had become mainstream in society. At the second CIAM (Congrès Internationaux d'Architecture Moderne) conference, the group form northern European cities discussed the issue of Existenzminimum, which refers to housing units that could be afforded by families with minimum wage incomes(Mumford, 2019, p. 291). This type of housing aimed to minimize expenses, providing more economical housing for ordinary people. However, due to the lack of systematic consideration of residential architecture, many houses based on this belief encountered problems. A typical example is Minoru Yamasaki's Pruitt-Igoe. To save costs, this building used a large amount of cheap materials and fixtures, such as doors and windows,

resulting in extremely poor living conditions. The building was completed in 1954 and was eventually demolished in 1972(Heathcott, 2012). The consequence of non-systematic consideration is more severe waste; such short-lived buildings are no different from the Kleenex culture criticized by Papanek.

In the 1960s, Buckminster Fuller, in his renowned "Operating Manual for Spaceship Earth," pointed out that the economic accounting systems of the time unrealistically regarded wealth as material, which does not increase. Therefore, this method of accounting was "anti-synergetic, depreciative, and entropic mortgagization." He called for the establishment of a truly economic accounting system, using design to change the Earth's environment(Fuller, 1969, p. 95). He called for the world to shift from a negative economic accounting system to a positive, global economic accounting system, proposing that "energy is wealth." (Fuller, 1967, p. 35)

Banham, in "The Architecture of the Well-Tempered Environment," pointed out that architecture is a self-regulating machine, with energy serving as a continuous thread throughout the work. He emphasizes that architectural technology involves the storage, selection, and regeneration of elements such as air, light, and humidity, corresponding to three architectural modes: "conservative mode," "selective mode," and "regeneration mode." The "conservative mode" and "selective mode" are associated with building forms in dry cold climates and humid warm regions, respectively. With technological advancements, more sophisticated techniques and materials, such as glass curtain walls and air conditioning, have enabled better control of the indoor environment. In Banham's view, the form of modern architecture is largely a natural outcome of humanity's pursuit of comfort through environmental regulation. (Banham, 1964). Therefore, energy and comfort are essential topics in community development, both historically and in the present, and will remain crucial in the future.

2.2 To Community

With the acceleration of urbanization and the advancement of the internet, more and more things are becoming interconnected. Knowledge originally used in the field of architecture is gradually being transferred to community design. Li and colleagues used the emergy analysis method to conduct a comprehensive evaluation of the renewal activities in old communities. Their analysis accounted for numerous variables, ranging from basic building materials to social welfare. They pointed out that community renewal remains a resource-intensive process; however, this process is not universally applicable (D. Li et al., 2021). Ayyoob and colleagues summarized existing Neighborhood Sustainability Assessment (NSA) tools, noting that most of these NSAs are derived from the field of sustainable building. They discussed the limitations of these tools, such as insufficient consideration of specific contextual issues, excessive complexity making them difficult to understand, and their inability to adequately address local contexts and specific needs (Sharifi et al., 2021).

In this paper, "Community" refers to commonly seen urban residential areas, also known as Housing Estates, Neighborhoods, or Blocks. These communities typically consist of multiple buildings and both indoor and outdoor public areas, which can be further subdivided into indoor private areas, indoor public areas, and outdoor public areas. The Sources and Flows within these communities are more numerous, making the design process more complex and harder to fully comprehend.

2.3 The Four Systems

In 2018, Yongqi Lou proposed the Four Systems, calling for attention to the interactions between nature, human, cyber, and artificial systems to address threats to human survival (Figure 2). He highlighted the significant gaps between various disciplines: research on humans is concentrated in social sciences, such as psychology and sociology; natural sciences focus more on the laws governing physical existence; and artificial systems encompass the combination of human and natural elements, such as architecture and economics (Lou, 2018). Today, cyber systems are rapidly evolving, with 5G networks making the Internet of Things (IoT) a reality. The development of artificial intelligence (AI) has made many tools smarter and more convenient to use, while also increasing the uncertainty of systems.

The Four Systems provide a clear and straightforward explanation of the composition of our world, helping more people understand the connections and interactions between the systems human live within.

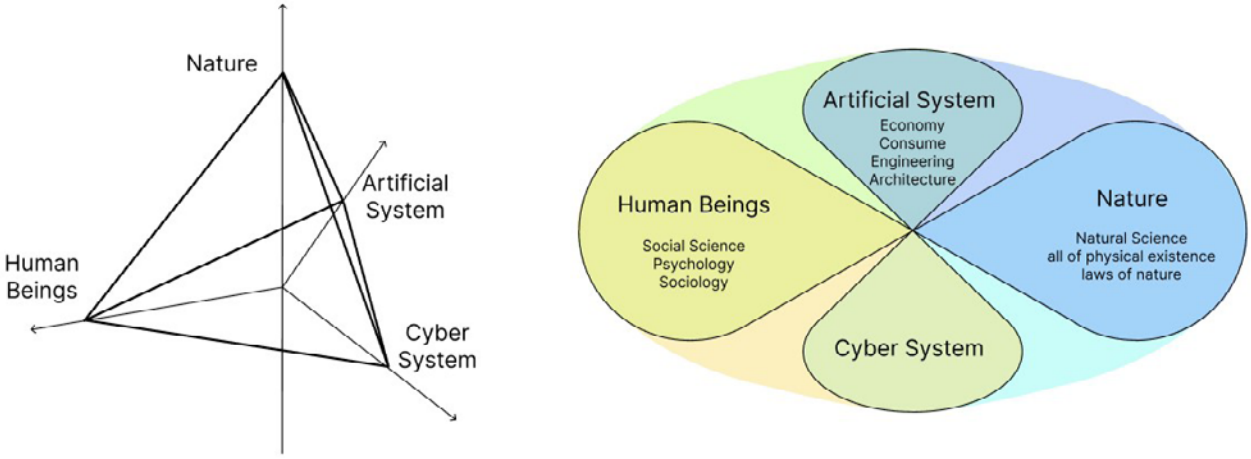


Figure 2. Coordinate system of the Four Systems and integration of disciplines.

2.4 Thermodynamic Lens

Ecologists Eugene P. Odum and Howard T. Odum pioneered eco-energetics. Eugene P. Odum proposed that the flow of energy in the environment could be represented using flow charts, commonly used in mathematics and computer science (E. P. Odum, 1968, p. 16). In the 1980s, Howard T. Odum, in his book "Systems Ecology," created the Energy Systems Language (Figure

3.). He elevated this thermodynamics-based analytical method from the field of ecology to the social level, transforming it into a scientific tool for social and environmental analysis(H. T. Odum, 1983). This analytical tool can help designers and decision-makers cope with increasingly complex environmental systems. Half a century later, its scope continues to evolve and expand, allowing information to be presented as a tool for energy flow. Based on the Energy Systems Language, Odum proposed using the solar joule (semj) as a unit of account for emergy, to quantify the energy embodied in all systems within the biosphere(Campbell, 2016, p. 97) This tool can be used to discuss any system capable of performing work.

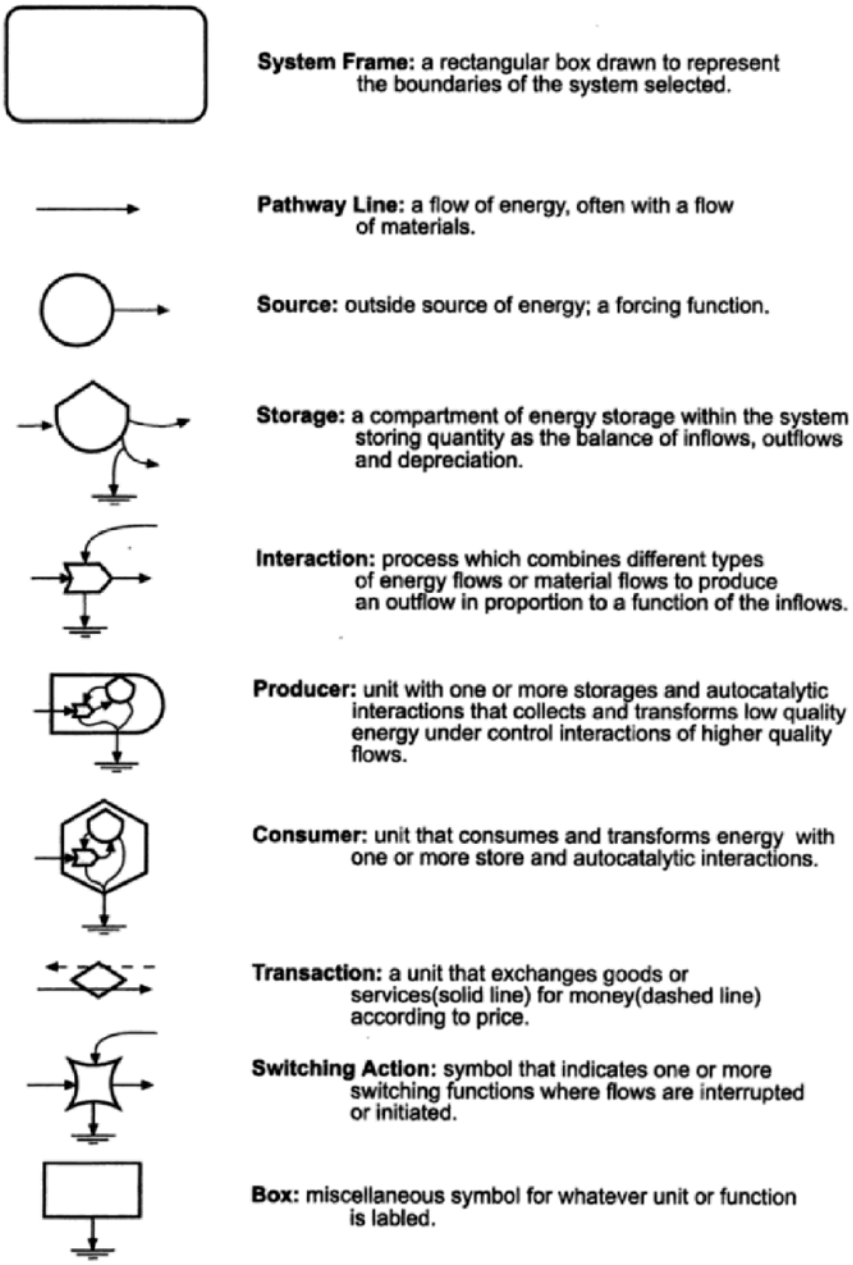


Figure 3. Energy Systems Symbols by Odum (image source: Muller, 2000, p. 282).

Thermodynamics involves the study of energy laws, focusing on thermodynamic systems. A thermodynamic system is a finite macroscopic region used for thermodynamic research, representing a specific part of the material world under study. Since this system is finite, it has boundaries; these boundaries separate the system itself from its external space, known as its surroundings. The boundary of a thermodynamic system delineates the spatial region occupied by the system, through which mass, heat, and mechanical energy can flow. The system can exchange various forms of energy with its surroundings through this boundary.

Thermodynamic systems can be classified based on the type of energy transfer permitted by their boundaries, including isolated systems, closed systems, mechanically isolated systems, adiabatic systems, and open systems (Figure 4). An open system is one that allows the transfer of both energy and matter with its surroundings. The built environment is an open, nonequilibrium thermodynamic system, a dissipative structure. The climate serves as the system's surroundings, while the building interface acts as the system's boundary. For the system to continue functioning, it must continuously obtain matter and energy from its environment.

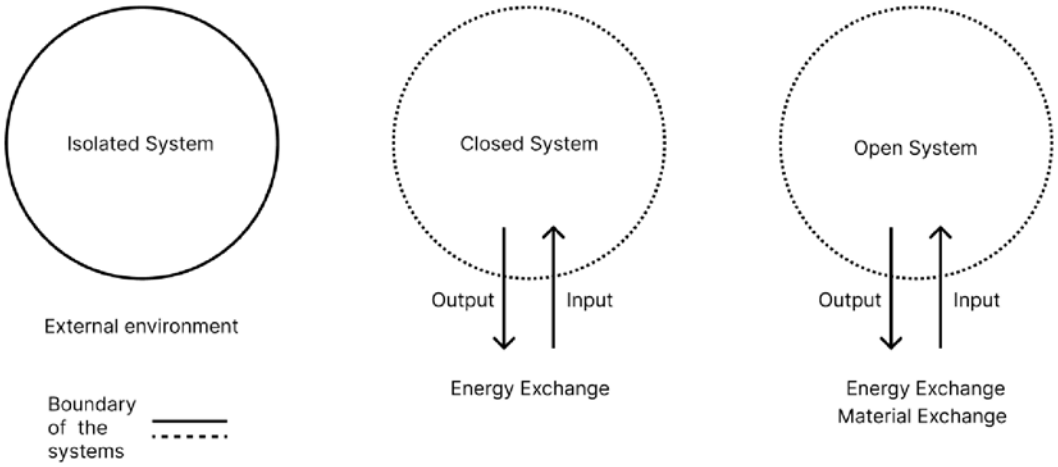


Figure 4. Three kinds of thermodynamic systems.

Building on Banham's theory, Abalos introduced the concepts of thermal source and thermal sink. In cold, dry northern climates, the interior acts as a source, providing heat through a thermal comfort core. To maximize sunlight exposure, houses are compact, and urban structures are loose, turning buildings into thermal machines. Conversely, in warm climates, the interior acts as a sink, where buildings are "empty" and no longer serve as machines for living but rather as centers for social life influenced by natural climatic patterns. Abalos advocates for a thermodynamics-based approach to managing built spaces, aiming to balance various thermodynamic factors to create spaces more conducive to social interaction and sensory experiences. This balance arises from the interplay between form, materials, and air(Abalos, 2015).

Braham introduced Odum's Energy Systems Language into the built environment, dividing the analysis of buildings into three purpose scales: site, shelter, and setting. In this framework, "Building-as-site" emphasizes the location, forming the first energy system shaped by various climatic factors. "Building-as-shelter" involves modifying and maintaining the microclimate through the enclosure of the building interface in a specific climate (Figure 5), representing the secondary energy system. "Building-as-setting" refers to the behavioral space for human activities, such as work and living, and includes material services like water and food, as well as concentrated flows like fuel, information, and money, making up the third energy system. Each level represents an environmental performance standard in building design, with continuous interaction between these scales. The movement of building interfaces and people transforms buildings into open systems (Braham, 2015).

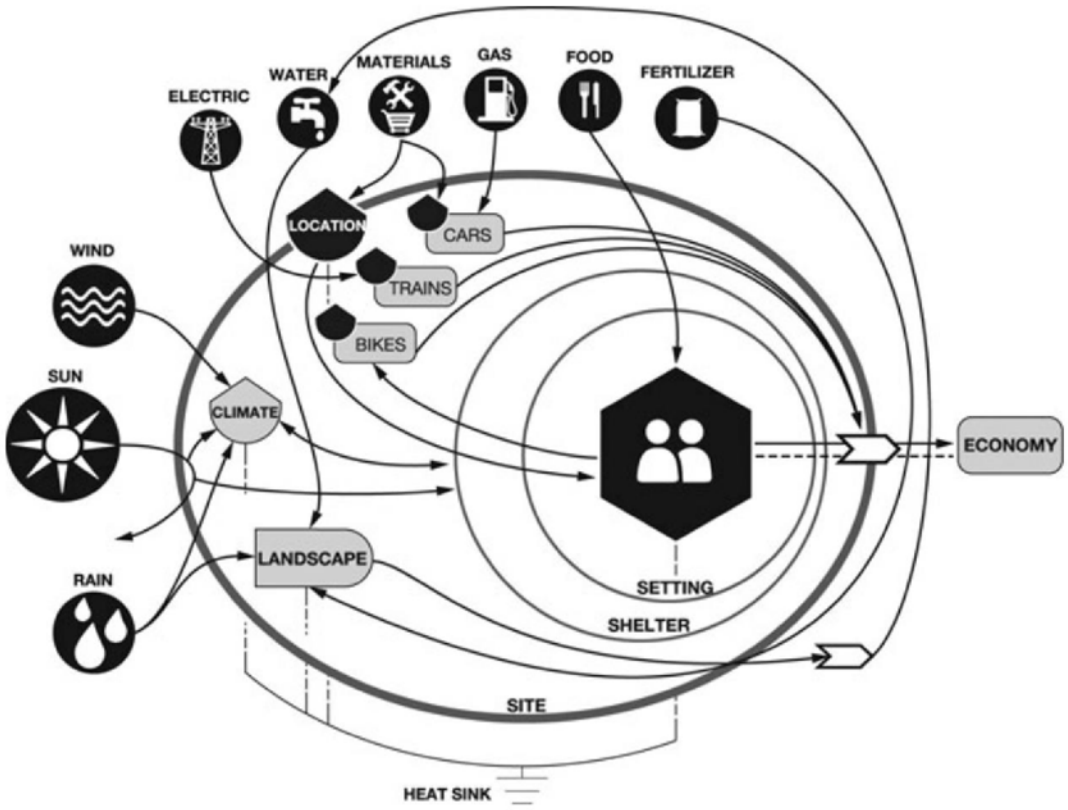


Figure 5. Thermodynamic diagram of the building-as-site (image source: Braham, 2015, p. 221)

3. Case Study

To better explain the connections among the Four Systems, this paper is based on Lou's Four Systems framework. It selects eight research cases that involve interactions between two or more systems and classifies them according to the two most relevant systems, as shown in the table below:

Table 1. Table layout. Captions for Tables are placed above.

Case No.	Reference	The included systems	Key Words
1	(Labdaoui et al., 2021)	Human Beings，Artificial System	Comfort Walkability Index, thermal comfort
2	(X. Deng et al., 2023)	Human Beings，Artificial System	Outdoor thermal comfort, Mobile measurement
3	(Ma et al., 2023)	Human Beings, Cyber System	Occupant behavior , Energy use intensity
4	(Konis et al., 2020)	Human Beings, Cyber System	Participatory sensing, Thermal comfort
5	(Hou et al., 2023)	Nature, Artificial System	Mean radiant temperature, Radiant heat transfer , Local thermal comfort
6	(Z. Deng & Chen, 2020)	Nature, Artificial System	Thermal comfort, Artificial neural network, Wearable device
7	(Necira et al., 2024)	Nature, Human Beings	Boulevard, heat stress, mitigation strategies
8	(Baquero Larriva et al., 2022)	Nature, Human Beings	Thermal comfort Older people Nursing homes Naturally ventilated Mediterranean climate

3.1 Human Beings & Artificial System: Case 1 and Case 2

The spaces inhabited by humans need to meet various needs, with the most fundamental being physiological comfort. Humans, as complex organic beings, are constantly exchanging energy and matter with their external environment. In this process, the human body must maintain a relatively stable core temperature to achieve a dynamic balance between heat production and heat dissipation, thereby ensuring comfort. This is related to the objective physical environment, affecting how the skin adapts to indoor conditions through its own temperature regulation, which can be improved through the design of community spaces or equipment. At the same time, as a subjective evaluation of human perception, it is also related to physiological and psychological states, such as activity level, clothing thermal resistance, social and cultural background, and behavior patterns.

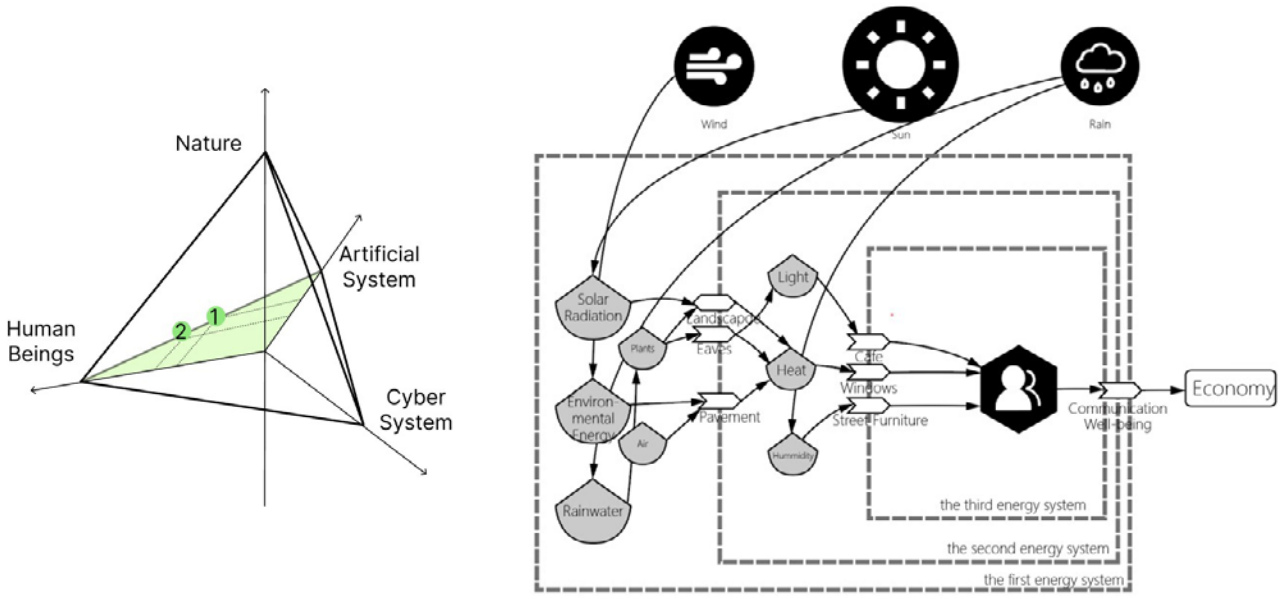


Figure 6. Left: The Positions of Case 1 and Case 2 in The Four Systems. Right: Thermodynamic diagram of Case 1 and Case 2.

Case 1 and Case 2 illustrate how improving artificial system designs can enhance the well-being of human systems. Case 1 investigates two communities in the center of Annaba, Algeria (Figure 7), assessing thermal comfort and walking facilities to derive the CWI (Comfort Walkability Index) values. The results indicate that the colonial center has a higher CWI value, offering a more comfortable walking environment, while the old town, with its inadequate walking facilities, shows a lower CWI value. This study emphasizes the importance of evaluating walkability at the community level and proposes specific measures to improve walking environment comfort (Labdaoui et al., 2021).

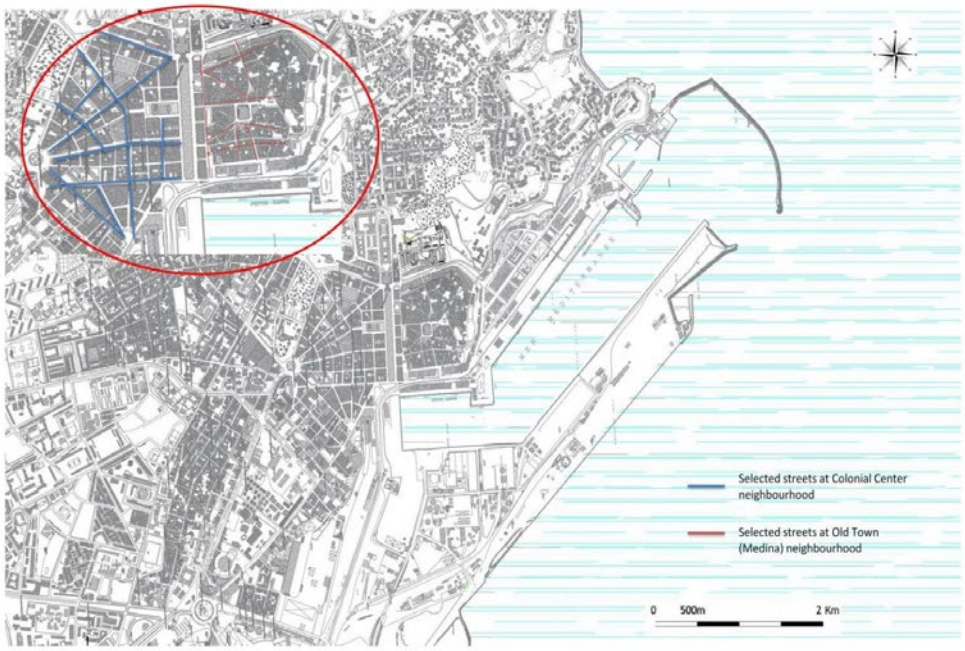


Figure 7. Selected streets at Colonial Center and Old Town in Annaba city center (image source: Labdaoui et al., 2021).

Case 2 compares two urban areas in Guangzhou: Yongqing Fang (a historic district) and Knowledge City (a new district). Using on-site monitoring and surveys, the study evaluates outdoor thermal comfort through PET (Physiologically Equivalent Temperature) and TCV (Thermal Comfort Vote). The results reveal significant differences in building environments and meteorological conditions between the old and new districts (Figure 8), which affect the perception of thermal comfort. The findings indicate that urban design strategies can significantly enhance pedestrian thermal comfort, demonstrating the interaction between artificial systems and human well-being(X. Deng et al., 2023).

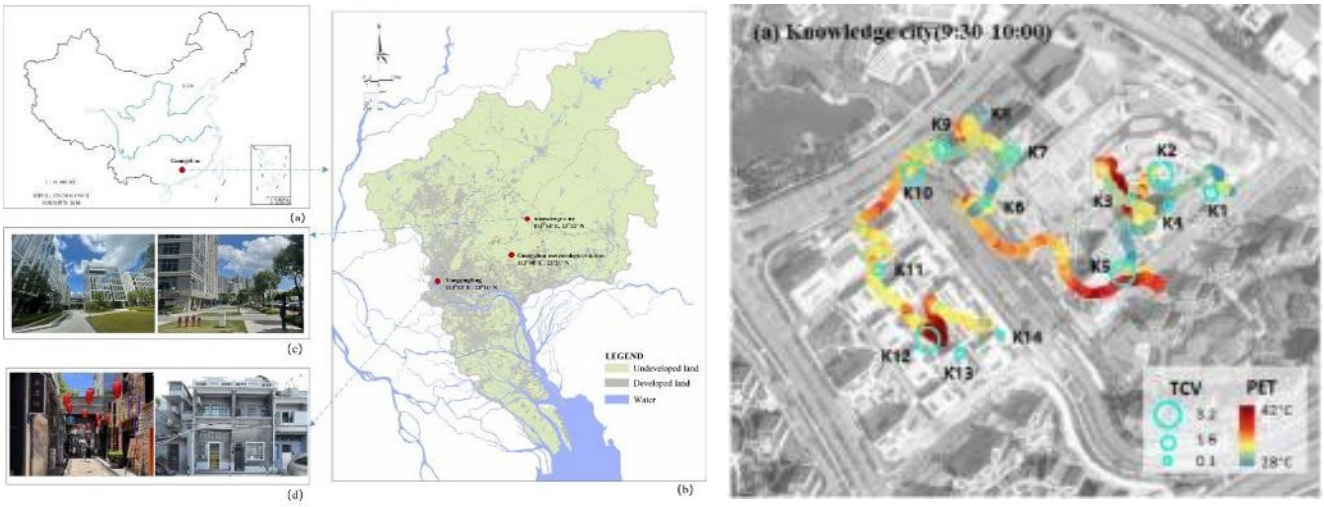


Figure 8. Left: Location of the study area. Right: Spatial distribution of PET for the routes and the corresponding TCV reported by subjects (image source: X. Deng et al., 2023, p.3).

Table 1. Comparison of Case 1 and Case 2 in the aspect of Human Beings & Artificial System.

Case No.	Human Beings	Artificial Systems
1	Walkability Comfort: Perception data from pedestrians were collected through questionnaires to understand the impact of different walking facilities on comfort.	Walking Infrastructure: The design elements such as sidewalk width, slope, shade, and seating influence the overall quality of the walking environment.
	Social Interaction: A comfortable walking environment can promote interactions among community members, enhancing social cohesion and overall well-being of residents.	Thermal Comfort: Using Physiologically Equivalent Temperature (PET) as an evaluation metric for thermal comfort, combined with microclimate data for assessment.
2	Thermal Comfort: The subjective evaluation of pedestrians regarding the thermal environment was studied using Physiologically Equivalent Temperature (PET) and Thermal Comfort Vote (TCV).	Urban Design and Morphology: How building height, density, and layout influence the local microclimate and pedestrian thermal comfort.
		Landscape Parameters: Factors such as greenery, water bodies, and building shading can impact the urban microclimate.

3.2 Artificial System & Cyber System: Case 3 and Case 4

Deploying Internet of Things (IoT) sensors in communities to gather real-time environmental parameters—such as indoor and outdoor surface temperatures, air temperature, and humidity—along with human body parameters and subjective comfort evaluations, combined with machine learning predictive models, can facilitate precise forecasting of building heating and cooling needs. Additionally, incorporating a real-time feedback control system with intelligent regulation models that dynamically adapt to environmental changes can minimize energy consumption while maintaining the comfort of community residents.

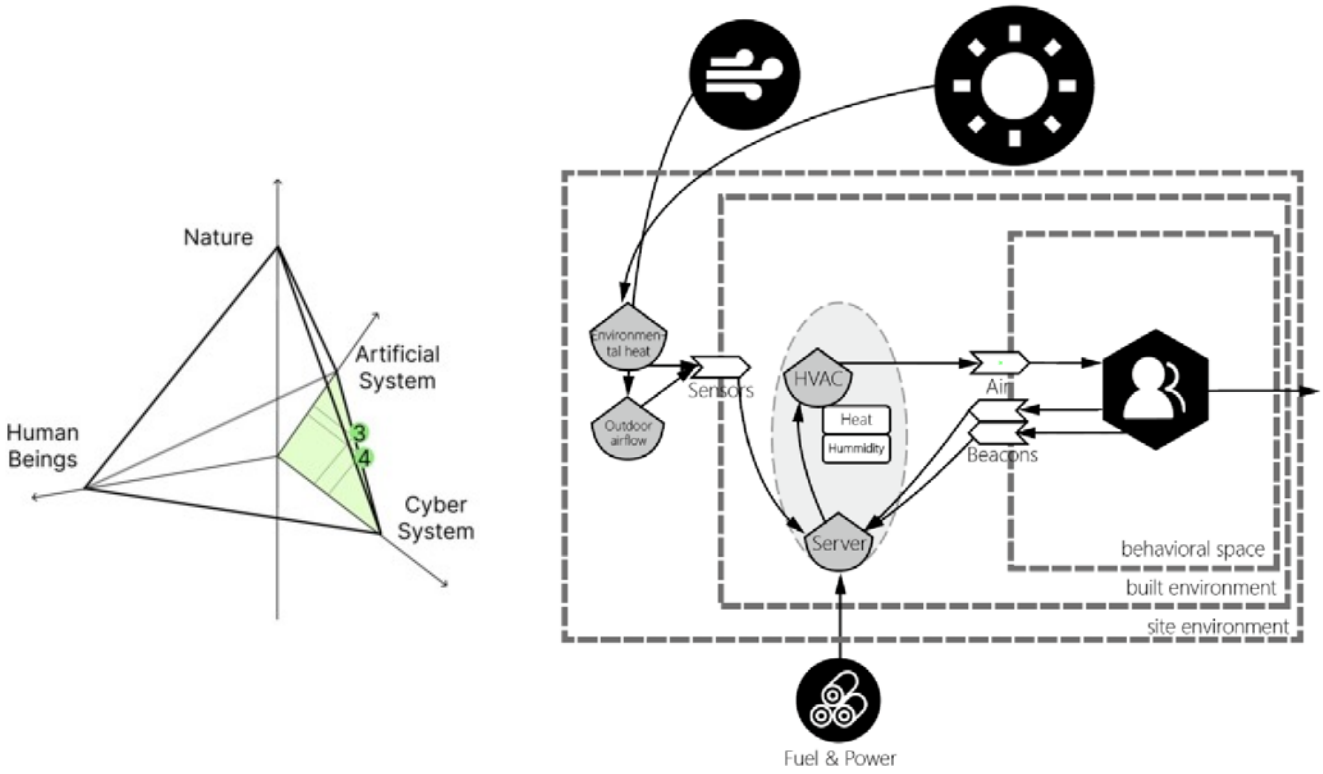


Figure 9. Left: The Positions of Case 3 and Case 4 in The Four Systems. Right: Thermodynamic diagram of Case 3 and Case 4.

Case 3 and Case 4 both demonstrate the importance of the involvement and feedback of cyber systems in optimizing performance within intelligent and data-driven artificial systems. Case 3 uses blockchain and Internet of Things (IoT) technologies to ensure the security and transparency of environmental data in buildings through Smart Contracts (Figure 10). The use of IoT enhances the sensitivity of building environment monitoring, and the study proposes incentive measures such as reward tokens to encourage users to reduce energy consumption, thereby achieving social participation in energy saving and emission reduction (Ma et al., 2023).

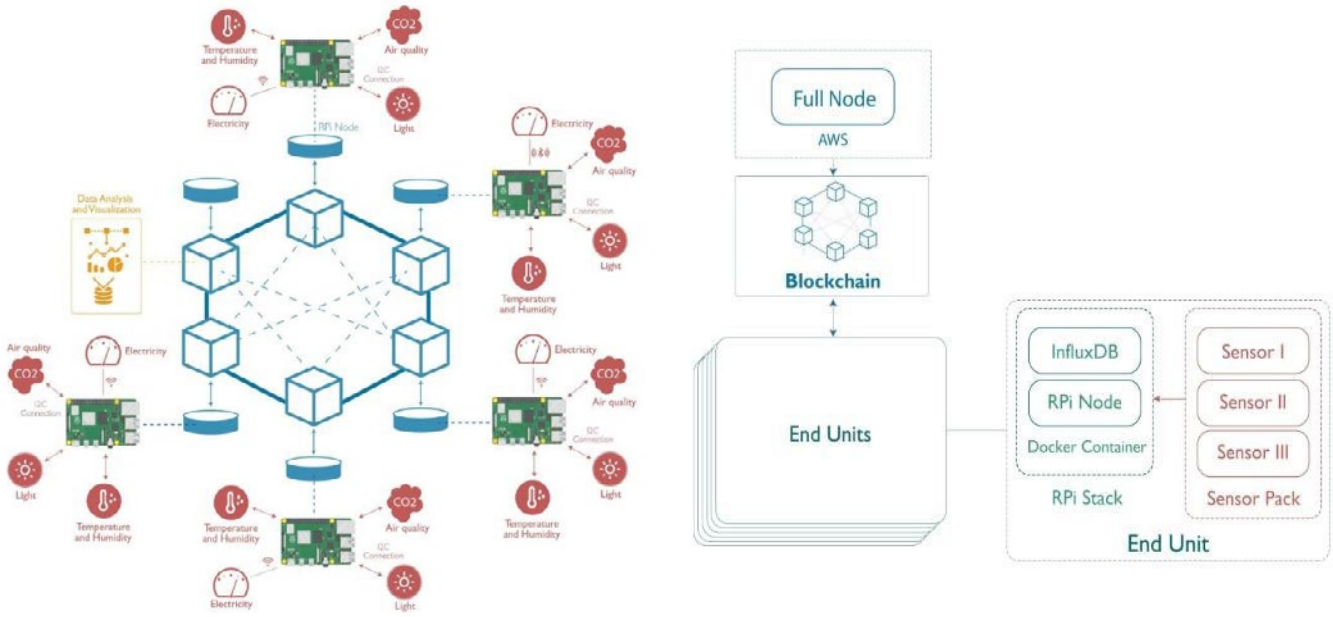


Figure 10. Schematic overview of the system infrastructure (image source: Ma et al., 2023, p.4)

Case 4 discusses a participatory sensing framework called TrojanSense, designed to manage thermal comfort in campus buildings. This system uses Bluetooth Low Energy (BLE) beacons and a mobile application to collect users' subjective feedback on indoor temperature through a combination of software and hardware (Figure 11). This approach aims to better understand and manage the thermal environment of buildings(Konis et al., 2020).

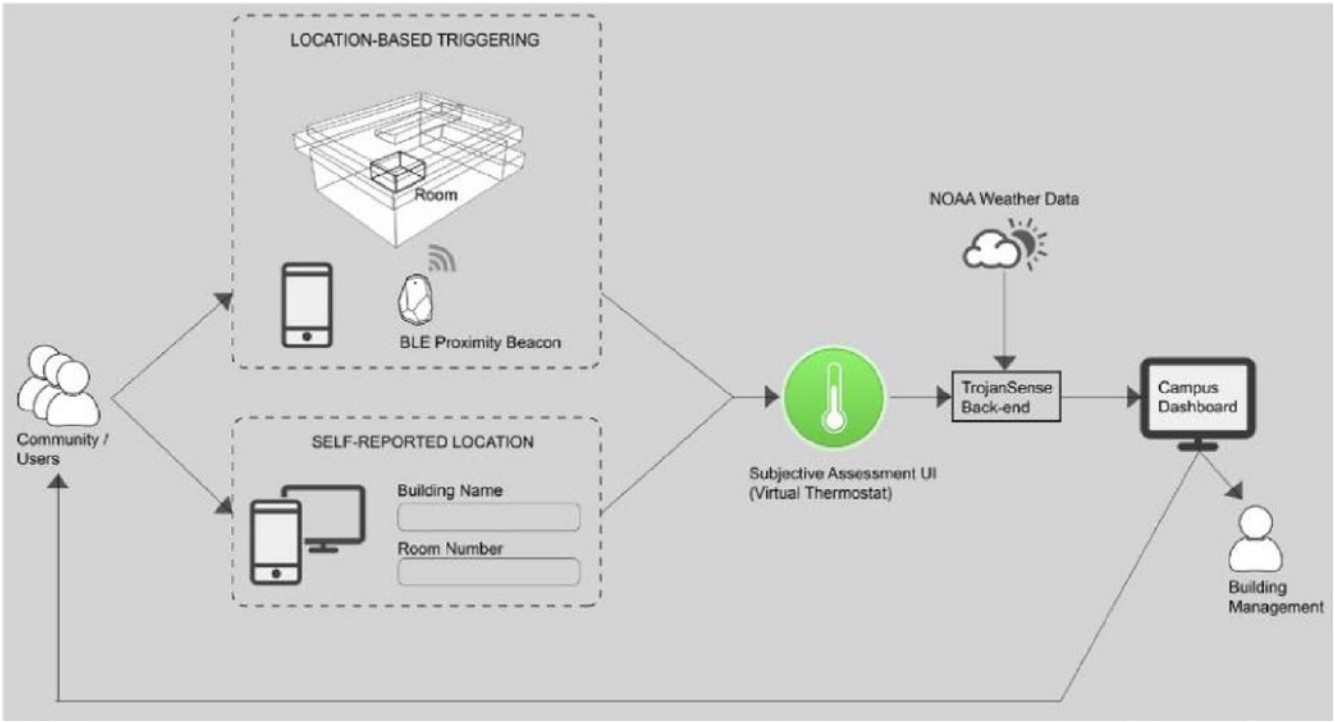


Figure 11. Framework of the TrojanSense open-loop feedback system (image source: Konis et al., 2020, p.4).

Table 2. Comparison of Case 3 and Case 4 in the aspect of Artificial System & Cyber System.

Case No.	Artificial Systems	Cyber Systems
3	Participation, Feedback, and Incentives: Through the IoT sensor network, users can access real-time environmental data and participate in providing feedback, which serves to incentivize energy-saving behaviors.	Blockchain and Smart Contracts: Blockchain technology provides a secure and transparent way to store and transmit sensor data. Due to the inherent characteristics of blockchain, users can more confidently rely on this data to make informed environmental decisions.
	Sensor Network: The study deployed a large number of IoT sensors within the campus, which monitor indoor environmental quality and energy consumption data in real time.	Internet of Things (IoT): IoT sensor networks collect environmental data in real time, which is then stored and verified using blockchain technology. Users can view real-time data through the platform and provide feedback, helping to improve environmental management strategies.
4	BLE Beacons and Sensor Network: The TrojanSense system deploys BLE beacons and a sensor network within buildings to monitor environmental parameters such as indoor temperature and humidity in real time.	Feedback Optimization: Utilizing participatory sensing technology, active user feedback is linked with real-time environmental parameters to establish a more interactive environmental control model.
		Thermal Comfort Management: User feedback helps building managers understand actual temperature needs, allowing them to adjust temperature control strategies by the micro-climate control systems.

3.3 Cyber System & Human Beings: Case 5 and Case 6

Wearable physiological sensors, such as ECG (electrocardiogram), EEG (electroencephalogram), SC (skin conductance), and respiration sensors, enable real-time acquisition of human perception data. These physiological data, combined with human comfort models, guide the assessment of group thermal sensations. This approach brings subconscious cognitions and feelings, which are difficult to perceive intuitively, to the forefront, facilitating the regulation and optimization of behavior and environmental design within communities.

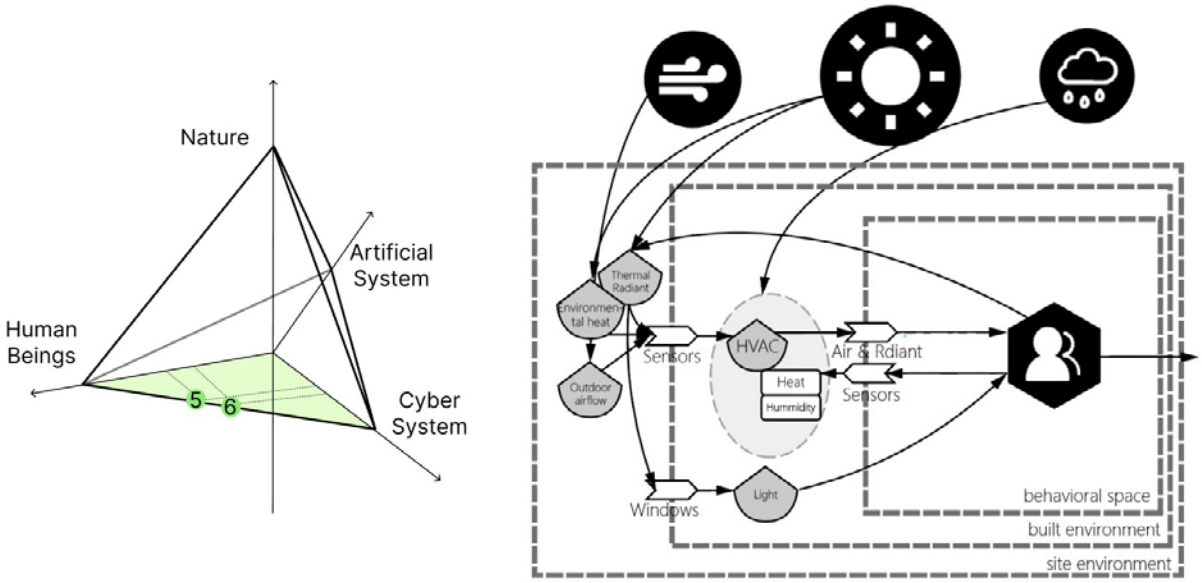


Figure 12. Left: The Positions of Case 5 and Case 6 in The Four Systems. Right: Thermodynamic diagram of Case 5 and Case 6.

Case 5 and Case 6 both demonstrate that the integration of natural and artificial systems is crucial for optimizing thermal comfort. Case 5 primarily investigates the potential impact of indoor radiant environments on human comfort and guides intelligent building design. Through a series of experiments conducted in a thermal laboratory, this study combines scanning and thermal imaging technologies with ray tracing simulations to provide high-resolution thermal models (Figure 13). These models comprehensively characterize longwave and shortwave radiant heat flows within a space and analyze their effects on Mean Radiant Temperature (MRT) (Hou et al., 2023).

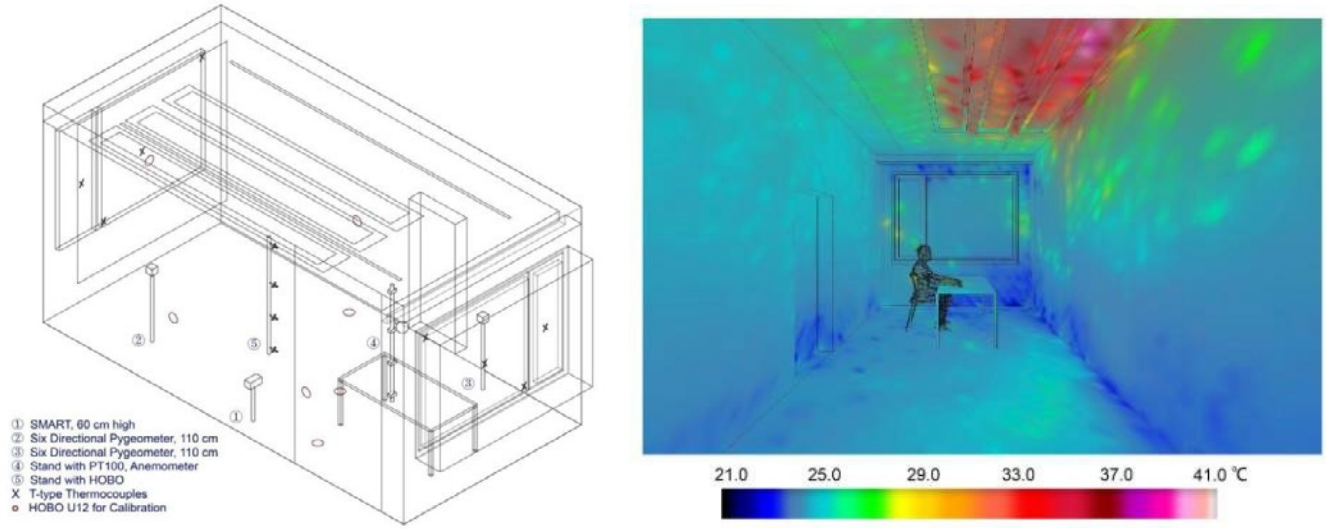


Figure 13. The sensors' layout in the experimental room and experimental room surfaces with the temperature mesh from the surface temperature data of SMART (image source: Hou et al., 2023, p. 6).

Case 6 aims to develop and validate an intelligent HVAC (Heating, Ventilation, and Air Conditioning) control system to improve thermal comfort in multi-user offices. This system uses wearable devices to collect users' physiological signals and predicts thermal sensations through an Artificial Neural Network (ANN) model (Figure 14), dynamically adjusting indoor temperature settings accordingly (Z. Deng & Chen, 2020).



Figure 14. Data collection devices used in this study. (a) thermostat on the wall, (b) data logger, (c) wristband (image source: Z. Deng & Chen, 2020, p. 2).

Table 4. Comparison of Case 5 and Case 6 in the aspect of Artificial System & Cyber System.

Case No.	Cyber Systems	Human Beings
5	Innovative Experimental Environment: The Smart Living Lab was established to simulate real building environments, utilizing a wide array of advanced sensors and wearable devices.	Human Thermal Comfort: The study assessed human thermal comfort in various radiant environments, focusing on the effects of shortwave and longwave radiation on different parts of the body.
	Smart Building Design: The research can provide design strategies for optimizing indoor environments, such as using reflective materials, adjusting window positions, and incorporating shading devices.	
6	Data Processing: The Artificial Neural Network (ANN) model predicts users' thermal sensations (Thermal Sensation Vote, TSV) based on the collected data. The model considers multiple input parameters, such as air temperature, relative humidity, and clothing insulation factor, and is trained and optimized using machine learning methods.	Wearable Devices: These devices enable users to participate in the regulation of building environment temperatures in a relatively unobtrusive manner. On one hand, they collect physiological data, and on the other hand, they make thermal sensation voting more convenient.
	Automated Control: The control system can automatically adjust temperature settings based on real-time physiological data, ensuring optimal thermal comfort in office environments across different seasons and varying numbers of occupants.	User Experience: The system is highly personalized, capable of providing individualized temperature control based on each user's specific physiological state, significantly enhancing user comfort.

3.4 Nature & Artificial System: Case 7 and Case 8

Climate is a natural phenomenon, and humans constantly engage in a struggle with it for survival. Architectural spaces are human creations that protect against the climate, acting as intermediaries between people and their environment. In modern times, artificial lighting has freed us from dependence on natural light, and air conditioning systems use mechanical energy to transfer indoor heat to the outdoors, creating a microclimate with suitable temperature and humidity for living spaces. The natural climate is both the external environment that artificial systems must adapt to and a source of external energy that they can utilize.

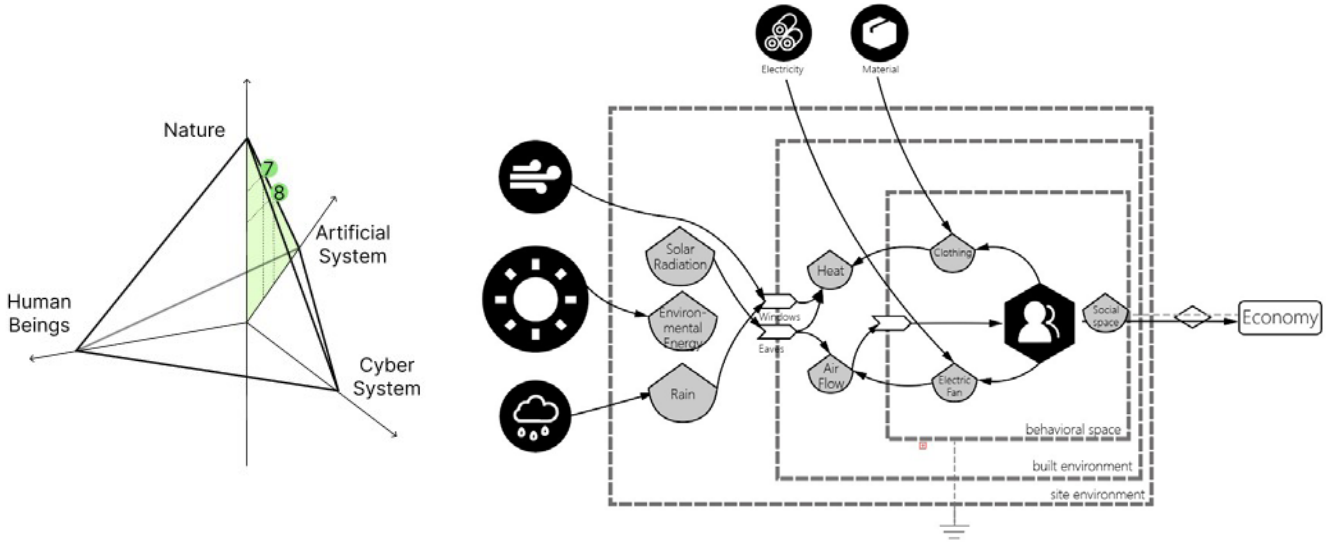


Figure 15. Left: The Positions of Case 7 and Case 8 in The Four Systems.
Right: Thermodynamic diagram of Case 7 and Case 8.

Case 7 and Case 8 demonstrate the immense potential of integrating natural elements and considering human needs in the design of artificial environments to enhance comfort and health. Case 7 explores methods to improve pedestrian thermal comfort in a hot desert climate through urban design strategies such as asymmetrical streets, high-reflectivity materials, and shading facilities (Figure 16). The study was conducted in Biskra, Algeria, and the results indicate that asymmetrical street designs, high-reflectivity materials, and effective shading strategies significantly improve pedestrian thermal comfort(Necira et al., 2024).

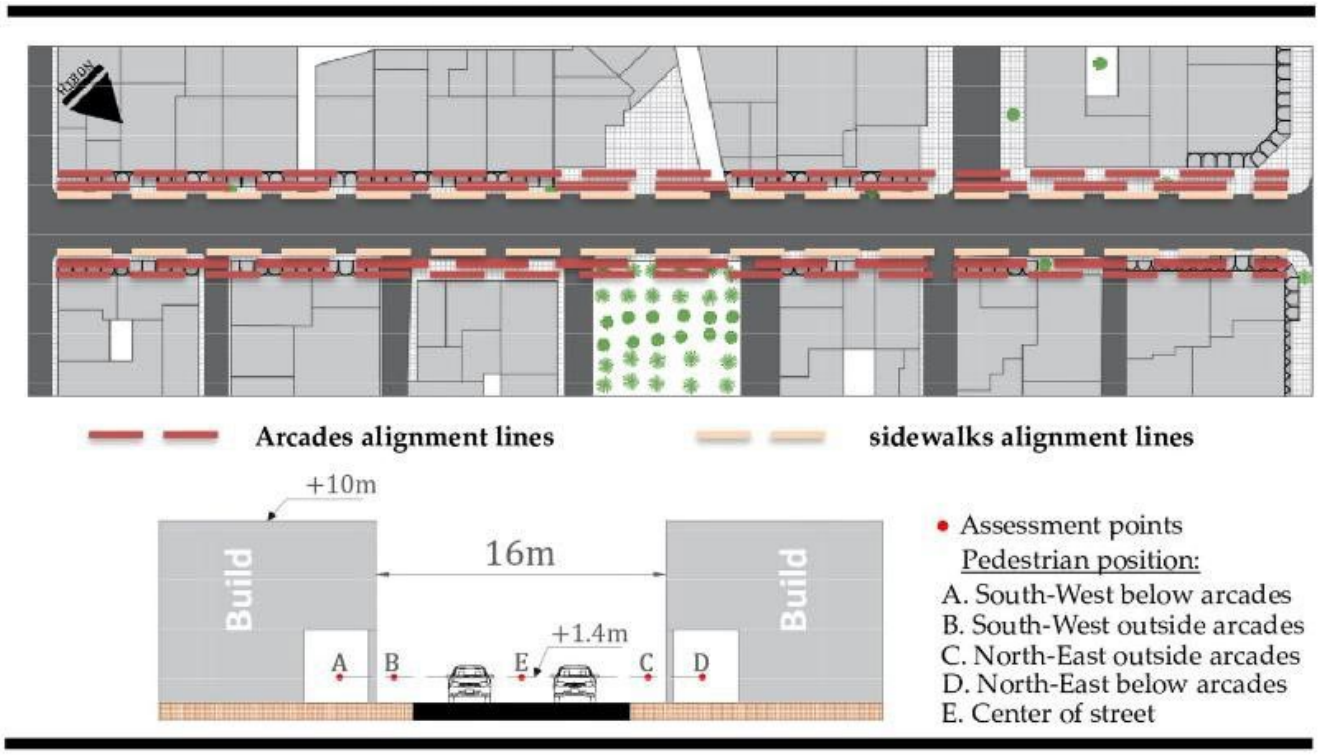


Figure 16 Modified parameters for the reference scenario. (image source: Necira et al., 2024, p. 12)

Case 8 analyzes the impact of climate on the thermal perception of residents (elderly) and non-residents (caregivers and therapists) in 18 nursing homes from three climatic zones. The study found that different climatic conditions affect the thermal comfort of nursing home occupants, with the neutral temperature for the elderly depending on the climate (Figure 17). This research is significant for regulatory agencies in developing design and operational guidelines for nursing homes under different climatic conditions (Baquero Larriva et al., 2022).

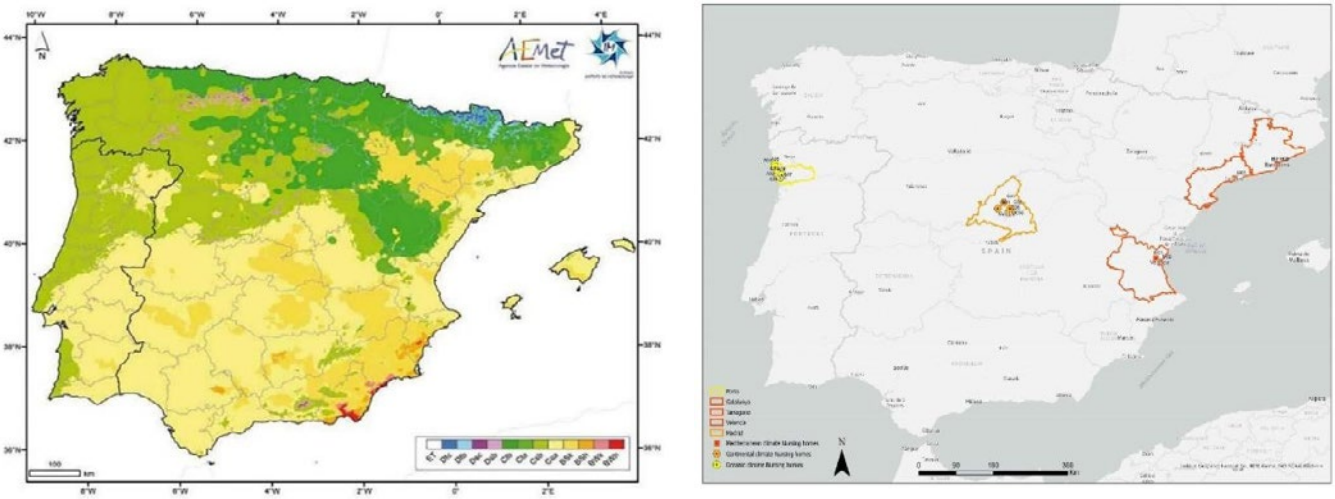


Figure 17. Left: Climate classification for the Iberian peninsula (image source: Iberian Climate Atlas) , Right: Distribution of the studied nursing homes (image source: Baquero Larriva et al., 2022, p. 4)

Table 5. Comparison of Case 7 and Case 8 in the aspect of Nature & Artificial System.

Case No.	Nature	Artificial Systems
7	Desert Climate: The study examined the outdoor physical environment of streets under specific climatic conditions, such as solar radiation, wind speed, and air humidity. These factors significantly impact pedestrian thermal comfort in hot desert environments.	Street Models: By measuring and simulating actual streets, the study explored strategies for improving pedestrian thermal comfort through artificial system interventions. These strategies included altering street geometry, using high-reflectivity materials, and designing shading structures.
	Natural Landscapes: The introduction of trees and green spaces is crucial for reducing the urban heat island effect and enhancing pedestrian thermal comfort. The study utilized asymmetrical street designs to optimize natural shading, leveraging natural landscapes to alleviate pedestrian heat stress.	
8	Climate-Adaptive Design: The study analyzed the impact of various climatic conditions in the Mediterranean region on indoor thermal environments and proposed building design strategies adapted to local climate conditions.	Smart Building Systems: The study found that occupants adopt various adaptive behaviors (such as adjusting clothing or using fans) when experiencing thermal discomfort. Building design can offer flexible solutions by incorporating features like automated window adjustments, shading devices, and air conditioning systems to enhance occupant comfort.
	Environmental Control: Prevailing wind directions vary across different regions. Through effective ventilation design, it is possible to achieve indoor comfort without relying on mechanical cooling systems.	

Discussion

"If we can build or enable a hybrid community combining the virtual and the real worlds, and at the same time, strengthen and enrich the interconnections among the human-nature-artificialcyber system, we will have an incubator for encouraging responsible behaviors and social interactions."(Lou, 2018) As Lou advocates, the community, being the center of urban residents' lives, requires systematic design as a sustainable and responsible practice. This paper combines historical research on building thermodynamics with cutting-edge studies on modern community environments to analyze the interactive elements that can be incorporated into community design. For example, variations in heat perception lead to different environmental temperature requirements. By studying the interactions among human sensation, incentive methods, and the Internet of Things (IoT), human-machine collaboration can achieve a balance between physical comfort and energy consumption, while also improving energy use through adjustments of human behavior . The neighborhood environment significantly impacts social interactions and social innovation potential. Therefore, research on natural climate, thermal environments, and building morphology can enhance thermal comfort in public community areas, transforming these spaces into true public areas that serve residents.

The cited cases all illustrate that community environments can be explained using thermodynamic systems. Every design action with a sustainable vision should comprehensively consider all involved elements and their systemic relationships. Braham once proposed, "We need a full energy accounting of the interaction between work and information in buildings."(Braham, 2015, p. 250) The scope of a community extends beyond buildings, involving more elements and having a closer relationship with the ecology system. Therefore, it is crucial to establish a universally applicable sustainability assessment for communities design and practice method. This paper provides preliminary ideas for sustainable community design, with the hope of studying more cases in the future and building a community design knowledge system based on thermodynamic principles through experiments and data.

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EXTENDED CURRICULUM PROGRAMMES IN SOUTH AFRICA: A FOCUS ON SOCIAL JUSTICE AND ARTS-BASED PEDAGOGIES

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Peninsula University of Technology (CPUT)

ABSTRACT | South Africa's historically segregated apartheid education system still affects students' academic performance in higher education. Extended Curriculum Programmes (ECPs) in South Africa (SA) attempt to bridge this gap by providing additional specialised support to prepare students from under-resourced high school backgrounds for success in their chosen fields. Many ECP students, however, struggle due to limited prior educational opportunities and language barriers, with English (which is often their second or third language) being the primary language of instruction. ECPs, as supported by the South African Government, present a valuable opportunity to integrate social justice principles and arts-based pedagogies to create inclusive learning environments. Arts-based pedagogies, offer alternative pathways to knowledge creation and are particularly valuable for students navigating language barriers. These pedagogies allow students to explore their experiences and engage with epistemological issues in a non-linguistic and accessible way. This paper explores Extended Curriculum Programmes (ECPs) in Design at a University of Technology in South Africa, focusing on social justice through arts-based pedagogies within these spaces. Collage as an arts-based pedagogy facilitates expression beyond language limitations and provide opportunities for students to explore and make meaning of their experiences of transitioning to university. Collages can foster dialogue and shared understanding within diverse learning communities and the collages generated by students who are part of this particular ECP generate rich data that help us understand the experiences of these students as they transition from school to university. Through a review of the literature and semiotic analysis of some of the collages created by students, this paper looks at how arts-based pedagogies such as collage can contribute to a more just and equitable higher education landscape in South Africa and be instrumental in students finding their voice while navigating their educational journeys.

KEYWORDS: SOCIAL JUSTICE, HIGHER EDUCATION,ARTS-BASED PEDAGOGIES, COLLAGE, EXTENDED CURRICULUM PROGRAMS

1. Introduction

This paper scopes literature related to Extended Curriculum Programmes (ECPs) in South Africa, social justice in higher education, using collage as an arts-based method of inquiry, and humanizing pedagogies. The paper opens with a discussion of ECPs' role in assisting students' transition from high school to university in South Africa. It dives into ECP students' demographics and many factors influencing their transition to higher education. The paper discusses the global background of social justice in higher education, referencing Palmer's paradoxes for establishing socially just learning environments and looks at Humanizing Pedagogies as the framework for the study. In addition, the paper explores the value of arts-based activities in these transitional spaces, with a special focus on collage as a tool of inquiry.

2. Extended Curriculum Programmes in South Africa

The continued effects of the apartheid basic education system in South Africa are one of the main contributors to the difference in the academic performance of students in Higher Education (HE) in South Africa (Shepherd, 2016). During Apartheid, an education department oversaw and supervised education for each ethnic and racial group independently. The apartheid government acknowledged four racial groups as per the nationalist government groupings: black Africans were all grouped under the term "Bantu" and eventually segregated along ethnic lines such as Zulus, Pedis, Tswanas, Sothos, Shangaan, Venda, and Ndebele, while those of Indian and Asian heritage were designated as "Indians". People of mixed ancestry, such as African, European, and Malay, were labelled as "coloured". People of Indian, Asian, and mixed races (Coloureds) had a poorer education than Whites but were considerably better off than the Bantu school system made available to Black South Africans. The apartheid government designed this system to segregate South

African education into the four perceived racial groups and in so doing designed inferior education for the non-white people to maintain the "subordinate and marginal status of the majority racial group of the country" (Thobejane, (Thobejane, 2013 p2). This narrative extended to language use in schools, where learners were taught in their mother tongue in the primary band and English and Afrikaans in high school. This left them with no high-level academic language ability in any of the languages. To this day Bantu languages as a mode of instruction are "associated with poor education" (Webb et al., 2010)

Foundation Provision (FP) also known in universities as Extended Curriculum Programs (ECPs) are an initiative of the Department of Higher Education and Training (DHET) in South Africa that aims to redress the academic inequalities caused by the apartheid history of South Africa. ECPs cater for students from designated groups who meet university requirements and gain admission, but, due to their initial educational and social disadvantage are less likely to complete their studies than those students who have access to schools that better prepare them for university (Garraway & Bozalek, 2019a). This is achieved by increasing the period by adding on an extra year and providing students with specialised support to succeed in their field of study.

According to FP policy, ECPs should focus on basic concepts, content and learning approaches that foster advanced learning. Initially in thinking about ECP, Garraway & Bozalek, (2019) refer to what Morrow, (2009) calls epistemological access. For Morrow, epistemological access entails "learning how to become a successful participant in an academic practice" and as not only depending on teaching but also the student's efforts. For epistemological access to be possible, Morrow (2009) states that students must have selfunderstanding and be able to relate this to their academic practice. As a result of South African history and more poignantly its educationally segregated history, ECP students, according to Furlong & Cartmel, (2009 p110), do not have "adequate background knowledge" to engage in mainstream studies yet. Students who form part of the first year of the ECPs in design, typically do not have a "classical" (Menon, 2003) art and design background and they come largely from rural and public schools that do not offer "the skills and competencies normally expected of a first-year post-matric university student" (Zulu, 2011 p447). The term "post-matric" (Zulu 2011, p447) here becomes key in highlighting ECP students' "proximity to high school level rather than second or third year" (Zulu, 2011 p447) at university. In their academic practice then as fist year design students it is difficult to relate their understanding of self, back to their practice as design students and by implication, makes epistemological access challenging for them.

Timmis et al. (2019 p78) highlight that research studies on young people migrating from rural areas to urban universities in South Africa show that whilst rurality itself is 'not

necessarily a disadvantage when it intersects with low income (rather than high income and historical privilege), it manifests as a challenge in students' lives and the making of their new identities as university students. Many different factors influence university transitions from rural areas, these include geography, financial resources, schooling, and language (Timmis et al., 2019). According to Timmis et al. (2019), geography relates to the high level of access urban areas typically must support, social services and infrastructure as opposed to their rural counterparts. These issues of access to resources often also apply to the basic education offerings in rural areas, putting ECP students on the back foot once they gain access to the university, where the systems and curricula tend to favour those with high income and historical privilege.

Timmis et al. (2019 p82.) stress that transitioning from one context to another inevitably means changes in the self and changing identities. The authors suggest that "transitions can be understood as identity making". During these transitions from school to university students make negotiations to access, participate and study and position themselves within the university. ECP students are often English second or third language speakers from rural areas. This fact adds to the complexity of their transitions into higher education, where the language of learning and teaching is English. Eisner, (2008 p5) states that it has become increasingly clear since the latter half of the 20th century that knowledge or understanding is not always reducible to language. He suggests that knowledge comes in different forms and the forms of its creation differ. Eisner says the idea of ineffable knowledge is not an oxymoron but suggests that the term knowledge should be liberated from the propositional, and birth what he calls the deliterization of knowledge. With words, according to Eisner (2008), defined as proxies for direct experiences, Eisner advocates for the deliterization of knowledge as it opens the door for multiple forms of knowing (Eisner 2008, p. 6) and knowledge building that is not dependent on a specific language for meaning making and is more inclusive. Within the ECP space in South Africa and more specifically in ECPs in Design, it is crucial that praxis that transcend linguistic barriers are explored, to create inclusive learning environments.

3. Collage as an Arts-Based Method of Inquiry and pedagogical tool

Arts-based inquiry as a pedagogical approach offers multiple forms of knowing. It includes activities such as creative writing, photography, music, poetry and visual art, as ways to engage with knowledge. These methods help users make the meaning that "eludes linguistic description" (Casey, 2009 p73) and has what Culshaw (2019, p. 268) calls "revelatory potential" as it unveils the things that people may not be able to communicate in words alone. This non-linguistic capability makes arts-based methods particularly useful in transitional environments like ECPs where individuals are learning a language other than their mother tongue. Art-based pedagogical experiences provide value for

both teacher and student. The student can explore their personal narrative and configure their experiences of particular subject matter into works of art. The viewer/teacher by engaging with the art is drawn into the art experience, which according to (Casey, 2009 p71) is a "dialogical process where the worlds of the artist and interpreter meet through experiencing the artwork". (Eisner, 2008 p7) describes art as enabling one to vicariously participate in a situation and thus allowing the viewer to "walk in the shoes of another" and understanding is gained through "empathic experience". "Collage creation allows a reflection on and the visual reconstruction of an experience to make that experience more familiar and, hopefully, understandable" (Culshaw, 2019 p271)

Kerry-Moran (2008) in Knowles & Cole, (2008 p500) expresses that "arts-related research links the emotional with the scholarly and places emotional learning on even ground with scientific understanding. This directly contradicts the notion that science, and by extension, good research, is devoid of emotion." One type of inquiry does not cancel out or replace the other, but rather, arts-based inquiry is seen to enrich and humanise scientific research. Cahnmann-Taylor & Siegesmund, (2018 p. 2) call arts-based research the next logical part in the shift to qualitative inquiry, which is causing a move from employing qualitative skills that emulate hard science paradigms to research that encourages "fearless academic and artistic border crossing".
Arts-based inquiry offers academic border crossers a variety of innovative apparatuses that bring about ongoing assemblages and mutations of the tools that can be used in research (Cahnmann-Taylor & Siegesmund, 2018). These tools create multi-sensory research and produce a permanent record of ideas. Arts-based inquiry also opens fresh discussions and allows for visual thinking rather than linguistic thinking (Culshaw, 2019)

Collage is a form of arts-based inquiry employed in various fields of study. The term collage originates from the French word collé which means glued. Pablo Picasso and Georges Braque used collage as a cubist technique, disrupting the notion that a painting represents a "uniform reality" (Gerstenblatt, 2013 p295). Collage "fragments space and repurposes objects to contextualise multiple realities" (Gerstenblatt, 2013 p295) and because of the ability of collage to consolidate multiple realities it is a good way to provide opportunities for inclusive communication and learning about or eliciting the different experiences of different people who now find themselves in the same context. Because of its non-linguistic nature, collage allows for narratives that are "silenced by the textual and linguistic" (Gerstenblatt, 2013 p295) to emerge. According to (Rose, 2016) collage can help in the discussion of identity and the mixing of subjects' own drawings with existing images can give insight into their visual culture. As an art-based inquiry method, collage is a means to include and hear the marginalised voices and encourage language-based, visual, textural, and non-verbal representations. Collages are an alternative

way to articulate authentic lived experiences and offer to us as researchers both a method of inquiry and analysis (Gerstenblatt, 2013).

4. Social Justice in Higher Education

"Education can change lives" (Rowan, 2019 p2) but education is not a "neutral act" (Rowan, 2019 p2). It can bring about conformity and render students invisible, or it can be the practice of freedom (Freire, 2000, p. 34). Hooks, (1994) claims that for education to be liberatory it should incite "mutual labour" (hooks, 1994 p14) in knowledge generation. This means that students are agents of knowledge building and creation and don't just use a "banking system" (hooks, 1994 p14) where knowledge building is a one-way street only imparted to them by the knowledgeable other. Zembylas, (2017, p37) calls this participatory way of knowledge building "curricular justice" as it considers how knowledge is generated in the colonial encounter while foregrounding higher education as public good.

Zembylas (2017) elaborates on the concept of higher education as public good and questions what this public good looks like in societies like South Africa, where gross inequalities have existed. He uses the idea of curricular justice (Connell, 1994) which places emphasis not only on the development of knowledge through the recognition of the interests of the least advantaged, but also emphasizes how this knowledge may be critical and useful to the communities of people that higher education (HE) seeks to address. Therefore, social justice in higher education is becoming critically aware (Sensoy & DiAngelo, 2012) of who the real communities of people that HE serves are, and making sure that their voices are heard, acknowledged, and affirmed in their classrooms. However, This acknowledgement and affirmation do not equate to equality but equity in terms of access to systems and structures that in HEIs are inherently unjust (Furlong & Cartmel, 2009). These unjust systems according to Sensoy & DiAngelo (2012) exercise unequal social power at both micro (individual) and macro (structural) levels, and it is therefore imperative that educators engaging with issues of social justice recognize this. Similarly, at a macro level, universities must implement policies and systems that promote equity rather than equality (Furlong & Cartmel, 2009). At a micro level, educators employ pedagogy and curriculum that facilitate equitable participation in knowledge formation. Additionally, larger institutions that want to contribute to the public good must prioritise graduates' need to be active citizens in a democracy that promotes social justice (Zembylas, 2017 p39). This entails making strategic choices around staffing and curriculum to empower such.

Rowan (2019 p98) advises that creating learning environments that are intellectually charged and demanding while recognising diversity and keeping students engaged are key in HE. This endeavour requires staff that "are confident in their ability to create

hospitable environments characterised by clear boundaries, high expectations, diverse forms of support, and opportunities for choice". Once staff members are confident in their ability to create such environments, the pursuit of "situated action in pursuit of educational and social justice" can begin (Rowan, 2019 p98). For example, academics wanting to implement socially just spaces in higher education must be aware of the "patterns of speech and silence that have been naturalised" (Rowan, 2019 p99). Rowan (2019) therefore suggests the employment of (Palmer, 2017 p76-77) paradoxes in creating socially just learning spaces. In Palmer (2017), paradoxes are described as ways teachers can induce creative tension. The space paradoxes are as follows:

1. **Bounded and open spaces:** Space of learning needs clear boundaries for learning to be clear and guided. However, according to Palmer (2017), openness in a learning space refers to the many ways in which the end result of learning/knowledge building can be achieved.

2. **Hospitable and charged spaces:** Learning spaces must have features that help students feel safe on their "educational expedition" but must also be charged so that students do not "fall asleep" but experience the risk of pursuing deep learning by engaging with topics of significance without trivializing them.

3. **Spaces that invite the voice of the individual and the group:** When students find their authentic voices rather than assimilating the educator's voice, they are more likely to learn (Palmer, 2017 p67) in a supported learning environment. However, in addition to having and voicing their own opinion, they should also show an ability to listen with care to the voice of their peers and then to consolidate the collective wisdom with their own and recognize its possible influence on their ideas and beliefs.

4. **Spaces that honour little and big stories:** According to Palmer (2017), learning spaces should not only be filled with the large abstract stories that inform learning but should also leave room for the "small but soulful realities that grow in our students' lives". The big stories should be used to frame the personal to make learning relatable.

5. **Spaces that support solitude and are surrounded by resources of community:** Learning spaces should provide opportunities for individual meaning-making and for the testing of such meaning by the larger group, which may be able to make the individual aware of those factors that impede their discernment.

6. **Spaces that welcome speech and silence:** Silence is a space of reflection and individual meaning-making, while when students speak they communicate the concrete meaning they have made. In this kind of space students may gain greater understanding by ascertaining the similarities and differences in the meaning they may have made in silence as individuals.

Sensoy & DiAngelo (2012) define socially constructed meaning as not inherently true but as agreed upon by society. If one were to use this definition in the making of socially just engagements or learning environments (especially for post-matric students transitioning into university) one could say that if the group agrees to particular ways of meaning-making and interaction, these become the norm in that community. In other words, we as educators have the power to create environments that are socially just by foregrounding particular values and creating particular kinds of spaces for learning as written by Rowan, (2019 p123) who says we as university educators have to "look well beyond familiar, common, rehearsed explanations regarding what effective or quality teaching is or looks like to investigate who benefits from our decisions" If we are to make sure that students entering university post-matric are fully benefiting from the transitional strategies that we employ we have to ensure that their voices are present and engaged in what we do in our classrooms.

5. Humanising Pedagogies

According to Freire, (2000), humanisation is the process of "becoming more fully human as social, historical, thinking, communicating, transformative, creative persons who participate in and with the world. Humanising pedagogies have at its heart Freire's notion that humans are motivated by a need to reason and engage in becoming (Salazar, 2013). According to Salazar (2013 p128) the philosophical, theoretical, and operational foundations of humanising pedagogy can be delineated into five essential tenets.

The first contends that the person's full development is essential for humanisation. The second argues that the denial of someone else's humanisation is a denial of one's own. The third tenet foregrounds how the journey for humanisation is an individual and collective endeavour toward critical consciousness. Following this, the fourth focuses on how critical reflection and action can transform structures that impede our and others' humanness, thus facilitating liberation for all. Finally, the fifth maintains that educators are responsible for promoting a more fully human world through their pedagogical principles and practices.

Cautioning against a narrow and dismissive view of educational theory and discourse, Fataar (2016) encourages a pedagogy based on recognition and engagement, including our students' social and subjective aspects. Engaging the ever-changing "humanity of people" (Fataar, 2016 p20) suggests rich thinking around humanizing pedagogies, which engages the participants in learning to the full by mapping the social aspects of their being onto the educational and pedagogical aspects. Thinking with Nancy Fraser (2009), Fataar explores humanising pedagogy as a three-dimensional conception of social justice. Fraser's (2008) three dimensional theory of social justice says that any work toward social justice require economic redistribution (equal share), cultural recognition (equal respect) and political representation (equal say).

Fataar argues that in addition to addressing how knowledge is distributed, a humanizing pedagogy must recognise students' knowledge, literacies, and identities. Fataar (2016 p19) highlights how, using Fraser's (2009) dimensions of social justice "schooling can be informed by vigorous and thoughtful interaction between school knowledge and the students' life knowledges". Fataar (2016) suggests that recognition of students' life knowledge would help them understand that their knowledge, thinking and world views are important in finding their place in society and that knowledge formation is generative as well as a matter of participation according to Fraser's (2009) participatory third dimension.

6. Methodology

1. Data collection

The data for this research project was gathered from individual written text and collages Data was collected in the second semester of the ECP in Design Foundation Year and was made up of artefact creation (collages) as well as written reflections on the artefacts created. In order to listen visually (Butler-Kisber, 2008) to students' experiences of their transition into higher education and design studies they were asked to create three collages. The three collage prompts are listed below and are framed in terms of Frasers (2008) framework for social justice:

1. How they see themselves including things they like to do and how they often feel (the individual collage)=(recognition)
2. How they see themselves as a university student including their life since they have been at university (university student collage)=(representation)
3. How they see themselves as designers (designer collage)=(redistribution)

After creating their collages students were asked to write a brief reflection on each of their collages. The reflections were an explication of the collages created and were used to further engage students in making meaning of the identities depicted in their collage. The written reflections were not focused on eloquent language and correct grammar and spelling but were rather a form of what Austin, (1975) calls performative definitions which are statements that define the state of things. These performative definitions give a subjective rather than objective description of the state of things and often a call to action. Ortlipp (2015) says that written reflections as a method of data collection provides reciprocity in research. The written reflections should provide the reciprocity Ortlipp (2015) speaks of by giving a conscious insight into what may have been unconscious decision-making while creating the collages.

2. Analysis

Semiotic document analysis was used to identify themes, inferences in the collages/ artefacts as well as the written reflections. The analysis of the collages attempted to excavate whether the collages allow for the three crucial parts of Fraser's Framework for social justice to emerge. The semiotic analysis utilizes what Butler-Kisber and Poldma (2010) identify as the three attributes of collage in qualitative research:

1. Collage as a form of elicitation – what are students collages saying about their identities? (recognition)

2. Collage as a reflective process – what are the similarities, recurring themes or links (if any) between the collages and what do they mean? (representation)

3. Collage as a way of conceptualizing ideas – what are students' aspirations around their university and designer identities? (redistribution)

7. Analysis and Discussion

In this section student collages will be analyzed semiotically. The three aspects of Nancy Fraser's Framework for social justice will be used to discuss the student collages and whether collage as arts-based pedagogy allow for socially just and humanizing expression of the experiences of ECP Design students at University.



Sometimes a person may feel that they have no purpose in life. Finding out who you are just takes the time of sitting down and thinking of the importance in your life. Who am I? I am [redacted] and I am a person with different personalities, characteristics, and identities. The are many ways, in which I identify myself, in fact, are the ways that define who I am. My Identity is something only I can fully define. I have a little sister, which makes me a sister; I have a loving parent, which makes me a daughter; I am in university studying graphic design, which makes me a student; and I have wonderful friends in desperate need of support, which makes me a wonderful best friend.

University is a competitive environment; in order to succeed in it a student needs certain skills. Those skills can only be learned. The are basic rules that we need to be follow in order to become a good student: study, do all the homework and the assigned reading, attend class, and, most importantly, develop self-discipline and time management. I learnt this the hard way when I was doing IT but I learnt my lesson.

During my information technology course we had a module called Multimedia we used to create logos, advertisement , this is were I fell in love with graphic design. When I go out to centres, supermarkets, the high streets around Cape Town I have seen lots of Graphics designs in advertising, Billboards companies for example in electronical products or any type of product the graphics advertising companies running around the world, just because of that I was inspired in the graphics designing and I was influence by the subject.

I was interested particularly in doing graphics design and the visual communication that I was inspired by combining images phrases and ideas to illustrate to the target and audience so that they would impact and react on those kind of illustrated for e.g. the billboards, poster, the product packaging and lots of more advertisement there. There are lots of elements on different types of media that I have already mentioned but there are also examples like Logos which really encourage people and make those people to think about logos

The are many ways a person identifiers themselves even beyond this. I am a very quiet person and art is a form of my speaking language.

Figure 1: Collage and Reflection 1

The imagery of books and technology in the collage can be interpreted as signifiers (in Saussure's terms) of educational and informational resources. The books, such as "What Colour is the Sun?" and "The Eye of the Reindeer," symbolize access to knowledge, suggesting an environment where educational resources are accessible and valued. The presence of digital devices implies a connection to modern technology, further indicating a space where technological resources are distributed in a way that facilitates learning and growth.

The collage features various elements that denote personal and cultural identity. For example, the word "family" and the image of hands holding a cut-out family represent the importance of familial bonds and social support systems. The central figure adorned with intricate patterns could symbolize individuality and uniqueness, suggesting a recognition of personal identity and self-expression. Additionally, the presence of plants and nature imagery can be interpreted as an appreciation for the environment and the natural world, further emphasizing the recognition of diverse forms of life and existence.

The collage does not explicitly depict political or civic engagement, but the word "winner" and the graduation cap symbolize achievement and success, hinting at the possibility of upward social mobility and empowerment. These elements suggest that individuals have the opportunity to excel and be recognized for their achievements, which is a form of representation in societal contexts.

Through the lens of Nancy Fraser's social justice theory, the collage presents a narrative where resources (educational and technological) are accessible, diverse identities (personal, familial, and environmental) are recognized, and individuals are empowered to achieve and be acknowledged. This aligns with the principles of redistribution, recognition, and representation, reflecting a holistic approach to social justice.



1.How do you see yourself as an individual:

What I did in this collage was I combined all the things I'm interested in and how I see myself as an individual, me being a skateboarder and being really passionate about it ,as well as with my fashion.

I added many different colours and pieces of clothing instead of adding one complete outfit because my sense of fashion comes in a variety of different materials,colours and patterns. I added the scenery that I feel I would be most comfortable surrounded by ,and of course added a skateboard or two for I am always seen holding a board or skating on it.

This really helps to make it easier for people when they first see me or this collage ,it's gives a slight look into the type of person I am ,with the scenery being a calm environment to it being a sunset in the streets ,it shows my sense of fashion and how I would dress myself and what I'm interested in. (163 words)

2. How do you see yourself as a university student:

What u did with this specific collage ,was I combined from bottom to top what I was accustomed to before entering university, and then as it goes up it shows the things I started getting interested in ,such as design and culture.

My clothing style has changed up a bit also ,wearing different colours. I have also dded more communication skills around my character ,like the microphone and "voice" by my head area.This indicates that I'm socialising, having my own voice and seeing how everyone is different and unique in their own way. Learning more about what I'm into. The top section of the collage has more vibrancy and colours to it.(112 words)

3.How do you see yourself as a designer:

I saw myself adapting and learning in a new way ,in this collage I added everything I got into and learnt.

From the bottom it shows a continued section from the previous collage ,how it started as a university student ,and then to the top it changes ,getting into art and design ,my fashion sense being more intense. Technique ,adapting my own style ,working different and my change in music.

This collage has the most colour and pictures added to it because it shows my current self and improving what I'm into and all about. I used the face disguise by the head area to show that I'm becoming a new person in my own way.(116 words)

Figure 2: Collage and Reflection 2

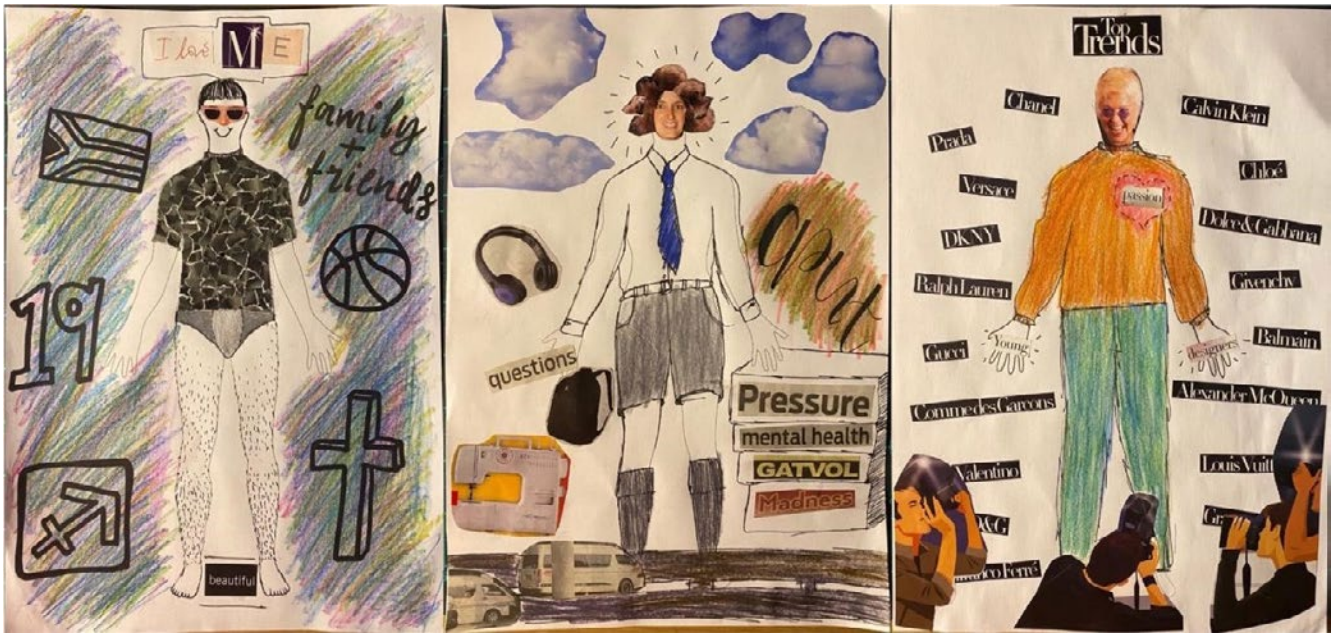
In the first panel, the figure holding a skateboard and wearing fashionable, eclectic clothing signifies access to cultural and recreational resources. The skateboard can be seen as a symbol of youth culture, freedom, and mobility, suggesting that these resources are available and valued within this societal framework. The presence of artistic and colourful backgrounds also implies a society rich in aesthetic and creative resources.

Each panel of the collage highlights different aspects of individuality and self-expression. The middle figure, with a megaphone and the word "VOICE" prominently displayed, represents the importance of having one's voice heard and acknowledged. This aligns with Fraser's dimension of recognition, emphasizing the need for individuals to be seen and respected in their uniqueness.

The third panel, with the phrase "WORK DIFFERENT" and the figure wearing a unique, bold outfit, underscores the value of diverse forms of work and expression. The inclusion of elements like the zebrapatterned hat and vibrant backgrounds signifies an embrace of diversity and unconventionality. The term "ALCHEMY" suggests a transformative process, acknowledging the ability to create and innovate in varied and personal ways.

The figure with the megaphone in the middle panel signifies advocacy and active participation. This element suggests that individuals are not only recognized but also have the platform to influence and contribute to societal discourse. The megaphone is a symbol of amplified voice and agency, reinforcing the idea of participatory democracy and representation.

Through the lens of Nancy Fraser's social justice theory, the collage presents a narrative where cultural and recreational resources are accessible (redistribution), diverse identities and forms of self-expression are celebrated (recognition), and individuals are empowered to voice their opinions and participate in societal structures (representation). The visual and textual elements work together to convey a society that values equity, diversity, and inclusion.



AN INDIVIDUAL

In this collage I drew myself with underwear and a t-shirt to show how relaxed and comfortable I am with my body There are the words "I love me" on top of the collage because I think that self-love is very important Around the drawing of myself, I drew the things that I love and that can tell others more about me: I'm South African, I am 19 years old, my birthday is the 27th of November so that means I'm a Sagittarius, I'm a Christian, My favourite sport is basketball and my family and friends mean the most to me My t-shirt is green as it is my favourite colour.

WORD COUNT: 112

A UNIVERSITY STUDENT

In this collage I drew myself in a school uniform to visually communicate that this is my life as a university student. I cut out parts of curly hair from a magazine and pasted it around my head to show how crazy I can become when there are too many assignments to be done. On the side I drew books and cut out and pasted words on the books. These are some words that come to my head when university is stressful like, 'pressure' and 'mental health'. At the bottom of the collage I drew a road and pasted pictures of taxis because sometimes I have to take public transport to get to university.

WORD COUNT: 113

A DESIGNER

In this collage, the first thing I added was the word "passion" by the area of my heart Fashion design is something that I love and have always wanted to do I pasted an excited face on the head because I feel good when I'm doing something that I love. At the bottom of the collage I pasted pictures of photographers taking pictures of "me" to show that this is my dream and I want to be successful and pursue fashion design. Around the drawing of myself, I pasted the names of a lot of successful designers and brands that I love, get inspiration from, and look up to. A few of my favourites are Balmain, Alexander McQueen, Dior and Chanel.

WORD COUNT: 120

Figure 3: Collage and Reflection 3

The images in Collage 3 don't directly address economic inequality, but there are hints of class and resource distribution through the use of fashion brands (Gucci, Chanel, etc.) suggesting economic stratification. There is a contrast between high fashion and everyday items (sewing machine, basketball) pointing to differing access to resources

The recognition dimension is more prominently featured through diverse body types and styles that challenge traditional beauty norms. Mental health labels ("Pressure", "Madness") indicate a push for recognizing psychological struggles. "Family friends" suggests valuing diverse relationships and religious symbol (cross) implies recognition of faith identities

The triptych format gives equal space to different identities/issues such as fashion industry representation via brand names and "young designers", youth culture represented through style and activities and mental health advocacy through explicit labelling.

Overall, the artwork seems to advocate for recognizing diverse identities (body types, styles, mental health experiences), representing various social groups and issues equally and questioning societal pressures (fashion, mental health stigma)

While economic redistribution is less explicit, the juxtaposition of high fashion with everyday elements hints at critiquing resource inequality. This analysis suggests the artwork aligns with Fraser's multidimensional approach to social justice, emphasizing the interplay between cultural recognition and social representation, while subtly touching on economic factors.



1. INDIVIDUAL
   In this collage I used a lot of small images that describes me and the certain things that I like. E.g. The South African flag represents my country, fitness shows I am very active, I love to gym and the plant describes my growth etc. (45 words.)

2. STUDENT
   In this collage I tried to express my creative side. I am a university design student and I still have so much to learn and improve. I made sure to get images that represent what I am studying for my future career. (42 words.)

3. DESIGNER
   The last collage represents my dream career as a graphic designer. These pictures are examples of what life would be like when I am qualified. These images show how fun work life would be and how I will be able to be an independent woman and flourish in what I am good at (designing.) (54 words.)

Figure 4: Collage and Reflection 4

While economic redistribution isn't explicitly addressed, there are implications of resource access to education and self-improvement ("EDU", "IMPROVEMENT") which alludes to pathways to economic mobility. "BUSINESS" and entrepreneurship hints at economic opportunity while technology access (computer, smartphone icons) implies digital resource distribution

- The recognition dimension is prominently through the inclusion of "African chic" which acknowledges cultural diversity. "YOUTH" emphasis recognizes young people's identities and concerns while multiple languages and cultural references (e.g., "BTS") show multicultural recognition. Diverse interests (music, fitness, art) validate various forms of self-expression

- The triptych format gives equal space to representation of different aspects of identity. The Individual, Student, and Designer roles are given equal prominence while a variety of communication methods (social media icons, QR code) suggest diverse channels for voice and participation. "Make it Official" implies formalized representation or legitimacy

- The "REDISCOVER" theme suggests a process of reframing or reclaiming identities and roles while "Critical thinking" and "Problem-solving" emphasize empowerment through education. The focus on creativity, passion, and innovation points to valuing diverse contributions to society

- This analysis reveals alignment with Fraser's multidimensional approach to social justice as it emphasizes cultural recognition of diverse identities and interests, hints at pathways to economic participation and mobility and suggests multiple avenues for representation and voice in society

While economic redistribution is less explicit, the overall message promotes empowerment through education, creativity, and self-expression. This aligns with Fraser's idea that social justice requires addressing both cultural and economic dimensions of inequality.

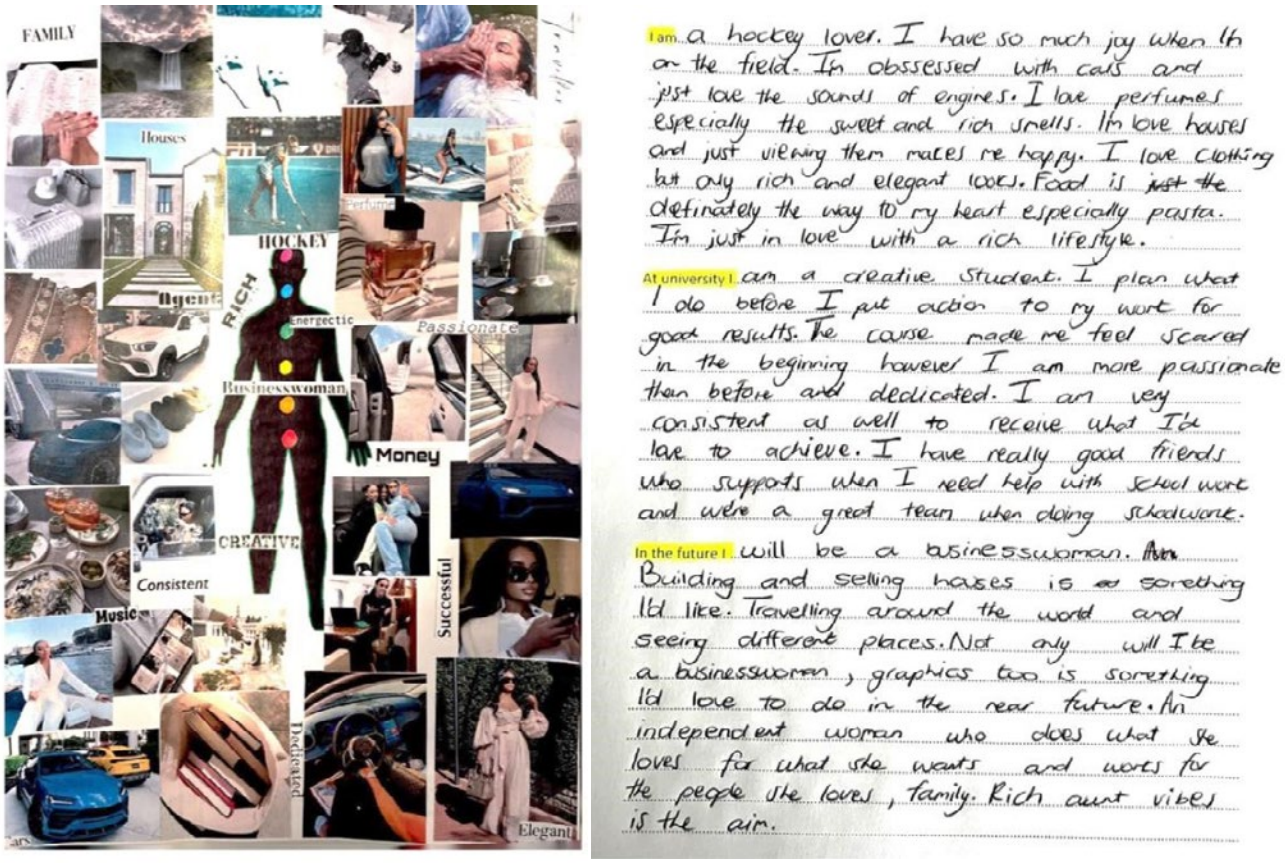


Figure 5: Collage and Reflection 5

The image contains several symbols of economic status and resource distribution:

- Luxury items: High-end cars, perfume, elegant clothing
- Property: Houses, implying home ownership
- "Money" explicitly mentioned
- "Businesswoman" suggesting economic participation and power

These symbols indicate a focus on affluence and economic success, which relates to Fraser's concept of redistribution. However, the emphasis seems to be on individual achievement rather than equitable resource distribution across society.

The image presents a specific identity for recognition as it uses female-centric representation. Most human figures appear to be women. "Businesswoman" label emphasizes professional identity. There are diverse activities such as hockey, water skiing, creativity, family roles and personal attributes depicted, such as "Energetic," "Passionate," "Creative," "Successful".

This aligns with Fraser's idea of cultural recognition, particularly for women in professional and multifaceted roles. However, the representation appears limited in terms of diversity (e.g., body types, ethnicities, socioeconomic statuses).

The central figure of the businesswoman with chakra-like points suggests a holistic representation of a woman's life and roles. However, the representation is narrow and focused on a particular lifestyle associated with success and affluence. Ther is limited diversity in the types of women and lifestyles shown and an emphasis on individual success rather than collective voice or participation

The collage format suggests a complex, multifaceted identity and "Family" is included, indicating recognition of personal alongside professional life. The mix of luxury and everyday items (e.g., books, food) attempts to show a balanced lifestyle.

While the image does touch on aspects of Fraser's framework, it falls short of a comprehensive approach to social justice. It celebrates individual success within existing structures rather than challenging systemic inequalities or promoting broader societal change. The focus on affluence and a particular lifestyle may inadvertently reinforce economic and cultural disparities rather than addressing them in the holistic manner Fraser's framework suggests

6. Conclusion

The exploration of ECPs in South Africa, social justice in higher education, arts-based inquiry, and humanizing pedagogies reveals a profound need for inclusive and transformative educational practices. The historical context of ECPs underscores the significant impact of apartheid policies on education and, consequently, the ongoing disparities in academic preparedness. The role of ECPs in addressing these inequalities is evident, resonating with the fundamental concept of social justice in higher education.

The utilization of arts-based methods, particularly collage, as an innovative tool for inquiry and expression in transitional spaces like ECPs, demonstrates the potential for multidimensional learning experiences. Collage offers a non-linguistic means to amplify marginalized voices and enrich the academic environment, aligning with the principles of social justice and inclusivity. The pursuit of social justice in higher education calls for a multifaceted approach, integrating curricular justice and equitable participation. The creation of socially just learning environments means a recognition of diverse voices, critical reflection, and a deliberate effort to challenge unequal power dynamics.

At the heart of this effort to transform rather than bridge the perceived gap, lies the concept of humanizing pedagogies, emphasizing the full development of individuals, critical consciousness, and the

responsibility of educators to promote a more fully human world. This resonates with the drive to recognize students' knowledge, literacies, and identities, fostering an inclusive and participatory learning environment. In the future, it is imperative to continue advocating for educational practices that honor the diverse lived experiences of students, foreground critical consciousness, and strive for a more equitable and inclusive educational landscape. Embracing humanizing pedagogies and arts-based inquiry can contribute to fostering a transformative, equitable, and socially just higher education experience.

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ABOUT THE AUTHOR

Amanda Morris is an early career researcher with a Master of Technology in Graphic Design (MTech GD) specializing in Design Education from the Cape Peninsula University of Technology (CPUT). She is currently a Doctoral candidate (DEd) in Education at the CPUT with research interest in Arts-based methodologies, Interpretive Phenomenological Analysis, Socially Just Pedagogies in Higher Education and Extended Curriculum Programmes (post-matric students transitioning into higher education). In addition to her academic pursuits, Amanda has been actively involved in the Extended Curriculum Programme (ECP) and Work Integrated Learning in the Faculty of Informatics and Design (FID) at CPUT, where she has fulfilled the role of coordinator and lecturer in the Design ECP as well as Faculty Coordinator of WIL in FID. Her work in these areas focus on supporting students' transition from secondary education to higher education and from higher education to the world of work, ensuring they are equipped with the necessary skills and knowledge to succeed in their chosen fields Amanda's research is driven by a commitment to creating inclusive and equitable learning environments. She employs arts-based methodologies to explore and address the diverse needs of students, particularly those from marginalized backgrounds. Her approach to socially just pedagogies aims to challenge traditional educational practices and promote a more inclusive curriculum that reflects the diverse experiences and perspectives of all students

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