2nd Design Factory
Global Network

RESEARCH CONFERENCE

Contributions for 'Designing for Multiplicity'
October 5th-6th 2023

ODTÜ
METU

Aalto University
Design Factory

Contents

Type of contribution


Research contribution


Experiential contribution

Acknowledgements

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Access the conference program
www.conference.dfgn.org/program

Preface from DFGN

We could not be prouder and more excited about the 2nd DFGN's Research Conference. DFGN is a community of doers in the field of education. Together, we are rethinking and redesigning how education is done in our institutions, by questioning what we see and, most importantly, what we have learned. The Design Factory Global Network consists of 40 higher education institutions and research centers, in 26 countries of the world. Our collaborative mindset and shared passion cross borders, languages, and bureaucracy.

We believe the world presents us with more complex challenges every day, but we see this as an opportunity to gather our skills and mindsets to impact society. One field alone cannot solve the issues that we see, that's the reason why we believe in the concept of "Multiplicity". One discipline itself should not be used as the means for giving answers to issues. Instead, we believe that it should be used as a starting point, as an inspiration for combining a bigger and more meaningful interaction between multiple approaches, cultures, disciplines, ways of thinking and countless ways of life.

During DFGN.R 2023, we have gathered contributions from a broad range of approaches led by inspiring individuals from around the world. Thanks to their sharings, you will reflect on topics related to:

Education: How does the diversity of teaching and learning methods in higher education enhance one's potential for fostering innovation?

Culture: In what ways is education centered around design fostering the development of a more inclusive culture that prioritizes ethics and the consideration of diverse perspectives?

Technology: How do recent technological breakthroughs influence education, promote inclusivity, and encourage the celebration of diversity and multiplicity?

The DFGN.R 2023 was hosted at the Middle East Technical University in Ankara, Türkiye, from the 5th to the 6th of October, 2023. For the second year, we brought a community of practitioners and people who go beyond what is expected from their role. We are educating the future generation of people making an impact in the world, but as important as that, we are educating the present generation. We are driving change, altogether, to improve the educational experience of our students, by empowering them with the tools for facing the always changing world. Our work aims to inspire more people.

At the DFGN.R conference, we aim to bridge "passion for doing" and "passion for reasoning" to help us navigate the dynamic world landscape, where we provide a compass towards the future of education. By fostering a global gathering of practitioners, scholars, and students from diverse fields, we aim to facilitate the exchange of insights and the inception of cross-disciplinary partnerships on a global scale in the present and future.

Preface from editors

A lot can happen between Design Factory Global Network Research (DFGN-R) conferences. Design factories and their communities of practice acknowledge that a passion for doing has increasing currency as the reality of wicked challenges stacks up. Hacking away one learner, project, paper, artifact, and intervention at a time is the reality of research and practice. As a global community of practice, the past ten years have demonstrated that co-created collective pursuits can promote change with shifts in transdisciplinary learning, research, and practice. The second Design Factory Global Network Research conference highlights the complexity and inconsistency we encounter daily on many levels represented in practice and research as agents for change, offering possibilities yet to be entirely understood or quantified, which warrants further investigation.

"Designing for multiplicity" is a transformative concept. It encapsulates the understanding that one-size-fits-all solutions are often inadequate to address our convoluted world's diverse needs and perspectives. Multiplicity challenges the conventional approach of 'designing for all' as the goal of inclusivity and equity. Instead, it recognizes the richness of human experiences, environments, and cultures and calls for a shift towards more adaptable, flexible, and context-specific design strategies. When we design for a specific group of people with particular needs, we improve the world for everyone. Think of audiobooks, initially developed for people with hearing impairment and later paving a new way for book fruition, or the design of public spaces for people with disabilities that become more welcoming spaces for all.

The Design Factory Global Network is a cornerstone for diversity made possible by a culture where conditions for ambiguity, debate, and conflict are possible. The network, rooted in a commitment to embrace multiple perspectives, practices, and pedagogies, exemplifies the value of exploring novel approaches to address contemporary challenges. In this context, 'multiplicity' emerges as a critical concept breathing new life and meaning into design and other related disciplines. It beckons us to question habits and norms and reimagine the creative process in ways that are more in tune with an interconnected and diverse world.

The discourse around design and innovation has faced crucial issues such as inclusivity, diversity, sustainability, equity, and social justice. While different approaches and perspectives have emerged from fields such as design, economics, education, sociology, and anthropology, the common thread that links these discourses is the overarching concept of 'multiplicity' demonstrated by interdisciplinary research and transdisciplinary practices. Multiplicity defies confinement to a single definition, and its potency lies in its ability to challenge the dominance of the singular. It challenges the conventional preference for unity and logic and advocates a worldview that celebrates difference, evolution, and transformation. Multiplicity can be aptly described

as a 'substantive noun,' denoting an entity belonging to the realm of the many, free from the constraints of unity and rigidity. It is a concept intricately linked to the formation of diverse entities, allowing for the exploration of de-territorialization, the assembly of unexpected connections, and the application of horizontal logic. The Design Factory Global Network is multiplicity: a system, a web of practices, a complex of people and cultures, an un-hierarchical set of disciplines, practices, and actions.

While design thinking may be the dominant paradigm mentioned in contributions to the Design Factory Global Network Research conference, the contributions represent a broad cross-section encompassing phenomenology, social theory, psychology, philosophy, artificial intelligence, and art. At first glance, this proceeding is a serendipitous collection of literature. Yet, there is a consistency underpinned by the challenges in response to the call for multiplicity based on the purpose of higher-order challenges. The challenges presented in the contributions resonate with principles of the 21st Century learning mission and United Nations' Sustainable Development Goals, given the effects of socio-technical rapidity, economic disparity, and climate change. The contributions in this volume offer valuable insights into how designers and innovators navigate the ever-expanding landscape of challenges and opportunities in multiple fields, from education and sustainability to healthcare and technology. Underpinned by the theme of multiplicity, they also represent the status quo at the time of writing in a post-COVID mop-up, in an age of unimaginable technological acceleration, war, and extreme climate change effects. The papers and experimental contributions push design thinking in directions that elevate pedagogy and enhance the art and science of learning, thinking, and doing, increasingly defined by novel approaches, experimental practices, and disruption.

In this Design Factory Global Network Research conference, we delve into abstract concepts and underlying principles from these academic works as research and practice. We uncover how integrating interdisciplinary approaches, innovative methodologies, and technology drives the evolution of design practices in an increasingly interconnected and dynamic world. A selection of our contributions will contribute to a special issue in the CERN Ideasquare Journal of Experimental Innovation. We are proud to create and support an outlet based on multiplicity, leveraging the culture of CERN, which took the best of knowledge from scientists and experts worldwide to investigate the basic structure of nature.

Through the lens of designing for multiplicity, we navigate a landscape where design is not a one-size-fits-all endeavour but a dynamic and adaptive process that responds to individuals' and communities' unique needs and aspirations. We observe how design thinking is dismantling conventional silos and forging connections between disciplines, cultures, and generations.

Designing for multiplicity is fundamentally about recognizing the complexity of our world and the myriad ways individuals, communities, objects, cultures, and systems interact. As we initiate this journey, we invite you to explore the transformative potential of contributions from a diverse community of practice informed by a passion-based culture. Collectively, we explore how this concept can shape the future of design and innovation, offering new opportunities to create a more inclusive, equitable, and sustainable world for all.

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Theme 1

Design thinking & pedagogy in higher education

The art, science and practice of teaching is explored with a generation who are shaping an information-driven, interconnected world suffering unimaginable socio-economic global change. The papers, while different in their program, all argue for a holistic approach that reflects the tenets of 21st century learning underpinned by design thinking principles that prioritise critical thinking, creativity, communication, collaboration, and problem-solving.

Çekindir et al. case study on an interdisciplinary design thinking course in higher education reinforces the role of design thinking experts in advancing multidisciplinary skills development. Ranti et al. applied design thinking for technology-driven learning solutions during the COVID-19 pandemic in Indonesia discovers the dual challenges in balancing remote student engagement and advancement of technological methods. As we surface from the COVID-19 pandemic Arumsari et al. investigate the challenges of Indonesian student reconnection by prototyping an app to connect students with peer mentors to activate experiential peer to peer-based learning. The development of the app informed by design thinking methods intelligently paired students based on traits, experience and expertise.

Creating illustrations with Midjourney, an AI-powered image generation platform, for the chapter openings in this publication involved experimentation and adaptation. The process was started by using sentences from the theme introductions to create prompts for pictures. The final results are curated from a collection of hundreds of images. The aim was for these pictures to mirror the research themes, potentially intriguing the reader, giving fresh viewpoints on these themes and stimulate dialogue.

As part of the process, additional descriptors regarding image style and color scheme were integrated to sharpen the prompts. The keywords *microscopical imaging* and *macro photography* were often used to embody the intention to magnify the smaller, often overlooked aspects of the subject, just as a microscope or a macro lens would do. This choice was driven by an inherent fascination for the minute and the substantial alike, and the often blurred boundaries where the micro meets the macro. The final prompt used, with all it's quirks, illogical aspects and inconsistencies, is used as a caption to the images.

"Design thinking and pedagogy in higher education. White background. Coarse, Blocky. Yellow and cyan. Pixelpunk. --s 750"

Image: Midjourney × Valtteri Bade, 2023

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The influence of expert diversity in design thinking education: Izmir design factory (IDF) mentor meetings

Abstract

Design Thinking education, characterised by its interdisciplinary approach, explores how mentors from diverse fields impact student learning within the process. This study delves into the implementation of Design Thinking Course Mentor Meetings at İzmir Design Factory (IDF) and aims to uncover how experts from various backgrounds influence students' learning experiences and the Design Thinking process's outcomes. By analysing the students' reflections through an analysis of their definitions of design, this research evaluates the impact of different experts on the students' learning and teaching experiences and on the students' perceptions of "Design" as it developed throughout the course. Furthermore, it examines the utility of Large Language Models (LLMs) as objective tools for analysing qualitative data in the form of textual reflections, enhancing our understanding of this educational process.

Key words:
Design Thinking education;
expert diversity;
mentor meetings.

Introduction

Design Thinking, often termed "design-based learning," is acknowledged in education for its potential to boost creativity, endurance, engagement, and innovation. It encourages students to tackle real-world problems using specific processes and methods, promoting learning through reflection. Design Thinking rests on the "3Ps" - people, process, and place, involving cross-functional teams, iterative innovation, and flexible spaces for collaboration (Schwemmle et al., 2017).

This approach excels in fostering collaboration among diverse students, catalysing design-driven global transformations (Rauth et al., 2010). It centres on problem-solving and addresses everyday challenges, offering a methodology for resolving common issues (Rauth et al., 2010). Two key concepts in design education are multidisciplinary learning and integrating diverse fields, which allow adoption to the evolving social landscape (Chiang et al., 2021).

However, successful outcomes require more than assigning projects; also essential are effective mentoring, guidance, and continuous critique. Considering environmental challenges, it is vital to incorporate ethical considerations, equity, sustainability, and environmental preservation into the curriculum (Meyer & Norman, 2020). Despite Design Thinking's integration into higher education, research on pedagogical aspects is limited (Withell & Haigh, 2013).

The İzmir Design Factory (IDF) implemented an interdisciplinary Design Thinking Course, comprising the "Design Thinking Project Course" and the "Professional Design Experiences Course," bringing together students from various universities for interdisciplinary projects with industries. The course focuses on three aspects: people, place, and process. 'People' encompass students, facilitators, instructors, research assistants, partners, and mentors; 'process' involves the non-linear Design Thinking process, and 'place' encompasses diverse learning environments. Instructors, facilitators, and mentors are pivotal in facilitating the project process, and therefore, this study aims to assess how expert perspectives from various disciplines impact students' learning in the Design Thinking process and how mentors' involvement affects learning outcomes in this course, accredited by Yaşar University (2019-2021).

Theoretical background

Design Thinking, rooted in human-centred design, has gained significance in education, encompassing creation, reflection, problem-solving, reasoning, and meaning creation as its core components (Johansson-Sköldberg et al., 2013). In the realm of design education, it is crucial to achieve a balance between practical skills and academic rigour, necessitating effective mentorship, guidance, and critique (Meyer & Norman, 2020). Furthermore, multidisciplinary and cross-disciplinary learning is essential to the education of designers who are sufficiently adaptable to respond to evolving societal needs (Chiang et al., 2021).

Design Thinking has found a key place in 21st-century education, enhancing critical reading, logical thinking, and problem-solving skills (Rotherham & Willingham, 2009). It encourages students to adopt a designer's mindset, empowering them to address complex challenges (Rim & Razzouk, Valerie Shute, 2012). Grounded in constructivist learning theory, Design Thinking emphasises learners' active role in constructing knowledge through their experiences and reflection (Piaget, 1970; Fosnot & Perry, 1996; Kolb, 1984; O'Dennel, 2012; Reich, 2008).

The constructivist approach in education shifts educators into the role of facilitators, enabling students to construct knowledge from their experiences (Trevors et al., 2016). Drawing from Bruner and Vygotsky's work, the constructivist theory emphasises that learning is an active, constructive process (Bada & Olusegun, 2015). This shift has led to various teaching and learning methodologies that position Design Thinking at the forefront (Dunne & Martin, 2006; Scheer, Noweski, & Meinel, 2012).

Design Thinking aligns seamlessly with holistic constructivist learning by fostering essential 21st-century skills (Scheer et al., 2012). As educational systems aim to nurture individual potential through constructivist learning, the demands of modern life underscore the significance of metacognitive competences, attitudes, values, and action skills (Dikmans, 2011; Weinert, 2003). Design Thinking, with its team-based approach, offers a framework for holistic learning through experience and reflection, aligning with constructivist principles (Kröper, 2010; Reich, 2008; Kolb, 1984).

Integrating Design Thinking into education allows students to grapple with complex problems and gain insights through experience, with teachers taking on the role of facilitators (Hasselhorn & Gold, 2006); and Design Thinking's meta-disciplinary nature closely aligns with the constructivist ideals of experiential learning and complex problem-solving (Lindberg et al., 2009). By formalising constructivist learning principles, Design Thinking becomes a method for team-based learning that nurtures 21st-century skills and metacognitive competences (Scheer, Noweski, & Meinel, 2012). By integrating content and constructivist learning principles, Design Thinking projects offer opportunities for experiential learning and metacognitive skill development (Scheer, Noweski, & Meinel, 2012). In essence, Design Thinking enriches the learning journey within a constructivist context.

Method and data

This paper discusses a case study conducted at the İzmir Design Factory, a design-education-research centre, focusing on an interdisciplinary Design Thinking course in higher education. This course addresses the need for a skilled workforce and is conducted in collaboration with local stakeholders to enhance competitiveness in the global market. It brings together students from various universities to engage in interdisciplinary projects involving key figures, including students, facilitators, instructors, research assistants, partners, and mentors.

The study primarily focuses on 3rd-4th grade Industrial Design students at Yaşar University and the mentors who guide them through the course. The Design Thinking course comprises the Partner Project Course and Mentor Meetings, where mentors from different fields share their knowledge and practical insights into project processes. These meetings align with the stages of the Design Thinking process (Fig.1).

During the 2020-2021 fall semester, 11 industrial design students participated in Mentor Meetings conducted by 15 mentors over 11 weeks. A qualitative research study was conducted to understand the role of experts in the Design Thinking learning process. Students' insights were collected through reflective writing in the form of a questionnaire study; the questionnaire included questions about what students learned, how learning would contribute to their future work, and their thoughts about the mentors. At the end of the semester, students presented final reports based on the insights gained from the mentor interviews in response to the question: "What is design?".

This study involved the collection of text data from the weekly questionnaire answers and the final submission, which were analysed through ChatGPT-3.5, an artificial intelligence tool.

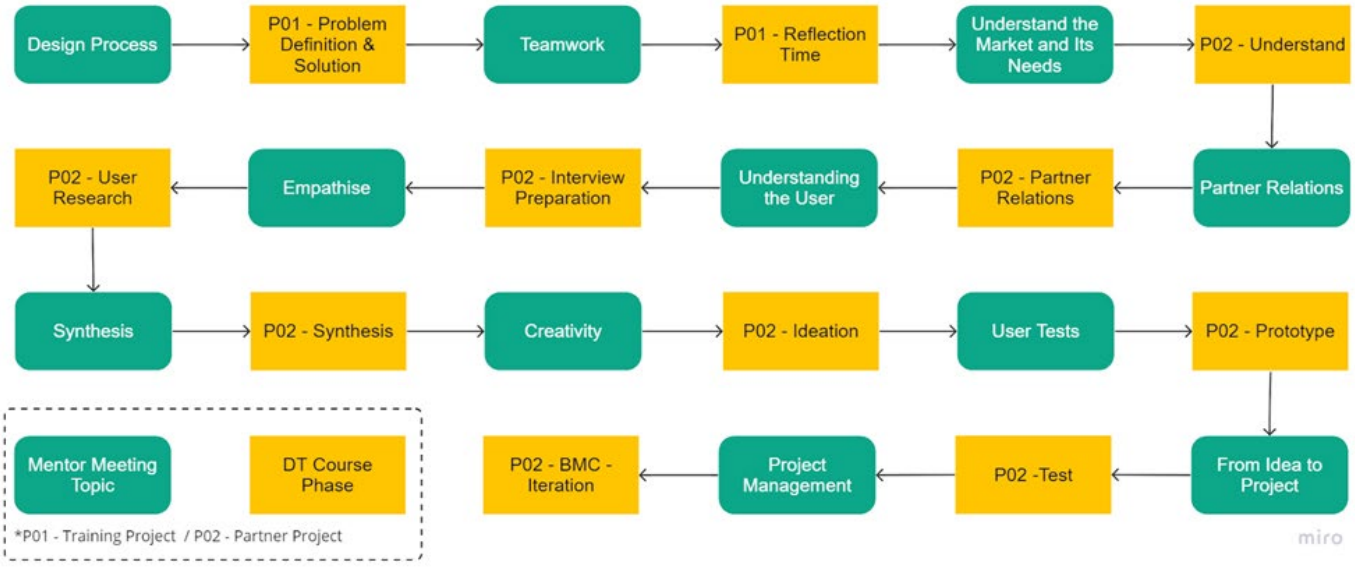

Fig. 1. 2020-2021 Fall Semester Mentor Meetings and DT Project Course Weekly Program created by authors

ChatGPT is a large language model (LLM) trained by OpenAI. Large language models (LLMs) like GPT are revolutionising social science research by simulating human-like behaviours and responses from vast amounts of text data. ChatGPT, an AI dialogue tool based on LLMs, generates human-like responses, enabling applications such as translation, content generation, and question-answering (Tajik & Tajik, 2023). The analysis identified common keywords such as design, process, empathy, user, and product. These keywords helped define concept headings, providing insights into students' perspectives on design and their learning experiences.

In summary, the study explores the impact of mentorship and expert guidance in an interdisciplinary Design Thinking course, shedding light on students' perceptions and learning experiences in design education.

Results

This study delves into students' reflections on Design Thinking, unveiling their comprehension of the design process and its essential elements. The analysis uncovered key themes and definitions (Fig.2):

Design: Students view design as a user-centric problem-solving process, enabling communication and expression. It encompasses three core elements: the process itself, the user, and the resulting product.

Design Process: The design process involves problem-solving stages, including problem understanding, ideation, prototyping, and implementation. It is characterised by divergence (exploring various ideas) followed by convergence (narrowing down to a solution).

Design Values: Central to the design process, these values encompass empathy (understanding user needs), creativity (generating unique ideas), sustainability (considering environmental and social impacts), and collaboration (emphasising interdisciplinary cooperation).

Design Output Objectives: The design output aims to provide users with meaning and value, thus influencing brand perception, anticipating future changes, and benefiting society. It also strives to enhance usability and user satisfaction.

Design Process Objectives and Characteristics: Design process objectives include continuous improvement, evaluating effectiveness, and effectively planning and organising progress. The process encourages learning from mistakes, embracing diversity, and generating new ideas.

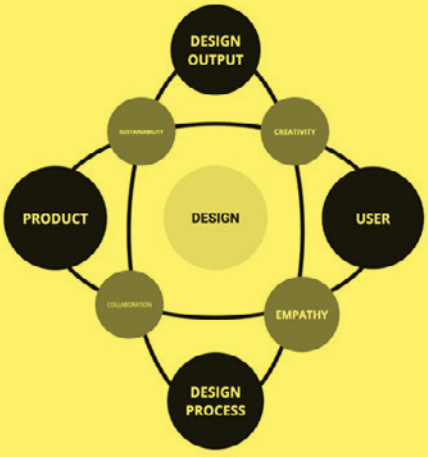

Fig. 2. Most Common Keywords Scheme created by authors

The study underscores the importance of language as a versatile tool in Design Thinking. Visual, mathematical, and verbal languages are employed to represent abstract concepts, explore hypothetical scenarios, and articulate complex ideas. Language plays a pivotal role in facilitating communication, idea generation, and problem-solving throughout the design process (Owen, 2007).

Furthermore, the study highlights the significant role of mentor meetings in enriching students' grasp of Design Thinking. These meetings provided students with insights from experts who drew from their professional experiences across various problem-solving stages. This active engagement with mentors not only improved students' ability to express their thoughts in writing but also fostered a sense of belonging within the Design Thinking community.

In summary, this research offers valuable insights into students' perceptions of Design Thinking and its core components. It accentuates the pivotal role of language as a tool in the Design Thinking process and, within this framework, emphasises the importance of mentorship in enhancing students' understanding and motivation.

Discussions and conclusions

This study delved into students' perceptions of design in the context of a one-semester Design Thinking course in higher education. Employing data from mentor interviews and student essays titled 'What is Design?', common themes were discerned, which included "design concept," "design process," "design values," "design output objectives," and "design process objectives and characteristics".

Operating within a constructivist educational model, students were encouraged to define design metacognitively. Their definitions portrayed design as a user-centred problem-solving process and a communication tool, aligning with Design Thinking's core principles: People, Process, and Place. The design process, as seen by students, followed the Double Diamond model defined by the Design Council: Discover, Define, Develop, and Deliver.

Design values such as empathy, creativity, sustainability, and collaboration were central, emphasising social benefit and aligning with students' collective design goals. Students viewed the design process as iterative and improvable, reflecting a metacognitive perspective influenced by constructivist teaching and expert mentorship. The study showcased the potential of AI, specifically ChatGPT, in educational research, in the streamlining of teaching tasks and enhancement of communication.

Within the constructivist framework, aspects considered vital were active knowledge construction through experiences and reflection. Engagement with expert mentors and the Design Thinking community enriched learning by providing access to tacit knowledge and real-world examples. Moreover, the study underscored Design Thinking's interdisciplinary, collaborative nature, highlighting the importance of diverse perspectives and expert feedback in fostering empathy, innovation, and inclusive design outcomes.

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References

Chiang, I.-Y., Lin, P.-H., Kreifeldt, J. G., & Lin, R.,2021, From Theory to Practice: An Adaptive Development of Design Education. Education Sciences, 11, 673. https://doi.org/10.3390/educsci11110673

Fosnot, C.T., & Perry, R.S., 1996, Constructivism: A psychological theory of learning. In C.T. Fosnot (Ed.), Constructivism: Theory, Perspectives, and Practice (2nd edn.), Teachers College, Columbia University: New York and London, pp. 8-38.

Home. Design Council - Design for Planet. (n.d.). https://www.designcouncil.org.uk/our-resources/the-double-diamond/Israel Institute of Technology, Haifa, 2022, pp.343-353.

Kolb, D. A., 1984, Experiential Learning: Experience as the Source of Learning and Development, Prentice Hall.

Meyer, M. W., & Norman, D., 2020, Changing Design Education for the 21st Century. She Ji: The Journal of Design, Economics, and Innovation, 6(1), 13–49. https://doi.org/10.1016/j.sheji.2019.12.002

Ne Yaparız: İDF. idf. (n.d.). https://www.izmirdesignfactory.com/ne-yapariz?lang=en

Owen, C., 2007, Design Thinking: Notes on Its Nature and Use. Design Research Quarterly, 2(1), 16-27.Rauth, I., Köppen, E., Jobst, B., & Meinel, C., 2010, Design Thinking: An Educational Model towards Creative Confidence. First International Conference on Design Creativity, ICDC 2010, 29 November - 1 December 2010, Kobe, Japan.

Razzouk, R., & Shute, V., 2012, What is design thinking and why is it important? Review of Educational Research, 82(3), 330–348. https://doi.org/10.3102/0034654312457429

Reich, K., 2008, Constructivist Didactic: Text and Student Book, Beltz Verlag, Weinheim and Köln, Germany.

Scheer, A., Noweski, C., & Meinel, C., 2012, Transforming constructivist learning into action: Design thinking in education. Design and Technology Education: An International Journal, 17(3), pp.8-19.

Schwemmle, M., Nicolai, C., Klooker, M., & Weinberg, U., 2017, From place to space: How to conceptualize places for design thinking. Design Thinking Research,275–298. doi:10.1007/978-3-319-60967-6_14

Tajik, E., & Tajik, F., 2023, A Comprehensive Examination of the Potential Application of CHAT GPT in Higher Education Institutions. https://doi.org/10.36227/techrxiv.22589497.v1

Withell, A.,and Haigh, N., 2013, Developing Design Thinking Expertise in Higher Education, in Reitan, J.B., Lloyd, P., Bohemia, E., Nielsen, L.M., Digranes, I., & Lutnæs, E. (eds.), DRS // Cumulus: Design Learning for Tomorrow, 14-17 May, Oslo, Norway. https://doi.org/10.21606/learnxdesign.2013.160

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Exploring student and teacher perspectives on education with technological advancement in Indonesia through design thinking in response to the COVID-19

Abstract

This research delves into the impact of COVID-19 and technological advancements on interactions between teachers and students in Indonesian education. By adopting a design thinking approach, the study investigates how social media, gamification, and advanced technology can enrich collaboration and adapt learning methods. Through design thinking workshops involving teachers and surveys gathering input from students, valuable insights are unearthed regarding the challenges they face, notably addressing empathy and learning difficulties. The outcomes illuminate students' preference for collaboration, inclusion, and rewards, demonstrated through active engagement with online quizzes, educational TikTok videos, and virtual reality collaborations. These solutions have garnered positive feedback, demonstrating potential for significant transformation. The research effectively underscores the transformative capacity of design thinking in reshaping Indonesian education by adeptly addressing these pronounced challenges.

Key words:
Education;
Design Thinking;
Technology;
Empathy;
Inclusivity;
Collaboration: COVID-19

Introduction

The COVID-19 pandemic has had a profound impact on education globally, and Indonesia is no exception. The importance and relevance of this research topic can be highlighted through the following points:

- Education gaps: COVID-19 widened education gaps in Indonesia, with limited access to digital resources and skills deepening the divide between students and teachers (UNICEF, 2020).
- Need for digital learning development: To tackle these challenges, it is vital to enhance digital learning content, promote digital skills, and improve connectivity in schools (UNICEF, 2020).

Research gaps exist regarding how students collaborate, empathise, and engage with technology-driven learning despite its widespread adoption (Widodo, 2022). Further, teachers face challenges adapting to technological changes and skills (Maddukelleng et al., 2023). To bridge these gaps in knowledge, this research aims to address the following research question:

1. What are the primary challenges faced by students and teachers in adapting to technology-driven learning during the COVID-19 pandemic, and how can design thinking help identify the potential solutions for these challenges?

This study examines the effects of COVID-19 and technology on education in Indonesia, exploring student and teacher perspectives. Through design thinking, innovative solutions will be proposed to improve student collaboration, empathy, and learning experiences.

Theoretical background

Previous research emphasises the importance of teachers' readiness to adapt to technological changes in education and acquire media and technology skills (Maddukelleng et al., 2023). Incorporating digital media in education can enhance instructional quality and students' competencies (Rusydiyah et al., 2020). Government policies on technology education impact teacher competence in utilising e-learning and social media (Salehudin et al., 2020; Khan et al., 2021), while well-designed online teaching practicums support prospective teachers in developing technological skills and effective instructional strategies (Sunggingwati et al., 2020; Patahuddin et al., 2022).

Design thinking, known for its problem-solving abilities and versatility (Brown & Katz, 2011), drives innovation and fosters creativity by embracing diverse perspectives (Stackowiak & Kelly, 2020). This research demonstrates the impact of design thinking on education, particularly on students' learning, including the development of digital skills (Rumahlatu et al., 2021). Additionally, the Stanford D School design thinking approach has shown effectiveness in enhancing students' creativity and entrepreneurial alertness (Pratomo et al., 2021).

The COVID-19 pandemic has posed challenges for online teaching and learning, requiring improved coordination, resources, and support (Putri et al., 2020). Changes in instructional strategies and collaborative efforts are needed to prevent learning gaps (Rasmitadila et al., 2020). This research examines the impact of online learning on students, considering social, economic, and cultural factors, as well as infrastructure, internet access, and financial support (Febrianto et al., 2020). It also explores student perspectives on challenges during the pandemic, including anxiety, data security, technological proficiency, and effective learning methods (Simamora, 2020; Lie et al., 2020).

Method and data

The research methodology employed in this study focuses on investigating the impact of COVID-19 and technological advancements on teacher-student interactions within Indonesian education. The study emphasises the pivotal role of participants' technological familiarity, stemming from the pandemic-driven shift to remote learning.

Within the context of the pandemic in Indonesia, technology emerged as a fundamental aspect of education. Both students and teachers swiftly adapted, transitioning from tools like Zoom to more collaborative platforms such as Google Meet and Classroom.

Throughout the COVID-19 pandemic, the integration of e-learning into Indonesian education, particularly in biology programs, centred around accessible platforms like WhatsApp, Google Classroom, and Zoom (Tauhidah et al., 2021). A comprehensive approach combined synchronous tools like Google Meet with asynchronous platforms like YouTube and discussion boards (Pratiwi & Ayu, 2020). Indonesian EFL teachers embraced online learning, while students efficiently utilised smartphones for assignments and leisure activities (Rahayu & Wirza, 2020).

Concurrently, this research employs a combination of qualitative data collection and surveys with 19 Indonesian students to gain insights into student perspectives. Furthermore, a design thinking workshop is conducted with four Indonesian teachers. The workshop adheres to the design thinking framework—empathy, problem identification, design solutions—endorsed by Gasparini (2015) and aligns with contemporary research advocating the use of MIRO for collaboration (Skubik-Peplaski et al., 2022). Notably, both students and teachers possess pre-existing technological skills, including proficiency in interactive platforms such as Zoom and Google Classroom.

Furthermore, empirical data from both students and teachers contribute to the formulation of design concepts using DALL-E, a text-to-image AI model. Previous research highlights DALL-E's potential in architectural design and solution generation (Paananen, Oppenlaender, & Visuri, 2023). The resulting images are assessed by students to gather feedback (Gasparini, 2015; Panke, 2019).

In conclusion, this research combines qualitative data, student surveys, and a teacher workshop within the framework of design thinking and mixed-methods research. The proposed solutions, enriched by participants' technological insights, hold the potential to reshape the immersive learning landscape in Indonesia. The inclusion of DALL-E-generated images enhances understanding, providing comprehensive insights into the evolving educational scenario.

Results

This research focused on the challenges encountered by students and teachers during the COVID-19 pandemic when adapting to technology-driven learning. It employed design thinking to identify potential solutions. The study emphasised three key aspects: empathy, problem identification, and design solutions, with a focus on inclusivity, collaboration, and interactivity between students and teachers (Figure 1).

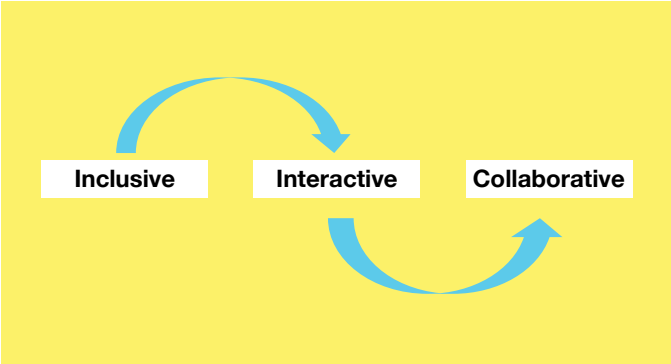

Figure 1 Design thinking approach

The student survey revealed findings related to study routines, reliance on technology, and motivation for learning. Students faced difficulties in returning to pre-pandemic routines and showed fluctuating motivation levels. They preferred interactive teaching methods for collaboration and social interaction, but some teachers presented material too quickly, leading them to seek additional learning sources like YouTube or TikTok. Students proposed design solutions involving collaborative problem-solving, practical application of theory, virtual reality (VR) technology for debates and presentations, and the development of an application with detailed explanations and discussion forums. (Table 1).

The workshop conducted with teachers using Miro and Microsoft Teams allowed for active collaboration and idea generation (Figure 2). Teachers expressed concerns about student engagement, decreased interest in learning, limited resources, technical challenges, and reduced interactivity (Table 1). They also reported feelings of annoyance, frustration, and being disregarded or undervalued by students (Figure 2).

Teachers proposed design solutions to address the challenges, such as group demonstrations, social media integration, collaborative content creation, and game-based learning with rewards. These solutions aimed to enhance student collaboration, engagement, and motivation (Table 1).

Figure 2 Design thinking workshop for teacher

Through the design thinking process, three design concepts were generated with DALL-E and tested with students (Figure 3). The Collaborative VR demonstration was the most preferred option, chosen by 79% of the students, indicating their receptiveness to interactive and collaborative learning experiences facilitated by VR technology (Figure 4).

Table 1 Analysis of Student and Teacher

	Student	Teacher
Empathy	1.Shift in learning habits 2.Impact of a technology and social media 3.Fluctuation motivation	1.Lack of engagement and decreased learning Interest 2.Technical challenges 3.Reduced interactivity
Problem Identification	1.Fast-paced teaching 2.Reliance on technology 3.Teacher-student dynamics	1.A lot of distraction which causing lack of focus 2.Addictive social media content 3.Comfort zone and exhaustion
Design Solution	1.Learning Application with Comprehensive Features: · Educational apps, platforms, interactive software. 2.Practical Application of Concepts: · VR technology for immersive and practical learning. 3.Interactive Teaching Aids and Q&A Sessions: · Interactive tools, quizzes platform and gamified learning.	1.Group Demonstrations and Social Media Integration 2.Collaborative content creation and feedback 3.Game-based learning and rewards

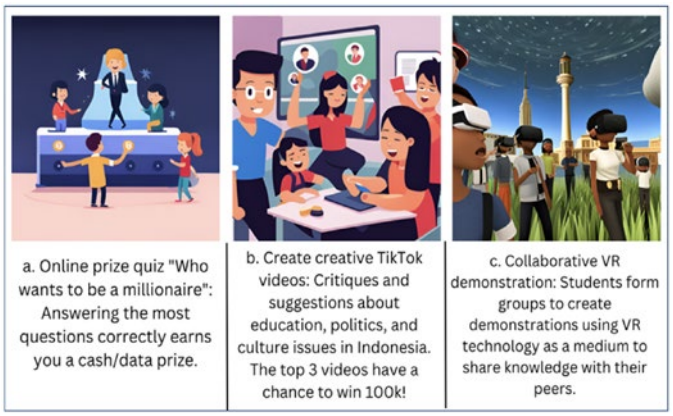

Figure 3 Design concept – Picture generated by Dall-E

Student surveys and teacher workshops employed different data collection approaches. The survey gathered individual responses, whereas workshops fostered collaborative idea generation. A comprehensive exploration of challenges and effective solutions was enabled by teachers' inventive and relevant solutions during meaningful discussions.

It's important to clarify that while this research did not facilitate direct interaction between students and teachers, data were independently collected from both groups. Subsequently, these insights were visually represented using DALL-E and then tested with students. This innovative approach enabled a comprehensive exploration of challenges and potential solutions. Despite the absence of direct student-teacher interaction in the workshop, it provided a platform for generating inventive solutions and gathering relevant insights.

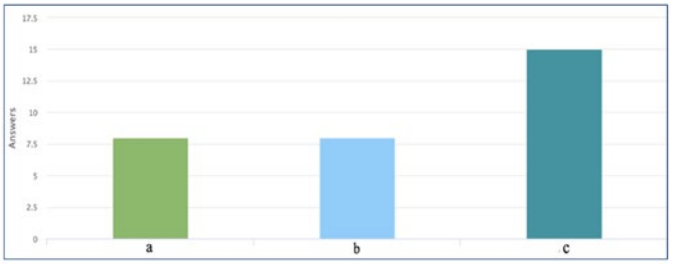

Figure 4 Design concept result

In conclusion, the research findings highlight the challenges faced by students and teachers in technology-driven learning during the pandemic. Design thinking methodologies proved valuable in identifying these challenges and proposing potential solutions. By incorporating inclusive, collaborative, and interactive strategies, educators can enhance student engagement, motivation, and overall learning experiences.

Discussions and conclusions

This study highlights that students lean toward adopting more technology while teachers focus on the significance of engagement and collaboration. In discussing the research, there's room to further explore the diverse perspectives of students and teachers. This contrast in viewpoints offers an opportunity for deeper insights.

Examining challenges faced by Indonesian students and teachers during the COVID-19 pandemic's technology-driven shift, the study employed design thinking to uncover potential solutions through empathy, identifying problems, and innovative design strategies. Findings emphasised that students faced difficulties in adjusting study routines, with technology's impact on motivation and teacher attitudes adding complexities.

Students notably preferred interactive teaching methods that fostered collaboration, aligning with a desire for engaging educational experiences. The role of technology in teaching varied among participants, with students proposing solutions like comprehensive learning apps, practical VR use, and interactive teaching aids.

This exploration not only unveiled technology's role but also emphasised diverse educational priorities. Implications highlighted the importance of tailored educational approaches that balance technology integration and active engagement.

Acknowledging limitations, the research focused on a specific context, recognizing potential cultural influences on participants' viewpoints. Additionally, while the proposed solutions hold promise, their effectiveness may differ across various educational settings. Future research should involve workshops with stakeholders to explore effective technology-driven learning solutions.

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References

Al Yakin, A., Muthmainnah, Ganguli, S., Cardoso, L., & Asrifan, A. (2023). Cybersocialization through Smart Digital Classroom Management (SDCM) as a pedagogical innovation of "merdeka belajar kampus merdeka (MBKM)" curriculum. Advanced Technologies and Societal Change, 39–61. https://doi.org/10.1007/978-981-19-8967-4_3

Brown, T., & Katz, B. (2011). Change by design. Journal of Product Innovation Management, 28(3), 381–383. https://doi.org/10.1111/j.1540-5885.2011.00806.x

Creswell, J. W. (1999). Mixed-method research. Handbook of Educational Policy, 455–472. https://doi.org/10.1016/b978-012174698-8/50045-x

Deckers, N., Fröbe, M., Kiesel, J., Pandolfo, G., Schröder, C., Stein, B., & Potthast, M. (2023). The infinite index: Information retrieval on generative text-to-image models. Proceedings of the 2023 Conference on Human Information Interaction and Retrieval. https://doi.org/10.1145/3576840.3578327

Febrianto, P. T., Mas'udahdah, S., & Megasari, L. A. (2020). Implementation of online learning during the COVID-19 pandemic on Madura Island, Indonesia. International Journal of Learning, Teaching and Educational Research, 19(8), 233–254. https://doi.org/10.26803/ijlter.19.8.13

HABIBI, A., MUKMININ, A., RIYANTO, Y., PRASOJO, L. D., SULISTIYO, U., SOFWAN, M., & SAUDAGAR, F. (2018). Building an online community: Student teachers' perceptions on the advantages of using social networking services in a teacher education program. Turkish Online Journal of Distance Education, 19(1), 46–61. https://doi.org/10.17718/tojde.382663

Hasanah, R. L., Wati, F. F., & Riana, D. (2019). Tam analysis on the factors affecting admission of students for Ruangguru Application. Jurnal Sistem Informasi, 15(2), 1–14. https://doi.org/10.21609/jsi.v15i2.778

Hesse-Biber, S. (2015). Mixed methods research. Qualitative Health Research, 25(6), 775–788. https://doi.org/10.1177/1049732315580558

Ivanov, D. (2022). Digital Supply Chain Management and technology to enhance resilience by building and using end-to-end visibility during the COVID-19 pandemic. IEEE Transactions on Engineering Management, 1–11. https://doi.org/10.1109/tem.2021.3095193

Jaya, V. M. (2023). Implementation of the inclusion program in the performing arts class at XYZ School in Jakarta. Edunesia: Jurnal Ilmiah Pendidikan, 4(1), 158–171. https://doi.org/10.51276/edu.v4i1.285

Khan, M. N., Ashraf, M. A., Seinen, D., Khan, K. U., & Laar, R. A. (2021). Social Media for knowledge acquisition and dissemination: The impact of the COVID-19 pandemic on Collaborative Learning Driven Social Media Adoption. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.648253

Kim, H. J., Yi, P., & Ko, B. W. (2022). Deepening students' experiences with problem identification and definition in an empathetic approach: Lessons from a University Design-Thinking Program. Journal of Applied Research in Higher Education, 15(3), 852–865. https://doi.org/10.1108/jarhe-03-2022-0083

Ko, H.-K., Park, G., Jeon, H., Jo, J., Kim, J., & Seo, J. (2023). Large-scale text-to-image generation models for visual artists' creative works. Proceedings of the 28th International Conference on Intelligent User Interfaces. https://doi.org/10.1145/3581641.3584078

Lake, D., Flannery, K., & Kearns, M. (2021). A cross-disciplines and cross-sector mixed-methods examination of design thinking practices and outcome. Innovative Higher Education, 46(3), 337–356. https://doi.org/10.1007/s10755-020-09539-1

Levy, M., & Huli, C. (2019). Design thinking in a nutshell for eliciting requirements of a business process: A case study of a design thinking workshop. 2019 IEEE 27th International Requirements Engineering Conference (RE). https://doi.org/10.1109/re.2019.00044

Li, Q., Zhang, J., Xie, X., & Luximon, Y. (2021). How shared online whiteboard supports online collaborative design activities: A Social Interaction Perspective. Advances in Creativity, Innovation, Entrepreneurship and Communication of Design, 285–293. https://doi.org/10.1007/978-3-030-80094-9_34

Liang, M., Lim, C. P., Park, J., & Mendoza, N. B. (2022). A review of ICT-enabled learning for schoolgirls in Asia and its impacts on education equity. Educational Technology Research and Development, 71(2), 267–293. https://doi.org/10.1007/s11423-022-10178-w

Lie, A., Mina Tamah, S., Gozali, I., Retno Triwidayati, K., Sari Diah Utami, T., & Jemadi, F. (2020). Secondary School Language Teachers' online learning engagement during the COVID-19 pandemic in Indonesia. Journal of Information Technology Education: Research, 19, 803–832. https://doi.org/10.28945/4626

Lindner, K.-T., Schwab, S., Emara, M., & Avramidis, E. (2023). Do teachers favor the inclusion of all students? A systematic review of primary schoolteachers' attitudes towards Inclusive Education. European Journal of Special Needs Education, 1–22. https://doi.org/10.1080/08856257.2023.2172894

Luo, J., Sarica, S., & Wood, K. L. (2021). Guiding data-driven design ideation by knowledge distance. Knowledge-Based Systems, 218, 106873. https://doi.org/10.1016/j.knosys.2021.106873

Maddukelleng, M., Jihan, J., Gunawan, H., Murcahyanto, H., & Pasaribu, W. (2023). Hybrid learning innovation: Challenges for developing teachers skills in Indonesia. Al Qalam: Jurnal Ilmiah Keagamaan Dan Kemasyarakatan, 17(2), 100. https://doi.org/10.35931/aq.v17i2.1959

Mailizar, M., Almanthari, A., Maulina, S., & Bruce, S. (2020). Secondary School Mathematics Teachers' views on e-learning implementation barriers during the COVID-19 pandemic: The case of indonesia. Eurasia Journal of Mathematics, Science and Technology Education, 16(7). https://doi.org/10.29333/ejmste/8240

Makawawa, J. C., Mustadi, A., Septriwanto, J. V., Sampouw, F., & Najoan, R. A. O. (2021). Primary school teachers perception of technological pedagogical content knowledge in online learning due to covid 19. Jurnal Prima Edukasia, 9(1), 86–96. https://doi.org/10.21831/jpe.v9i1.35245

McCurdy, R. (2019). Problem-based design thinking tasks: A third space pathway to engage empathy in STEM. Proceedings of the 2019 AERA Annual Meeting. https://doi.org/10.3102/1431229

Panis, I. C., Setyosari, P., Kuswandi, D., & Yuliati, L. (2020). Design gamification models in higher education: A study in Indonesia. International Journal of Emerging Technologies in Learning (iJET), 15(12), 244. https://doi.org/10.3991/ijet.v15i12.13965

Panke, S. (2019). Design thinking in education: Perspectives, opportunities and challenges. Open Education Studies, 1(1), 281–306. https://doi.org/10.1515/edu-2019-0022

Patahuddin, S. M., Rokhmah, S., Caffery, J., & Gunawardena, M. (2022). Professional Development Through Social Media: A comparative study on male and female teachers' use of Facebook groups. Teaching and Teacher Education, 114, 103700. https://doi.org/10.1016/j.tate.2022.103700

Pham, Y. D., Fucci, D., & Maalej, W. (2018). A first implementation of a design thinking workshop during a Mobile App Development Course Project. Proceedings of the 2nd International Workshop on Software Engineering Education for Millennials. https://doi.org/10.1145/3194779.3194785

Pitoyo, M. D., Sumardi, S., & Asib, A. (2020). Gamification-based assessment: The washback effect of Quizizz on student's learning in Higher Education. International Journal of Language Education, 1–10. https://doi.org/10.26858/ijole.v4i2.8188

Prasetya, D. D., Wibawa, A. P., Hirashima, T., & Hayashi, Y. (2020). Designing rich interactive content for blended learning: A case study from Indonesia. Electronic Journal of E-Learning, 18(4). https://doi.org/10.34190/ejel.20.18.4.001

Prasetyo, A. R., Nurtjahjanti, H., & Ardhiani, L. N. (2021). Impact of changes in teaching methods during the COVID-19 pandemic: The effect of integrative e-learning on readiness for change and interest in learning among Indonesian University students. The International Review of Research in Open and Distributed Learning, 22(2), 87–101. https://doi.org/10.19173/irrodl.v22i2.5143

Pratiwi, Z. F., & Ayu, M. (2020). The use of describing picture strategy to improve secondary students' speaking skill. Journal of English Language Teaching and Learning, 1(2), 38–43. https://doi.org/10.33365/jeltl.v1i2.603

Pratomo, L. C., Siswandari, S., & Wardani, D. K. (2021a). The effectiveness of design thinking in improving student creativity skills and entrepreneurial alertness. International Journal of Instruction, 14(4), 695–712. https://doi.org/10.29333/iji.2021.14440a

Pratomo, L. C., Siswandari, S., & Wardani, D. K. (2021b). The effectiveness of design thinking in improving student creativity skills and entrepreneurial alertness. International Journal of Instruction, 14(4), 695–712. https://doi.org/10.29333/iji.2021.14440a

Putra, P., Liriwati, F. Y., Tahrim, T., Syafrudin, S., & Aslan, A. (2020). The students learning from home experiences during covid-19 school closures policy in Indonesia. Jurnal Iqra' : Kajian Ilmu Pendidikan, 5(2), 30–42. https://doi.org/10.25217/ji.v5i2.1019

Rahayu, R. P., & Wirza, Y. (2020). Teachers' perception of online learning during pandemic covid-19. Jurnal Penelitian Pendidikan, 20(3), 392–406. https://doi.org/10.17509/jpp.v20i3.29226

Rasmitadila, R., Aliyyah, R. R., Rachmadtullah, R., Samsudin, A., Syaodih, E., Nurtanto, M., & Tambunan, A. R. (2020). The perceptions of primary school teachers of online learning during the COVID-19 pandemic period: A case study in Indonesia. Journal of Ethnic and Cultural Studies, 90–109. https://doi.org/10.29333/ejecs/388

Rojanarata, T. (2020). How online whiteboard promotes students' collaborative skills in laboratory learning. Proceedings of the 2020 8th International Conference on Information and Education Technology. https://doi.org/10.1145/3395245.3396433

Rumahlatu, D., Sangur, K., Berhitu, M. M., Kainama, S. Y., Kakisina, V. V., & Latupeirissa, C. (2021). Resource Based Learning Design Thinking (RBLDT): A model to improve students' creative thinking skills, concept gaining, and digital literacy. Cypriot Journal of Educational Sciences, 16(1), 288–302. https://doi.org/10.18844/cjes.v16i1.5528

Rusydiyah, E. F., Purwati, E., & Prabowo, A. (2020). How to use Digital Literacy as a learning resource for teacher candidates in Indonesia. Jurnal Cakrawala Pendidikan, 39(2), 305–318. https://doi.org/10.21831/cp.v39i2.30551

Santoso, P. H., Istiyono, E., & Haryanto. (2022). Physics teachers' perceptions about their judgments within differentiated learning environments: A case for the implementation of Technology. Education Sciences, 12(9), 582. https://doi.org/10.3390/educsci12090582

Simamora, R. M. (2020). The challenges of online learning during the COVID-19 pandemic: An essay analysis of performing arts education students. Studies in Learning and Teaching, 1(2), 86–103. https://doi.org/10.46627/silet.v1i2.38

Stackowiak, R., & Kelly, T. (2020). Design thinking overview and history. Design Thinking in Software and AI Projects, 1–16. https://doi.org/10.1007/978-1-4842-6153-8_1

Tan, K. H., Rajendran, A., Muslim, N., Alias, J., & Yusof, N. A. (2022). The potential of TikTok's key features as a pedagogical strategy for ESL classrooms. Sustainability, 14(24), 16876. https://doi.org/10.3390/su142416876

Tarigan, K. E., & Stevani, M. (2021). The impact of covid-19 on online learning in K12 Indonesian schools: MACRO, Meso, and micro levels. International Journal of Arts and Humanities Studies, 1(1), 23–32. https://doi.org/10.32996/ijahs.2021.1.1.4

Tauhidah, D., Jayanti, U. N., Rahmasiwi, A., Pamungkas, R., & Saifulloh, A. (2021). Utilization of e-learning platforms by lecturers during the COVID-19 pandemic in Indonesia. JPBI (Jurnal Pendidikan Biologi Indonesia), 7(3), 198–207. https://doi.org/10.22219/jpbi.v7i3.16816

UNICEF. (2020). Strengthening Digital Learning across Indonesia - UNICEF. UNICEF. https://www.unicef.org/indonesia/media/10531/file

Wirani, Y., Nabarian, T., & Romadhon, M. S. (2022). Evaluation of continued use on Kahoot! as a gamification-based learning platform from the perspective of Indonesia students. Procedia Computer Science, 197, 545–556. https://doi.org/10.1016/j.procs.2021.12.172

Zainuddin, Z., Chu, S. K., Shujahat, M., & Perera, C. J. (2020). The impact of gamification on learning and instruction: A systematic review of empirical evidence. Educational Research Review, 30, 100326. https://doi.org/10.1016/j.edurev.2020.1003

Theme 2

Exploring multiplicity & diversity in media & materials

The constellation of experiential contributions highlights embodied, tacit, and experimental diverse learning and designing. Thinking with things, learning by doing, experiential and authentic learning, co design, inclusivity and accessibility are terms increasingly found in curriculum that acknowledge diverse modalities for learning and meaning making.

Learning experiences, cultural connection, and sense of belonging for a student cohort in Yonsai University is explored by Choi et al. through olfactory sensation. Experimentation with scent is mapped from a user's perspective. Similarly, crafted objects that carry cultural significance, both traditional and contemporary are explored as a powerful catalyst by Passi. The artefacts pose a dual purpose as both object and symbol for discussion on the sexual and reproductive health of women in low resource environments. Sierra et al. apply the analogy of tapestry in weaving the moderating task of integration in teams to achieve disciplinary diversity for innovation learning profiled by the case of the ATTRACT initiative in the EU. Sierra et al. in creating the methods to weave in integration for teams recognise there is a correlation between diversity and innovation suggesting that increasing diversity of knowledge in teams may lead to higher innovation outputs.

"The constellation of experiential contributions highlights embodied, tacit, and experimental diverse learning and designing: White background, Pink and cyan, Hyperrealistic, Minimalism --c 40 --s 750.

Image: Midjourney × Valtteri Bade, 2023

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Multiplicity and diversity: the key to innovation

Abstract

This study explores the role of diversity in promoting learning innovation within educational course-teams. The focus is on the courses conducted under the Attract Academy Umbrella; a co-innovation program funded by the European Commission's Horizon 2020 Program. The sample consists of three educational courses involving students from Esade Business School, Instituto Europeo Di Design (IED), and Telecom and Computer Science Engineers students from UPC. The study adopts a case study approach, collecting qualitative and quantitative data from 88 students. Preliminary findings suggest that the integration of diversity positively influences creative and innovative outcomes. The study aims to contribute to the research on how diversity impacts learning innovation. The limitations include the correlational nature of the analysis and the need for further generalization.

Keywords:
Innovation.
Creativity.
Multiplicity,
Diversity.
Challenge Based Innovation.
Experience Learning.

Introduction

Innovation, driven by novel and practical ideas, has been a historical catalyst for human progress (Castañer, 2016). Today, Western society places a strong emphasis on innovation, as the European Commission's "Horizon 2027" innovation projects. Consequently, equipping future generations with the ability to innovate is paramount.

In a rapidly evolving world, higher education increasingly prioritizes fostering learning innovation (Figueiredo et al., 2022; Lahdenperä et al., 2022). Diverse collaborative teams play a central role in driving this innovation (Klein, 1996; Tuertscher et al., 2013). Previous research explored disciplinary, gender, and cultural diversity as factors contributing to innovation (e.g., Bantel & Jackson, 1989; Ancona & Caldwell, 1992; Ely, 2004; Auh & Menguc, 2005; Dahlin et al., 2005). However, the specific ways in which these diverse elements influence learning innovation remain unclear. Our research aims to uncover the impact of disciplinary diversity and multiplicity on learning innovation while examining the moderating role of integration.

This study is significant because understanding diversity integration can shape educational experiences and foster learning innovation (e.g., Charosky et al., 2018; Deo et al., 2020; Holzer et al., 2018). Our primary objective is to comprehend how disciplinary diversity and multiplicity affect learning innovation in higher education while investigating the role of diversity integration. In this paper, we briefly review key concepts and then delve into how diversity influences learning innovation across three educational courses, culminating in meaningful conclusions.

Theoretical background

Learning innovation

Creativity involves generating novel ideas, while innovation centers on the creation of new, practical ideas (Castañer, 2016). To differentiate creativity from innovation effectively and avoid ambiguity, we view innovation as the outcome of an idea-generation process (e.g., Amabile, 1983, 1988) (Castañer, 2016).

The surge of interest in learning innovation has led to the proliferation of methodologies and approaches aimed at fostering creative problem-solving (Brown, 2008; Jackson, 1991). Design Thinking, in particular, has emerged as a versatile framework for learning and applying innovation principles (Calgren et al., 2014; Chang & Yen, 2021; Panke, 2019). Research has underscored the effectiveness of Design Thinking in cultivating innovation competencies among learners (Liedtka & Ogilvie, 2011; Meinel et al., 2011).

Innovation teams

Historically, important innovations have resulted from collaborative teams exchanging information and pursuing common goals (Castañer, 2016). Teams are pervasive across sectors and hierarchical levels, serving as the cornerstone for clustering competencies and problem-solving in institutions.

A structured definition defines a team as "*two or more individuals who socially interact; possess common goals; are brought together to perform organizationally relevant tasks; exhibit interdependencies with respect to workflow, goals, and outcomes; have different roles and responsibilities; and are together embedded in an encompassing organizational system, with boundaries and linkages to the broader system context and task environment*" (Kozlowski & Ilgen, 2006, p. 79). Many studies on team innovation focus on R&D teams as their primary sample (e.g., Shin & Zhou, 2007; Miron-Spektor et al., 2011).

The Role of Diversity

In modern education, diversity encompasses more than just cultural and gender differences; it extends to disciplinary diversity. It involves individuals from various academic fields contributing unique knowledge, methodologies, and problem-solving approaches (Klaassen, 2018). Embracing it challenges teams to merge, clash, and intertwine ideas, fostering innovation and transformative change (Bailey et al., 2021). However, diversity alone is insufficient; students must recognize and reconcile differences in backgrounds and disciplines (Bailey et al., 2021). Interpersonal skills are crucial in diverse teams to integrate these differences (Figueiredo et al., 2022).

Multiplicity emerges when individuals with diverse academic backgrounds converge in an educational setting, bringing varied perspectives. This diversity fosters a cross-fertilization of ideas, exchange of best practices, and interdisciplinary collaboration. By welcoming input from different fields, universities can unlock novel problem-solving approaches.

Among the tapestry of disciplinary backgrounds, integrating multiplicity plays a crucial role in unlocking learning innovation's full potential (García-Rodríguez et al., 2012). Integration involves leveraging differences as sources of new knowledge and insights (Eppinger & Kressy, 2002). When teams prioritize inclusive and collaborative learning environments, they facilitate meaningful interactions among students and scholars, encouraging the synthesis of diverse perspectives to address complex challenges.

Method and data

The sample consists of 3 educational courses (CBI-FP with 27 students, CBI4AI with 34 students & TeSi with 27 students) based on the Challenge Based Innovation methodology (Papageorgiou et al., 2021; G. Charosky et al., 2018; Hassi et al., 2016), a challenge-driven education experience using a design thinking and systems thinking approach to solve societal challenges applying cutting edge technologies to develop holistic and sustainable long-term solutions. They explore challenges framed under the SDG framework, identifying societal challenges to solve using early-stage development cutting-edge technologies from the Attract Academy Umbrella developing social innovative and impactful solutions, plus the participation of the Experiential Learning Innovation team from IdeaSquare at CERN.

We are using a case study approach; the findings integrate qualitative and quantitative research (Yin, 2012). We have collected qualitative and quantitative data from 88 students in total doing the following:

- Recurring feedback forms.
- Final feedback session.
- Final learning reflection feedback form.
- Students' outcomes.
- Student diversity information.

Results

Are participants aware of diversity? The initial findings in the realm of multiplicity shed light on this question. Remarkably, 94% of the participants demonstrated an awareness of the diversity present in their teams. An overwhelming 82% recognized the significance of disciplinary diversity within their teams. Furthermore, an impressive 78% felt confident in their ability to work productively with individuals from diverse disciplinary backgrounds, spanning 27% business students, 30% designers, and 43% engineers. These teams also encompassed a range of ages (20 to 44 years old) and cultures (representing 40 different nationalities).

Qualitative feedback echoed this awareness and positive opinion on diversity. One participant noted, "*The main learnings and inputs have been firstly to work in a group with people from totally different fields*" (CBI4AI Interaction Design, IED). Others

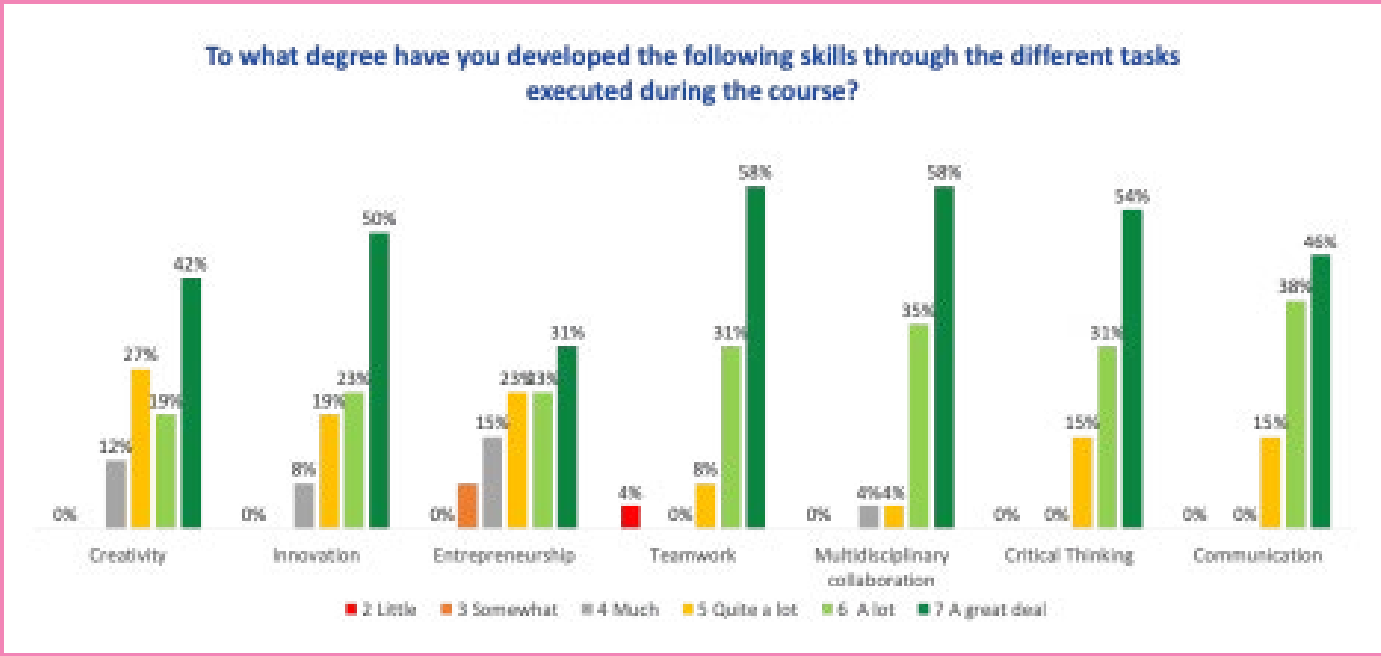

Fig. 1. CBI 2022, CBI4AI & TeSi 2023 Self-assessment analysis

expressed their growth in handling diverse teams and the value of new perspectives and collaborative teamwork. Diversity was seen as a rich source of learning experiences that equipped participants with lifelong skills.

What are the most valuable skills in working in diverse teams? Participants indicated that the most valuable skills and competences gained were related to dealing with a multidisciplinary environment (78%) and the ability to collaborate effectively within teams (72%). This consensus emerged from both quantitative and qualitative data.

The main valuable skills pointed out are related to people interaction skills, *"it shows us how to work together with passion in a long-term project with a great multidisciplinary team, making people grow in a lot of ways."* (CBI Physics Engineering UPC student). As well as empathy as a key element to innovate and focus on the end user: "*Being open to taking information from other backgrounds, and being more empathetic will all add more value to my career*." (CBI4AI, Interaction Design Master, IED).

Diversity predicts learning innovation? Analyses demonstrated strong correlations between diversity and innovative outcomes. Teams characterized by higher levels of diversity, including representation from at least three different disciplines, more than three nationalities, and a broader age range, consistently outperformed others.

Qualitative insights reinforced these findings, with participants recognizing the far-reaching impact of diversity beyond knowledge and expertise. They acknowledged the importance of diversity in shaping their future careers, particularly in interdisciplinary teams. *"It has helped me see how to think for innovative solutions while having always in mind the final user and the impact we wanted to make."* (CBI, Telecom Engineering Degree, UPC) pointing out the importance of understanding people to create useful solutions to problems. It's from the ideas discussions and exchanges that good and meaningful ideas come through: "*Explaining my mindset and how the ideas can work is also challenging, as others may not understand how things work in my sector easily"* (CBI4AI, Master in Business Analytics, Esade).

Moderating role of integration

Finally, the moderation role of integration is observed when all individuals recognized the integration of different knowledge, they scored higher in innovation. Integration of diversity is pointed as crucial for the generation of innovation and their future career: *"For my future it's important to be part of a team with people from different fields, cultures, points of view... Overall it's really enriching being part of it."* (CBI4AI, Computer Science Masters, UPC). Further follow-up interviews with former participants could verify those impressions.

Discussions and conclusions

This study provides initial insights into R&D team processes and the impact of diversity on innovation. Integrating diversity into team dynamics has proven beneficial for fostering innovation, a skill crucial for both learning and future careers.

This research aligns with prior studies recognizing the importance of processes in enhancing learning innovation within diverse teams (e.g., Paulus & Yang, 2000; Sethi et al., 2001; Auh & Menguc, 2005; Somech, 2006; Cabrales et al., 2008; Chowhan,

2016). However, it has limitations, as it is correlational and cannot establish causality. Unmeasured variables like personality might influence outcomes.

Future research can improve measurements by assessing self-efficacy, creativity, and innovation before and after courses to quantify improvements in innovation capabilities. Additionally, we are developing a comprehensive diversity index, considering factors such as age, nationality, and gender, to explore correlations with innovation levels and project quality, as preliminary analysis suggests.

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References

Amabile, TM (1983). The social psychology of creativity: A componential conceptualization. Journal of Personality and Social Psychology, 45, 357-376.

Amabile, TM (1988). A model of creativity and innovation in organizations. Research in Organizational Behavior, 10, 123-167.

Ancona, D. G., & Caldwell, D. F. (1992). Demography and design: Predictors of new product team performance. Organization Science, 3(3), 321-341.

Auh, S., & Menguc, B. (2005). Top management team diversity and innovativeness: The moderating role of interfunctional coordination. Industrial Marketing Management, 34(3), 249-261.

Bailey, J., Read, J., Linder, B. & Neeley, L. (2021). Interdisciplinary team-based learning: An integrated opportunity recognition and evaluation model for teaching business, engineering, and design students. Entrepreneurship Education and Pedagogy, 4(2), 143-168.

Bantel, K. A., & Jackson, S. E. (1989). Top management and innovations in banking: Does the composition of the top team make a difference?. Strategic Management Journal, 10(S1), 107-124.

Brown, T. (2008). Design thinking. Harvard business review, 86(6), 84.

Cabrales, Á. L., Medina, C. C., Lavado, A. C., & Cabrera, R. V. (2008). Managing functional diversity, risk taking and incentives for teams to achieve radical innovations. R&D Management, 38, 35-50.

Carlgren, Lisa, Maria Elmquist, and Ingo Rauth. "Design thinking: Exploring values and effects from an innovation capability perspective." The Design Journal 17.3 (2014): 403-423.

Castañer, X. (2016). Redefining creativity and innovation in organizations: Suggestings for redirecting research. International Journal of Innovation Management, 20(4), 1640001.

Chang, C.C., Yen, W.H. (2021). "The role of learning style in engineering design thinking via project-based STEM course", Asia Pacific Journal of Education, 1-19.

Charosky, G., Leveratto, L., Hassi, L., Papageorgiou, K., Ramos-Castro, J., & Bragós, R. (2018). "Challenge based education: an approach to innovation through multidisciplinary teams of students using Design Thinking", 2018 XIII Technologies Applied to Electronics Teaching Conference (TAEE), La Laguna: Spain, 1-8

Chowhan, J. (2016). Unpacking the black box: understanding the relationship between strategy, HRM practices, innovation and organizational performance. Human Resource Management Journal, 26(2), 112-133.

Dahlin, K. B., Weingart, L. R., & Hinds, P. J. (2005). Team diversity and information use. Academy of Management Journal, 48(6), 1107-1123.

Deo, S., et al., 2020, Creativity and engineering education: Assessing the impact of a multidisciplinary project course on engineering students' creativity, International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers. https://doi.org/10.1115/DETC2020-22250

Díaz-García, C., González-Moreno, A., & Jose Sáez-Martínez, F. (2013). Gender diversity within R&D teams: Its impact on radicalness of innovation. Innovation, 15(2), 149-160.

Ely, R. J. (2004). A field study of group diversity, participation in diversity education programs, and performance. Journal of Organizational Behavior, 25(6), 755-780.

Eppinger, S. D., & Kressy, M. S. (2002). Interdisciplinary product development education at MIT and RISD. Design Management Journal (Former Series), 13(3), 58-61.

Flinterman, J., Teclemariam-Mesbah, R., & Broerse, J. (2001). Transdisciplinary: the new challenge for biomedical research. Bulletin of Science, Technology and Society, 21, pp. 253-266.

Figueiredo, S., Ganoo, A., Eriksson, V., & Ekman, K. (2022). Future-ready skills development through Experiential Learning: perceptions from students working in multidisciplinary teams. CERN IdeaSquare Journal of Experimental Innovation, 6(2), 12–19. https://doi.org/10.23726/cij.2022.1397

García-Rodríguez, F. J., Gil-Soto, E. & Ruiz-Rosa, I. (2012). New methods in university entrepreneurship education: A multidisciplinary teams approach. Creative Education, 3(06), 878.

Gassmann, O. (2001). Multicultural teams: Increasing creativity and innovation by diversity. Creativity and Innovation Management, 10(2), 88-95.

Hassi, L., Ramos-Castro, J., Leveratto, L., Kurikka, J.J., Charosky, G., Utriainen, T.M., Bragós, R., Nordberg, M. (2016). Mixing design, management and engineering students in challenge-based projects, in: Proceedings of the 12th International CDIO Conference.

Holzer, A., Gillet, D., Laperrouza, M. (2018). "Active Interdisciplinary Learning in a Design Thinking Course: Going to Class for a Reason", IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018, Wollongong, Australia, 906-911.

Jackson, M.C. (1991). Creative Problem Solving: Total Systems Intervention. In: Systems Methodology for the Management Sciences. Contemporary Systems Thinking. Springer, Boston, MA.

Klaassen, R. G. (2018). Interdisciplinary education: a case study, European Journal of Engineering Education, 43:6, 842-859, DOI: 10.1080/03043797.2018.1442417

Klein, J. T. (1996). Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities. University of Virginia Press.

Kozlowski, S. W., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. Psychological science in the public interest, 7(3), 77-124.

Lahdenperä, J., Jussila, J., Järbenpää. A., & Jumisko-Pyykkö, S. (2022) Developing students innovation capability trough interdisciplinary producto development projects for industry. 1st Design Factory Global Network Research Conference Proceedings, Designing the Future 5-6 October, 2021.

Liedtka, J., & Ogilvie, T. (2011). Designing for growth: A design thinking tool kit for managers. Columbia University Press.

Meinel, C., Leifer, L., & Plattner, H. (2011). Design thinking: Understand-improve-apply (pp. 100-106). Berlin, Heidelberg: Springer.

Miron-Spektor, E., Erez, M., & Naveh, E. (2011). The effect of conformist and attentive-to-detail members on team innovation: Reconciling the innovation paradox. Academy of Management Journal, 54(4), 740-760.

Papageorgiou, K., Hassi, L., Bragós, R., Charosky, G., Leveratto, L., & Ramos, J. (2021). Prototyping the future of learning: reflections after seven iterations of Challenge-Based Innovation (2014-2020). "CERN IdeaSquare Journal of Experimental Innovation", 30 Juny 2021, vol. 5, núm. 1, p. 5-10.

Panke, S. (2019). "Design Thinking in Education: Perspectives, Opportunities and Challenges", Open Education Studies, 1 (1), 281- 306.

Paulus, P. B., & Yang, H. C. (2000). Idea generation in groups: A basis for creativity in organizations. Organizational Behavior and Human Decision Processes, 82(1), 76-87.

Sethi, R., Smith, D. C., & Park, C. W. (2001). Cross-functional product development teams, creativity, and the innovativeness of new consumer products. Journal of Marketing Research, 38(1), 73-85.

Shin, S. J., & Zhou, J. (2007). When is educational specialization heterogeneity related to creativity in research and development teams? Transformational leadership as a moderator. Journal of Applied Psychology, 92(6), 1709.

Simons, R. (2000). Performance measurement and control systems for implementing strategy. Upper Saddle River, New Jersey (USA): Prentice Hall.

Somech, A. (2006). The effects of leadership style and team process on performance and innovation in functionally heterogeneous teams. Journal of Management, 32(1), 132-157.

Tuertscher, P., Garud, R., & Nordberg, M. (2008). The emergence of architecture–the case of ATLAS, CERN. In academy of Management Annual Meeting Anaheim.

Yin, R. K. (2012). Case study methods. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), APA handbook of research methods in psychology, Vol. 2. Research designs: Quantitative, qualitative, neuropsychological, and biological (pp. 141–155).

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DESIGN

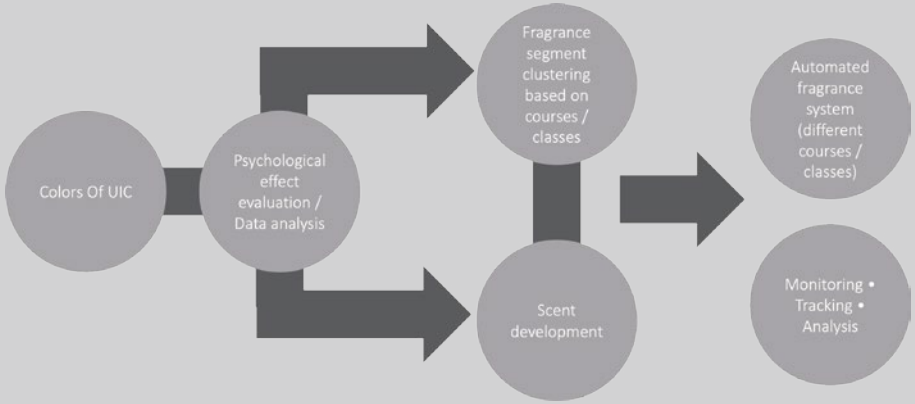
Fragrance as a medium creating cultural connection and enhancing learning experiences in university

'Underwood International College (UIC), Yonsei University', is a highly selective liberal arts institution that provides interdisciplinary education to students from 66 countries, fostering a global and inclusive learning environment. UIC has implemented diverse programs to promote cultural exchange and diversity. To be proven with the effect of programs, in perspective of design thinking, UIC has created a signature fragrance collection called 'Potions Of UIC'. Former research has proven that fragrances highly affect cognitive functions and brain activity. After providing students the set of perfumes, in a qualitative and quantitative methodology, the evaluation will be executed based on following criterias; learning experiences, cultural connection, and sense of belonging. The 'Potions Of UIC' collection comprises three signature scents: Shoot For The Stars, Universe, and Ptzzz-. Each scent is carefully blended to convey specific messages and create a comforting and inclusive atmosphere. 'Shoot For The Stars' encourages ambition and uses violet as the main note to promote positive behaviours. 'Universe' fosters unity and equality, selecting sandalwood to enhance productivity. 'Ptzzz-' symbolises each student's value as a shining light, using grapefruit to stimulate creativity. Furthermore, throughout continuous user tests, an optimised automated diffusing system, specialised for each courses and classrooms, will be developed. UIC plans to enhance tailored and immersive learning environments, empowering and inspiring students on their cultural/educational journey.

Key words:
Fragrance,
Cultural embracement,
Learning experiences,
Automated system,
Inclusive design

FRAGRANCE AS A MEDIUM CREATING CULTURAL CONNECTION AND ENHANCING LEARNING EXPERIENCES IN UNIVERSITY

AUTOMATIC FRAGRANCE DIFFUSING SYSTEM



EXPECTED USER JOURNEY

FRAGRANCE COLLECTION: POTIONS OF UIC

YONSEI UNIVERSITY
UNDERWOOD INTERNATIONAL COLLEGE
Design Factory Global Network

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Objects for impact

An artifact crafted by humans, embodies cultural or historical significance, with the ability to encapsulate a moment in time, revealing past actions and traditions. Open to intentional design and contextual embedding, it possesses the ability to spark discourse, narrate stories, catalyze thought, and stir emotions.

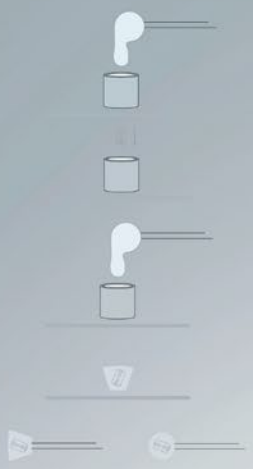
This study delves into and presents an approach to crafting a series of artifacts that facilitate discussions on a crucial yet complex subject: the sexual and reproductive health of women in low-resource environments. This exploration is rooted in research conducted by a social impact organization located in Helsinki with a focus on four specific countries: Tanzania, Kenya, Nigeria, and India. The primary objective of this work is to explore how the practice of discursive design alongside artistic object studies can further emotional engagement towards a social impact problem like the health and well-being of women in low-resource settings.

Methodologies of Human Centered Design, Discursive Design, Visual Research and Applied Art are employed to study the research matter and analyze how artefacts are designed, formed and contextually embedded to represent such a topic. Through this process, narratives of bodily harm, tension, dependency, agency, mobility, society, freedom and pivotal moments in the life journey of these women are explored via three collections of pieces: Encapsulation, a fusion of ceramic and glass, probing physicality and conceptuality; Future Fossils, petrified contextually linked items in glass, telling stories of harmful conditions; and Objects Translated, rendering women's journey transition moments in adorned ceramics, unraveling complexities and interconnections. (Passi, 2019)

Key words:
artefacts, discursive design, experimental design, applied art, glass, ceramics.

Passi, S. (2019). Objects for impact [Master Thesis]. In aaltodoc.aalto.fi. https://aaltodoc.aalto.fi/handle/123456789/41433

Scope (2019) Translating women's voices into art. Retrieved August 31st, 2023 from https://scopeimpact.fi/translating-womens-voices-into-art



Cola Bottle Caps and Can Clips
A set of objects that represent harmful, self induced abortion practices

Coins from Kenya
A set of objects that represent Transactional Sex

Scissor and Blade
A set of objects that represent tools used in Female Genital Mutilation and unsanitary medical equipment

Lock and Key
A set of objects that represent a lack of agency and mobility, and restrictions set by society

Coins from Kenya
A set of objects that represent Transactional Sex

Cola Can
An object that represents harmful, self induced abortion practices

"These objects are a translation of the complex valences expressed by women for each transition point on the life course. They are an attempt to grasp this complexity – the connections, ruptures interstices in women's lives as well as the biological, demographic, historical, psychological and socioeconomic contexts in which they unfold." (Scope Impact, 2019)

Death
Grandmotherhood
Menopause
Motherhood
Postnatal care
Labour & Delivery
Prenatal care
Pregnancy

Marriage & partnership
Family planning
Sexual inititiation
Adolescence
Menarche
Pre-adolescence
Birth
Infancy
Foetal development

OBJECTS FOR SUSHANT IMPACT PASSI

Design Factory Global Network

Aalto University

Theme 3

Organizational design for multiplicity & diversity

The theme of Organizational Design for Multiplicity and Diversity includes papers dealing with Design Thinking (DT) and Human Centered Design in professional settings or contexts. Challenging as it may be, implementing these methods in non-design environments is proven to foster innovation, improve collaborations, increase empathy, and optimize skills.

The papers in this section offer novel insights on ways of integration of DT in such environments. Van der Marel discusses a case study of applying DT among hospital employees, showing how it fosters innovative working culture and produces a beneficial transformative potential for the staff members. Spiegeler Castañeda et al. present “Mindset Muscle Training”, a tool developed to train and increase DT mindset. They reveal that applying this tool to encourage a better implementation of DT in a cross-organizational interdisciplinary setting leads to positive results. Eriksson et al. explore the ability of engineering students to identify and map different stakeholder’s roles as a way to improve their ability to design inclusive and holistic solutions for challenges.

"Organizational design for multiplicity & diversity, White background. Pink and magenta, Microscopical image --c 40 --s 750"

Image: Midjourney × Valtteri Bade, 2023

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How issue framing changes through design training: a hospital case study

Abstract

This study examines the impact of design training on issue framing within a professional setting. The study was conducted in a regional hospital, where a participatory design initiative was organised for employees from various roles. Participants were asked to share ideas for a more open and innovative working culture before and after the design workshops. These statements were collected and analysed based on thematic similarity. The findings reveal a shift in participants' framing, indicating increased self-efficacy, empathy, and systems thinking. Ideas for change transformed from external dependencies to actionable strategies within their control, reflecting a deeper understanding of the organisation's complexity and a focus on improving the experience for all stakeholders. This research highlights the transformative potential of design training in empowering employees to identify and address challenges effectively, thereby contributing to fostering a more open and innovative organisational culture.

Keywords:
professional education,
design training,
issue framing,
open culture

Introduction

Creating an open and innovative culture is widely acknowledged as a significant driver of organisational success (Amabile, 1998). This is particularly true in organisations with frontline workers (e.g. receptionists or nurses), who often identify issues early on (Tangirala & Ramanujam, 2012) yet might lack the ability to influence decision-making. Raising perceived needs that require attention, resolution, or management, referred to as 'issues', might be hindered due to self-imposed or external constraints. Issues are generally ill-structured, resulting in a wide variety of ways to formulate and address them (Dutton & Ashford, 1993). They can be any aspect of the organisation's operations, policies, practices, or

external environment that may harm its performance, efficiency, reputation, or overall well-being.

To support issue sharing, participatory design initiatives have increased in popularity in organisations. Participatory design initiatives include employees in decision-making through design workshops and provide design training for participants. Inviting people to influence decision-making in design workshops has been shown to lead to more effective and sustainable outcomes while supporting employee creativity, resulting in organisational profit and success (Piper et al., 2012). Additionally, design training positively impacts employee connectedness, job satisfaction, and retention (Edmondson & Besieux, 2021).

As such, participatory design initiatives support tackling immediate issues and contribute to larger organisational transformations (Smith & Iverson, 2018). Indeed, these larger transformations happen through increased employee voice: the likeliness of employees taking a proactive stance and speaking up about needs and opportunities on the work floor (Morrison, 2023). Subsequently, participatory design initiative participants indirectly impact other employees and the organisational culture. However, how employees frame these issues greatly influences the desire and ability of other employees to participate equally in these transformations.

Despite the growing evidence supporting the benefits of participatory design initiatives, a notable research gap exists concerning the influence of such initiatives on issue framing. This paper aims to contribute to filling this research gap by examining the impact of design training on issue framing within a professional setting. Specifically, we ask how hospital employees frame ideas for a more open and innovative working culture before and after participating in design workshops.

Theoretical background

Framing involves the cognitive and linguistic processes through which individuals interpret situations and present information, fundamentally shaping their understanding of problems and potential solutions and influencing their decision-making (Schön, 1984). Individuals' framing of issues reveals their strategies, actions, and solution space (Paton & Dorst, 2011). In the context of organisations, framing thus reveals how individuals understand the complexity of their organisational context, perceive opportunities, and make sense of organisational challenges. In short, different frames highlight distinct aspects of organisational reality.

These frames are reflected in ongoing employee conversations and interactions. Work floor conversations serve as a means of sense-making, knowledge-sharing, and socialisation, contributing to the development and evolution of organisational culture (Hatch, 1993). Through conversations, individuals negotiate meaning, establish shared interpretations, and construct a collective understanding of organisational values, goals, and norms (Hatch, 1993). Thus, when studying change in organisational culture, the dynamics between employees and their conversations cannot be ignored. By examining individuals' frames, researchers and practitioners can better understand how organisational issues are interpreted, how challenges and opportunities are identified, and how decisions are made. Understanding how design training impacts issue framing is thus crucial for organisations seeking to foster innovative and adaptable cultures.

Method and data

A regional hospital adopted a new strategy to support a more open and innovative culture. As part of this shift, the author conducted a participatory design initiative (targeted at reducing patient and family aggression toward employees) to which all employees were invited. Twenty-eight employees signed up for this project: nurses, care providers (e.g., social worker, orderly, and paramedic), and support service providers (e.g., HR manager, occupational health and safety officer, and linen services team leader). The initiative consisted of five elements, each one month apart:

- a one-hour one-on-one introductory interview;
- a full-day design training;
- a full-day discover and define design workshop;
- a full-day develop and deliver design workshop; and
- a full-day project closing workshop.

In the introductory interview and the closing workshop, participants were asked what was needed to create a more open and innovative working culture in the hospital. These ideas were recorded and transcribed verbatim. The ideas of participants who only shared one idea (either in the interview or closing workshop) were omitted from the results. This resulted in fourteen issues before participating in design workshops and fourteen after. These issues were analysed, described in a one-sentence statement, and categorised based on thematic similarity to reveal themes. This was done through an iterative sense-making process leveraging an in-depth understanding of the context and participants while reflecting critically on the themes that emerged from the data (Sundler, Lindberg, Nilsson, & Palmér, 2018).

Results

Tab. 1. Pre-workshop ideas for a more open and innovative working culture

Statements	Themes
Better nurse-to-patient ratio *More experienced nurses* *Additional ward* *Separate observation room* *Better transportation options* *Better hospital layout*	Need for more resources
More possibility to join meetings *Less blocking of ideas by managers* *Less negative talk between team members* *More civility between team members* *More equality*	Need for a different way of thinking or working
Leveraging expertise from other hospitals *Putting up a suggestion box*	Other

In the Introduction interview, most issues described a **need for more resources**. These issues most commonly came from nurses, who lamented having insufficient time or mental capacity to think about change. For example, improving the nurse-to-patient ratio would give them more time to reflect and think. Other logistical suggestions were mainly linked to alleviating nurses' stress to increase headspace.

The second biggest category of issues shared before the design workshops described desires to **shift how people think or work**. Service support providers shared most of these issues, predominantly related to a lack of equality. This ranged from being included in decisions to more supportive interactions amongst team members and with managers to increase psychological safety.

Two participants provided an issue that could not be categorised in either. One reflected a need for external support, wishing for better support from doctors and other hospitals to make use of their expertise, and another's concrete suggestion was to put up a suggestion box to be able to report issues and ideas anonymously.

Several issues shared in the project closing workshop described actions to **improve their own or team's practice**. Similar to the need for more resources expressed in the Introduction interviews, they were related to efficiency, freeing up time to think about more changes. For example, nurses saw opportunities to streamline and improve their own practice, and service support providers described ways to improve the team culture.

Another cluster of needs shared after the design workshops reflected **enhancing patient experiences**, pitching ideas to help patients feel more comfortable. This, they argued, would then make everybody's job easier, again freeing up time to keep improving their practice.

A third category of needs targeted **better internal coordination**, showing that participants understood the interconnectedness of issues more. For example, they felt doctors could improve their practice to improve nurse-patient interactions and reduce their workload.

Lastly, one participant, other than the one who suggested this in the Introduction interview, pitched to put up a suggestion box.

Tab. 2. Post-workshop ideas for a more open and innovative working culture

Statements	Themes
Including pain points in referral *Better pressure injury strategies* *More uniform bedside handover* *Align own team's needs* *Embed strengths-based practice*	Improving own or team's practice
Nametags with roles to reduce patients' confusion *Freeing up car park space near the entrance for patients* *Placing a board above hospital beds with photos of five things important to patients* *Better communication of waiting times*	Enhancing patient experiences
Doctors finishing after-hours board and med charts *Communicating clearer timelines internally* *Doctors doing discharge summaries to free up beds quicker* *Earlier involvement of security to avoid escalations*	Better internal coordination
Putting up a suggestion box	Other

Discussions and conclusions

Ideas for a more open and innovative working culture expressed before and after the design workshops predominantly reflected a need for more time to reflect, think, and improve. However, the needs shared before the workshops mainly described actions they could not influence, such as wanting more resources, others to work differently, or bringing in outside expertise – all to support their work. The needs after the workshops, in turn, showed an increased ability to make changes themselves, included more ideas to improve the experience for others, and had concrete ideas for others to make work easier and more efficient for all. As such, this study suggests that the design workshops supported participants in becoming better able to push for change effectively through a greater understanding of the complexity of the organisation, having increased empathy for other stakeholders, and gaining a higher perceived self-efficacy.

Evaluating how employees frame their ideas for a more open and innovative culture revealed meaningful themes. However, this study was conducted in one location with a small sample size. Additionally, every participant shared only one idea before and after the workshop. It is thus not certain to what extent these abilities were enhanced for each participant. More studies are needed to understand better how it supports them in identifying and addressing issues more adequately. These studies can be executed in professional settings and student courses to understand better how people's perceptions of what should and can be changed shift as a result of engaging with design tools.

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References

Amabile, T. M. (1998). *How to kill creativity* (Vol. 87). Boston, MA: Harvard Business School Publishing.

Dutton, J. E., & Ashford, S. J. (1993). Selling issues to top management. *Academy of management review*, *18*(3), 397-428.

Edmondson, A. C., & Besieux, T. (2021). Reflections: voice and silence in workplace conversations. *Journal of Change Management*, *21*(3), 269-286.

Hatch, M. J. (1993). The dynamics of organizational culture. *Academy of management review*, *18*(4), 657-693.

Morrison, E. W. (2023). Employee voice and silence: Taking stock a decade later. *Annual Review of Organizational Psychology and Organizational Behavior*, *10*.

Paton, B., & Dorst, K. (2011). Briefing and reframing: A situated practice. *Design studies*, *32*(6), 573-587.

Piper, D., Iedema, R., Gray, J., Verma, R., Holmes, L., & Manning, N. (2012). Utilizing experience-based co-design to improve the experience of patients accessing emergency departments in New South Wales public hospitals: an evaluation study. *Health services management research*, *25*(4), 162-172.

Schön, D. A. (1984). *The reflective practitioner: How professionals think in action* (Vol. 5126). Basic books.

Smith, R. C., & Iversen, O. S. (2018). Participatory design for sustainable social change. *Design Studies*, *59*, 9-36.

Sundler, A. J., Lindberg, E., Nilsson, C., & Palmér, L. (2019). Qualitative thematic analysis based on descriptive phenomenology. *Nursing open*, *6*(3), 733-739.

Tangirala, S., & Ramanujam, R. (2012). Ask and you shall hear (but not always): Examining the relationship between manager consultation and employee voice. *Personnel Psychology*, *65*(2), 251-282.

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Mindset muscle training – fostering the design thinking mindset in organisations

Abstract

Design Thinking (DT) has been widely used across disciplines. Despite the ubiquitous usage, we still lack understanding of the individual and organizational barriers to adopt DT. We therefore developed a method for training empathy as part of the DT mindset and conducted a study at the Research Campus ARENA2036. Our results point out that the training measurably increased the DT mindset and generated a supportive infrastructure to help participants explore new ways of thinking and behaving. The proposed training concept can be scaled to include other DT mindset aspects and provides a framework for fostering the DT mindset in organizations.

Key words:
Design Thinking;
Mindset;
Empathy.

Introduction

Design Thinking (DT) is a mindset and an approach for developing innovative and human-centred solutions to complex problems and has been widely used in organisations across disciplines (Wrigley et al., 2020). Creating an agile learning and working culture, improved collaboration, and better product development are only some of the motivators for implementing DT (Carlgren et al., 2016). Organisations use DT for internal challenges, to optimise customer engagement, or for individual skill-building (Liedtka, 2014). Successful implementation, however, is often hindered by barriers, both with respect to the approach itself as well as the mindset.

Despite the ubiquitous usage of DT, we lack an understanding of the individual and organisational barriers that would actually allow for adopting DT practices (Micheli et al., 2019). This contradiction between the benefits and barriers of establishing a DT mindset requires extensive research efforts, challenged by the complexity of understanding and measuring the mindset in individuals and organisations (Carlgren et al., 2016). Previous work investigated teaching and practising the DT mindset with experimental learning for MBA students, suggesting learning objectives and guidance for the DT mindset attributes (Groeger et al., 2019). Liedka et al. provide advice to teach DT to non-designers to 'find and pursue innovation opportunities in their own corners of their organisations' (Liedtka et al., 2017).

We aim to build on these findings and investigate ways to train the DT mindset on the Research Campus ARENA2036 (Hoßfeld & Ackermann, 2020) within a cross-organizational and interdisciplinary setting. We hypothesise that a concept based on a Design Science approach can measurably increase the DT mindset within employees in such an environment. In this work, we propose and evaluate a training for the DT mindset to lower the barriers for a successful implementation of DT.

Theoretical background

Difficulties implementing DT in organisations may be attributed to three overarching categories: process, management, and culture. A misfit with existing processes and structures (Carlgren et al., 2016), the incorrect implementation of the process as well as the non-linear nature of the process (Brown & Katz, 2011; Redante et al., 2019) can hinder a successful implementation. DT may threaten existing power dynamics within management because the immediate value of DT is often difficult to prove (Carlgren et al., 2016), and it is challenging to measure the results (Redante et al., 2019). Furthermore, the fear of failure and running risks (Redante et al., 2019), as well as a lack of required organisational culture and mindset, might not deliver the required results or even lead to failure (Kimbell, 2011).

Collaboration and the ownership every team member develops are decisive for creating value with DT. Culture and mindset can therefore be seen as key for its successful implementation. A personal mindset includes all individual values, behaviours, preferences, habits, and attitudes (Thames & Webster, 2009, p.19). In organisations, mindset refers to organisational culture and includes the group mental models, traditions, and behaviours (Waterman Jr et al., 1980). When training mindset in organisations, it is key to be aware of the different attitudes towards unknown situations. Dweck et al. introduced a concept differentiating between a growth and a fixed personal mindset (Dweck, 2006). Building on that, Liedka et al. observed a tendency in non-designers to think with a fixed mindset, e.g. to be averse to risk mistakes as well as to go beyond their past experiences. Persons with a growth mindset, however, see 'life as a journey of discovery, are comfortable with iterations and even failure, embrace challenges and persist in the face of setbacks' (Liedtka et al., 2017). When training the DT mindset in organisations, it is important to keep in mind that persons with a growth mindset might be more open to learning and to developing further in this direction.

This paper mainly focuses on empathy as a pivotal part of the DT mindset (Dosi et al., 2018). This is especially relevant in the setting of a Research Campus since the simultaneity of analytical and empathetic thinking is particularly challenging to navigate (Jack et al., 2013), which in turn qualifies the ecosystem under investigation as a role model environment for DT studies. Moreover, mode switching becomes increasingly important in socio-technical contexts. The central task is accordingly to identify, develop, and test tools that allow for a seamless switching between different modes, thus allowing participants to develop an empathetic DT mindset whilst working on technological issues. This paper builds on the findings of Groeger et al., describing that the usage of DT tools fosters the DT mindset, even when detached from the DT process (Groeger et al., 2019).

Method and data

To tackle the complex and intangible problem of training the DT mindset, we opted to choose a Design Science approach, thus creating an abductive method out of existing theories. The concept was created by building on the comprehension that establishing and changing a mindset needs time, practice, and reflection (Tranquillo, 2016). Therefore, we set up a short and regular format with integrated tools from DT. The training was labelled 'Mindset Muscle Training' and was implemented as a pilot project with six trainings with a duration of 45 minutes each over three weeks (Tab. 1). The study included a treatment group (n=12) and a control group (n=9) evaluated with a pre- and a post-test. Adopting a self-assessment questionnaire with a 5-point Likert scale (1: I do not agree at all; 5: I completely agree) (Dosi et al., 2018), we focused on four categories, which we considered most relevant for an empathic mindset (A: empathy, B: human centeredness, C. critical questioning, and D: Open to different perspectives / diversity). Furthermore, a reflective element was created with the task for the participants to note elements they would like to transfer into their daily work. The questionnaire can be found in the Supplementary Materials for reference.

For the control group, we created a one pager as a simple way of introducing a new mindset. This one-pager was also given to the treatment group in the first training session. Before the one-pager was handed out, a baseline measurement was made as a pre-test. Three weeks later, after six trainings, participants did the post-test. We then calculated the difference between the pre- and post test to get the increase after the three weeks of the study. Moreover, the questionnaire included questions about the general concept and the teaching structure.

Tab. 1. Contents of the 6 training sessions.

Trainings	Contents
1	Introduction to Design Thinking Warm-up (Tangram)
2	Empathy Map Storytelling
3	User journey Storytelling
4	Persona Storytelling
5	Value Proposition Canvas Pitch
6	futuregame2050 / https://www.thefuturegame2050.com/ (last access: July 2020) Persona Storytelling

Results

Fig. 1 shows the increase in Likert points after the three week study with respect to the baseline for both the treatment and the control group. In category A, we observed an increase of Likert points (LP) of the mean value in the treatment group and LP in the control group. Category B showed an increase of LP for the treatment group and LP for the control group. The highest increase in the treatment group was observed for category D with LP and C with LP. While the standard deviation of the post-test increase was higher than the actual increase for the control group in all of the categories, the standard deviation in the treatment group was smaller than the increase in categories B, C, and D. We additionally analysed the individual increase of each participant by comparing the increase of the Likert scale with the respective self-observation of the participants. Examining the categories A to D, the majority of the treatment group participants noted an improvement for all of the categories. In the control group, however, two or less participants per category observed an increase. All 12 participants rated that they would recommend the training to their colleagues, and 11 of the 12 participants would integrate such a training regularly into their daily work. Furthermore, 58% of training participants noted that the training helped to improve their out-of-the-box thinking capabilities and 67% found the training useful to establish new contacts on the research campus.

Discussions and conclusions

In this work, we developed and conducted a 'Mindset Muscle Training' on the Research Campus ARENA2036 e.V. (Hoßfeld & Ackermann, 2020) to foster the DT mindset. Teaching and learning a DT mindset is challenging for organisations and individuals (Liedtka et al., 2017) as a mindset change requires time, self-reflection, and practice (Tranquillo, 2016). Also, a significant incongruence between the conceptualization, measurement, and training findings leads to contradictory Results about the trainability (Lam et al., 2011). In the context of ARENA2036, the format of short and regular sessions with reflective elements was perceived well by participants and could be integrated into their daily work. The 'Mindset Muscle Training' generated a safe and supportive infrastructure to help participants explore new ways of thinking and behaving, which is also shown by the stronger increase of the DT mindset for the treatment group, both measured with a Likert scale and in the self-observation of the participants. Interestingly, the standard deviation of the pre- to post-test increase within the treatment group was much smaller with respect to the actual increase in Likert points when compared with the control group. This points in the direction that the increase of the DT mindset in participants was a result of the training. Also, some participants of the treatment group self-assessed an increase in their DT mindset, even though the measured values of the Likert scale weren't increased or even decreased. This underlines that the training made participants aware of and reflect on their personal mindset, which is a requisite for developing further in this direction. The Results of this study, however, must be interpreted with care. Due to the limited number of participants, we neither tested these differences for significance nor included sociographic data like age, gender, or profession. Also, training a DT mindset changes the perception of participants with respect to their own mindset, which hardens the comparison with untrained participants. Future research should focus on testing the 'Mindset Muscle Training' over longer periods of time with larger study groups, as well as on adapting the training and evaluation to include other DT mindset aspects and new models to measure the DT mindset (Vignoli et al., 2023).

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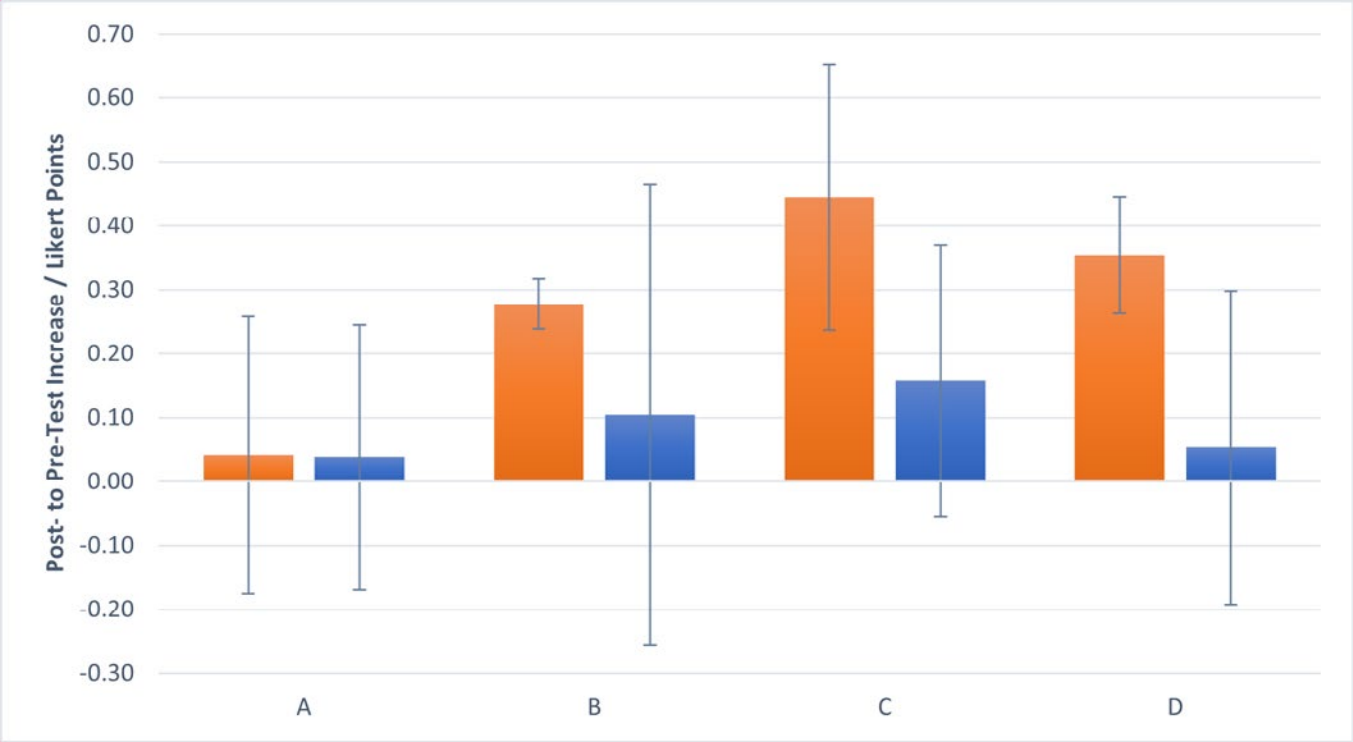

Fig. 1. Increase treatment group (orange) vs. control group (blue) in Likert points (mean value);
A: empathy, B: human centeredness, C. critical questioning and D. Open to different perspectives / diversity

References

Brown, T., & Katz, B. (2011). Change by Design. Journal of Product Innovation Management, 28(3), 381–383. https://doi.org/10.1111/j.1540-5885.2011.00806.x

Carlgren, L., Rauth, I., & Elmquist, M. (2016). Framing design thinking: The concept in idea and enactment. Creativity and innovation management, 25(1), 38–57.

Dosi, C., Rosati, F., & Vignoli, M. (2018). MEASURING DESIGN THINKING MINDSET. DS 92: Proceedings of the DESIGN 2018 15th International Design Conference, 1991–2002. https://doi.org/10.21278/idc.2018.0493

Dweck, C. S. (2006). Mindset: The new psychology of success. Random house.

Groeger, L., Schweitzer, J., Sobel, L., & Malcom, B. (2019). Design thinking mindset: Developing creative confidence. Academy of Design Innovation Management Conference 2019.

Hoßfeld, M., & Ackermann, C. (2020). Der Forschungscampus ARENA2036. In T. Bauernhansl, M. Fechter, & T. Dietz (Hrsg.), Entwicklung, Aufbau und Demonstration einer wandlungsfähigen (Fahrzeug-) Forschungsproduktion (S. 1–3). Springer. https://doi.org/10.1007/978-3-662-60491-5_1

Jack, A. I., Dawson, A. J., Begany, K. L., Leckie, R. L., Barry, K. P., Ciccia, A. H., & Snyder, A. Z. (2013). FMRI reveals reciprocal inhibition between social and physical cognitive domains. NeuroImage, 66, 385–401.

Kimbell, L. (2011). Rethinking design thinking: Part I. Design and culture, 3(3), 285–306.

Lam, T. C. M., Kolomitro, K., & Alamparambil, F. C. (2011). Empathy Training: Methods, Evaluation Practices, and Validity. Journal of MultiDisciplinary Evaluation, 7(16), 162–200. https://doi.org/10.56645/jmde.v7i16.314

Liedtka, J. (2014). Innovative ways companies are using design thinking. Strategy & Leadership, 42(2), 40–45. https://doi.org/10.1108/SL-01-2014-0004

Liedtka, J., Salzman, R., & Azer, D. (2017). Democratizing innovation in organizations: Teaching design thinking to non-designers. Design Management Review, 28(3), 49–55.

Micheli, P., Wilner, S. J., Bhatti, S. H., Mura, M., & Beverland, M. B. (2019). Doing design thinking: Conceptual review, synthesis, and research agenda. Journal of Product Innovation Management, 36(2), 124–148.

Redante, R. C., De Medeiros, J. F., & Cruz, C. M. L. (2019). Motivators and Barriers for Using Design Thinking in NPD. New Global Perspectives on Industrial Engineering and Management: International Joint Conference ICIEOM-ADINGOR-IISE-AIM-ASEM, 249–257.

Thames, B., & Webster, D. W. (2009). Chasing change: Building organizational capacity in a turbulent environment. John Wiley & Sons.

Tranquillo, J. (2016, Juni 26). Mirror Mirror: Reflection and the Building of Mindsets. 2016 ASEE Annual Conference & Exposition. https://peer.asee.org/mirror-mirror-reflection-and-the-building-of-mindsets

Vignoli, M., Dosi, C., & Balboni, B. (2023). Design thinking mindset: Scale development and validation. Studies in Higher Education, 48(6), 926–940. https://doi.org/10.1080/03075079.2023.2172566

Waterman Jr, R. H., Peters, T. J., & Phillips, J. R. (1980). Structure is not organization. Business horizons, 23(3), 14–26.

Wrigley, C., Nusem, E., & Straker, K. (2020). Implementing Design Thinking: Understanding Organizational Conditions. California Management Review, 62(2), 125–143. https://doi.org/10.1177/0008125619897606

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Identifying and framing potential stakeholders in complex innovation ecosystems

Abstract

While engineering is often characterised as a technical and analytical discipline, it is essential to recognize that engineers do not design products or systems in isolation; they design them to function within societal and environmental systems. However, analysing the types and fields of stakeholders to produce holistic stakeholder maps may be daunting for students. The process may be scaffolded through the inclusion of specific stakeholder roles, which students may use as a starting point. Drawing from 31 students' stakeholder analyses, this case study explores students' ability to identify different types of stakeholders and the range of roles they could play, when provided with a set of stakeholder roles as a point of departure. Findings highlight that students were able to identify a diverse range of stakeholders as well as the multiplicity of stakeholder roles. Many connections were, however, close to the provided industry context and the students' backgrounds compared to other potentially relevant contexts. The role prompting did however result in 33 unique stakeholders and 66 stakeholders identified by multiple students, particularly in customer, supplier, and possible collaborator roles. As such, combining individual, scaffolded mappings can help to capture innovation ecosystems more systematically and illuminate more diverse collaboration opportunities in development projects.

Key words:
Stakeholder mapping; engineering innovation; framing

Introduction and Theoretical background

Building socially driven empathetic capacity during mechanical engineering education allows students to better understand the needs, desires, and limitations of the end-users (Walther, Miller & Sochacka 2017), while also potentially improving their instrumental contribution to the stakeholder partnership (Bridoux & Stoelhorst 2016). By understanding different user groups and their diverse backgrounds, engineers can design solutions that are inclusive, accessible, and accommodate a wide range of user abilities. This is also a precondition for developing stakeholders' engagement and cooperation (Jones et al., 2018). Stakeholder partnerships benefit from a clear

understanding of roles and their implications, which can be explored through perspective-taking. As such, it is important to not only define the characteristics of the stakeholders, such as the interest and power dimensions captured in traditional stakeholder mapping (Boonstra & de Vries 2008), but also the different capacities through which stakeholders connect to a sought-after end goal (Freeman et al., 2018).

Understanding the roles that stakeholders can play in development provides an opportunity to construct a more holistic mapping of the stakeholder ecosystem, including, for example non-human stakeholders (Tallberg, García-Rosell & Haanpää 2022) and support more collaborative, human-centered innovation processes (Kojmane & Aboutajeddine 2016).

Mapping this complexity can create new value, as stakeholder intentions and values linked to roles facilitate mutual benefit (Freeman et al., 2018). This study explores the perceived scope and multiplicity of stakeholder connections identified through role-based stakeholder analysis in the context of an engineering course.

Method and data

To explore the diversity of stakeholders connected to engineering innovation as well as the diversity of roles that a single stakeholder can be seen as playing, first-year master's level mechanical engineering students were tasked with a role-based stakeholder analysis of a healthcare technology under development. The diagnostic healthcare technology aims to bring the detection and study of pathogens and other diseases to point-of-care. Completed stakeholder analyses were submitted by n=31 students. Stakeholder roles were used to scaffold the activity and support student exploration. The potential roles (Tab 1) communicated to students were stakeholders as beneficiaries, collaborators, competitors, customers, hostiles, suppliers, and supporters. The customer, supplier, collaborator, and supporter roles were drawn from the Aalto Design Factory stakeholder mapping tool1. The tool was originally developed to support identifying co-creation opportunities in the context of a Business, within an applied research project to support small-business experimentation during the pandemic funded by the Finnish Government. Students were able to assign multiple roles to a single stakeholder and could include additional stakeholders.

The stakeholder analyses were open-coded to identify the types of stakeholders noted and the multiplicity of their roles. The most prominent stakeholder groups identified by students and the extent to which students recognized the multiplicity of stakeholder roles within a single case was established through Qualitative Data Analysis (QDA).

1 https://designfactory.aalto.fi/toolkits/

Results

Stakeholders connected to specific roles were associated with an array of individuals and organisation as customers (n=84), suppliers (n=84), collaborators (n=71), competitors (n=68), supporters (n=67), beneficiaries (n=56), and hostiles (n=53). The final list of stakeholders (n=99) included both individuals as well as public and private organisations of varying specificity. The nature of the case impacted the identified stakeholders, which were predominantly health and well-being related or engineering and technology related. The distribution of stakeholders' roles identified, and relative novelty varied (Tab 2).

Health and Wellbeing stakeholders (n=254) represented stereotypical stakeholders but a very wide variety of types of actors. These covered all seven roles of stakeholders, and most stakeholders were connected to several roles. The three most common roles were competitors (n=64), beneficiaries (n=51), and hostiles (n=42 mentions). Three stakeholders were identified as active within six of the noted seven roles. When viewed through the lens of multiplicity, the role-based analysis frame supported the identification of diverse roles of individual stakeholders.

Engineering and Technology (n=131) mentions focused mainly on companies, mainly identified as suppliers (n=87). Subcategories within this theme included materials and technology,

Tab. 1. Stakeholder role characteristics

Role	Defining Characteristic of person or organisation who/that:
Beneficiary	directly benefits from the existence of the technology and product
Collaborator	play an active role in developing and/or commercialising the technology and product.
Competitor	has a technology or product which offers (or will offer) the same or very similar benefits and value, thus directly competing for resources and end-users.
Customer	is positioned to purchase the product or service once available.
Hostile	perceives the existence of the technology and product as negative or problematic.
Supplier	plays an active role in supporting a range of resources for the development and commercialization of the technology and product.
Supporter	perceives the existence of the technology and product as positive and is willing to offer limited knowledge and input to ensure it succeeds.

Tab. 2. Relative novelty and variety of stakeholders identification within initial role-based analysis

Types of stakeholders identified	Health & Wellbeing Stakeholders	Engineering & Technology Stakeholders	Additional Stakeholders
Relative novelty of identified stakeholders	38% stakeholders identified by 5+ students; 42% stakeholders identified by 2-4 students; 19% by just 1 student.	38% stakeholders identified by 5+ students; 14% stakeholders identified by 2-4 students; 48% by just 1 student.	39% stakeholders identified by 5+ students; 20% stakeholders identified by 2-4 students; 41% by just 1 student.
Variety of identified stakeholders	An average of n=6 stakeholders identified per student.	An average of n=4 stakeholders identified per student.	An average of n=6 stakeholders identified per student.
Variety of recognized stakeholder roles	7/7 stakeholder roles identified, only n=5 stakeholders identified in a single role across the maps.	7/7 stakeholder roles identified, only n=10 stakeholders identified in a single role across the maps.	7/7 stakeholder roles identified, only n=17 stakeholders identified in a single role across the maps.

product components, sensors and testing, informatics, energy, and raw materials. While connections were found to all roles, any specific stakeholder was typically noted only in one or two roles.

The remaining instances (n=215) included both more general stakeholders, such as generic research stakeholders (n=50, predominantly mentioned as collaborators), as well as a wide range of more specific and distant stakeholders, such as a variety of marine mentions (n=37, predominantly as customers) and funding (n=26, predominantly as supporters).

Discussions and conclusions

Findings reveal that students were able to identify a range of potentially relevant stakeholders to consider in development. However, the role-based analysis also revealed opportunities for additional scaffolding to support considering social and sustainable impact. Diverse actor types were recognized as stakeholders, including that they can act in more than one role, which can create a basis to reframe the challenge from the role perspective of a single stakeholder. Furthermore, a third of stakeholders were unique across the 31 maps, emphasising the value of combining individual perspectives for a more holistic understanding. This holistic understanding is vital in maximising the mutual benefit from stakeholder interactions, which requires methods that make social aspects such as the roles of the stakeholder salient for effective decision-making (Bridoux & Stoelhorst, 2016).

The intentions, values, and goals linked to different roles offer central bonding points for successful reciprocity in potential development collaborations (Freeman, Phillips & Sisodie 2018; Jones, Harrison & Felps 2018), a next step that initial mapping should facilitate. As such, future studies should examine how readily stakeholder identification translates into collaboration intentions, as well as compare the variety of stakeholders in role-prompted and unprompted stakeholder maps. Furthermore, while the current study utilised a practice-based mapping tool as a scaffold, research-based stakeholder role categories could be developed to further support identifying collaboration opportunities in R&D projects. The current study suggests that prompting for a variety of roles can offer a starting point for considering different frames into an innovation ecosystem, helping to identify a broad range of stakeholders.

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References

Boonstra, A., & de Vries, J., 2008. Managing stakeholders around inter-organizational systems: A diagnostic approach. The Journal of Strategic Information Systems, 17(3), 190-201. https://doi.org/10.1016/j.jsis.2008.04.001

Bridoux, F., & Stoelhorst, JW. 2016. Stakeholder relationships and social welfare: A behavioral theory of contributions to joint value creation. Academy of Management Review, 41(2), 229-251. https://doi.org/10.5465/amr.2013.0475

Freeman, R., Phillips, R, & Sisodia, R. 2018. Tensions in stakeholder theory. Business & Society, 59(2). https://doi.org/10.1177/0007650318773750

Jones, T., Harrison, J., & Felps, W. 2018. How applying instrumental stakeholder theory can provide sustainable competitive advantage. Academy of Management Review, 43(3), 371-391. https://doi.org/10.5465/amr.2016.0111

Kojmane, J. & Aboutajeddine, A., 2016. Strengthening engineering design skills of first-year university students under resources constraints. International Journal of Mechanical Engineering Education, 44(2), pp.148-164. https://doi.org/10.1177/0306419016641006

Tallberg, L., García-Rosell, J.C. & Haanpää, M., 2022. Human–animal relations in business and society: Advancing the feminist interpretation of stakeholder theory. Journal of Business Ethics, 180(1), pp.1-16. https://doi.org/10.1007/s10551-021-04840-1

Walther, J., Miller, S. E., & Sochacka, N. W., 2017. A model of empathy in engineering as a core skill, practice orientation, and professional way of being. Journal of Engineering Education, 106(1), 123-148. https://doi.org/10.1002/jee.20159

Theme 4

Re-Thinking for research & innovation

As our world is in a constant flux of change, research and innovation have become the centre of our society. Conversely, educational systems are still based on accumulating and transmitting knowledge, and industries are still centered around institutions and hierarchies. To keep up with the pace of change, we need to re-imagine education and industries for research and innovation. Collectively, the papers in this section emphasize the significance of hands-on learning, real-world collaboration, innovation hubs, multidisciplinary teamwork, and prototyping in shaping the expertise and skills of future professionals, guiding educational institutions and industries in fostering a culture of research and innovation among the next generation of learners.

Dieing et al. explore the benefits of digital fabrication micro-courses, which enhance practical and 21st-century skills in engineering students, aligning to produce change agents. Raty et al. discuss the impact of international product development projects on students' expertise and competencies, highlighting the importance of real-world collaboration in preparing students for the professional world. Mattila et al. delve into the role of innovation hubs as catalysts for innovation and bridges between academia and industry, identifying key themes related to their mechanisms and contributions. Kuikka investigates the development of transferable skills among higher education students through multidisciplinary teamwork, emphasizing themes like effective communication, diversity, and personal and group learning experiences. Kirjavainen et al. examine prototyping activities in industrial innovation, highlighting the importance of personal networks and the challenges in high-technology industrial contexts.

“As our world is in a constant flux of change, research and innovation have become the centre of our society: bright, cheerful, optimistic, hyperrealistic --s 750.”

Image: Midjourney × Valtteri Bade, 2023

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Prototyping in practice – Paths and partners for testing novel industrial product and service ideas

Abstract

Prototyping is a core activity in developing new products, processes, and organisations, to mention a few. This paper describes the prototyping activities of 31 engineering design professionals in a high-technology industrial company, examining the distribution of different types of activities across different phases of development based on thematic interviews. Examining 62 prototyping and testing pathways, we found that most prototyping paths started with the practitioners' own activities, which was also more likely to lead to paths with more prototyping steps than if the first prototyping activity took place with a stakeholder. Overall, the paths were short, indicating a lack of iteration. Both internal and external stakeholders were involved in collaborative prototyping. This collaboration was enabled by personal and unit-level relationships and different stakeholders were involved in different phases of development. Taken together, our results suggest that practitioner attention in prototyping may focus on latter development phases and demonstrate less iteration than what literature might suggest, with opportunities for prototyping highly dependent on personal networks in the high-technology context in the absence of flexible prototyping budgets.

Key words:
Prototyping;
Collaboration;
Idea advancement

Introduction and theoretical background

Product developers often face a need to test ideas and assumptions to make informed design decisions. Extant research has identified a wide array of prototyping tools, methods, and purposes. For example, workflow simulations, storyboards, mock-ups, scaled prototypes, virtual models, AR, and full-scale models (Camburn et al., 2017) are amongst the vast techniques for prototyping, and the COVID-19 pandemic further ushered in digital prototyping practices (Hölttä-Otto et al., 2023). Furthermore, the recent rise in design thinking and service design has further broadened the types of actors and contexts leveraging and exposed to different types of prototyping practices, as prototyping is a central practice in both (Fayard, Stigliani & Bechky 2017; Micheli et al., 2019).

Indeed, research has documented a range of benefits to prototyping. It enhances evaluating, testing, understanding, creating new ideas, and communicating (Lim et al., 2008), helps in active learning (Camburn et al., 2017), and provides support for iteration by encouraging learning through failure in the early phases of development (Micheli et al., 2019). Iterative prototyping correlates with better chances of meeting complex design requirements and generating new ideas (Camburn et al., 2017), as prototypes help in answering questions that arise during a design process (Houde & Hill, 1997). Prototyping in collaboration also has many benefits. It is an effective activity when it comes to sharing knowledge and co-creating with various stakeholders (Bogers & Horst, 2014), testing hypotheses and potential different problem framings (Paton & Dorst, 2011), and allows describing and trying out something that does not yet exist (e.g., Sanders, 2010).

However, sometimes it can be tricky to set the objectives for prototyping through understanding and deciding what to prototype, with whom, and with which techniques (Camburn et al., 2017). Despite the documented benefits, it is unclear to what degree and with whom prototyping is practised in different contexts. Those new to design approach may find it hard to iterate ideas (Rekonen & Hassi, 2018). Even experienced professionals may not take full benefit of the array of methods available - for example, Laakso and Liikkanen (2012) show how structured methods, for e.g., idea generation and rapid prototyping, are used only scarcely amongst creative professionals. The goal of this study is to investigate prototyping in practice, and find out with whom, which methods, and to what extent prototyping takes place in industry.

Methodology and results

The data was collected as a part of a larger research project, where the authors were responsible for planning the data collection, and two of the authors conducted the interviews. Thirty-one semi-structured thematic interviews focusing on critical incidents (Chell, 1998; Flanagan,1954) were conducted with product development professionals developing B2B products and services in an industrial technology company. The interviews focused on advancing ideas and collecting descriptions of varying incidents. The interviewees were asked to describe both well-received and shot-down ideas, instances where they collaborated or where their ideas resulted in filing invention disclosures. They were also asked whether their ideas were tested or prototyped. The interviews lasted an average of 52 minutes and were audio-recorded and later transcribed verbatim.

The interviews were thematically coded to identify recurring patterns in prototyping activities. First, all instances where the interviewees talked about testing or prototyping were tagged in the interview transcripts. Second, these segments were categorised according to the type of stakeholders involved in the activity, the number of prototyping steps described, the type of activity taking place, and the phase of the development process. The analysis resulted in 62 individual prototyping descriptions or paths. For example, the following quote illustrates testing the prototype with a customer in the latter stages of a product development process:

> *"Then we will move on to a plant facility where we have a lot of business otherwise as well. We have these partnering plants where we do a lot of product development in collaboration with them."*

The resulting 62 prototyping paths show that in addition to prototyping by themselves, product development professionals included stakeholders in their prototyping and testing activities

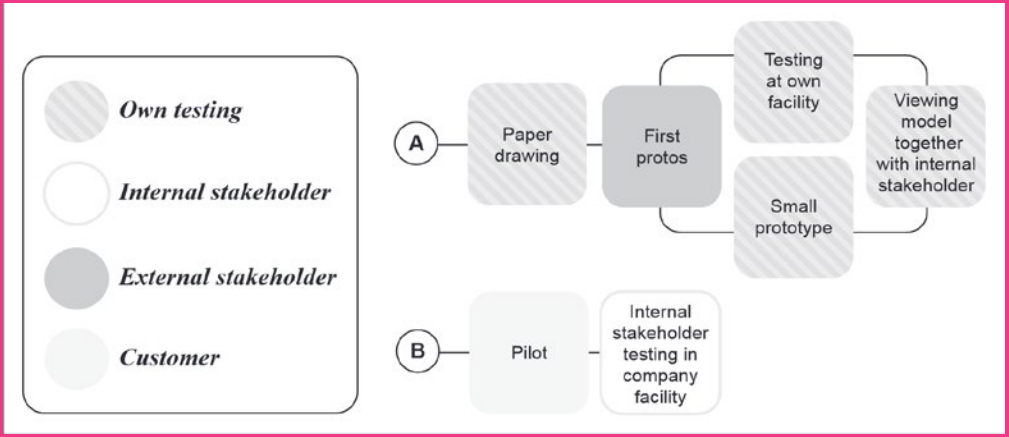

Fig. 1. Two prototyping paths out of the identified 62 paths showing different stakeholders and number of steps.

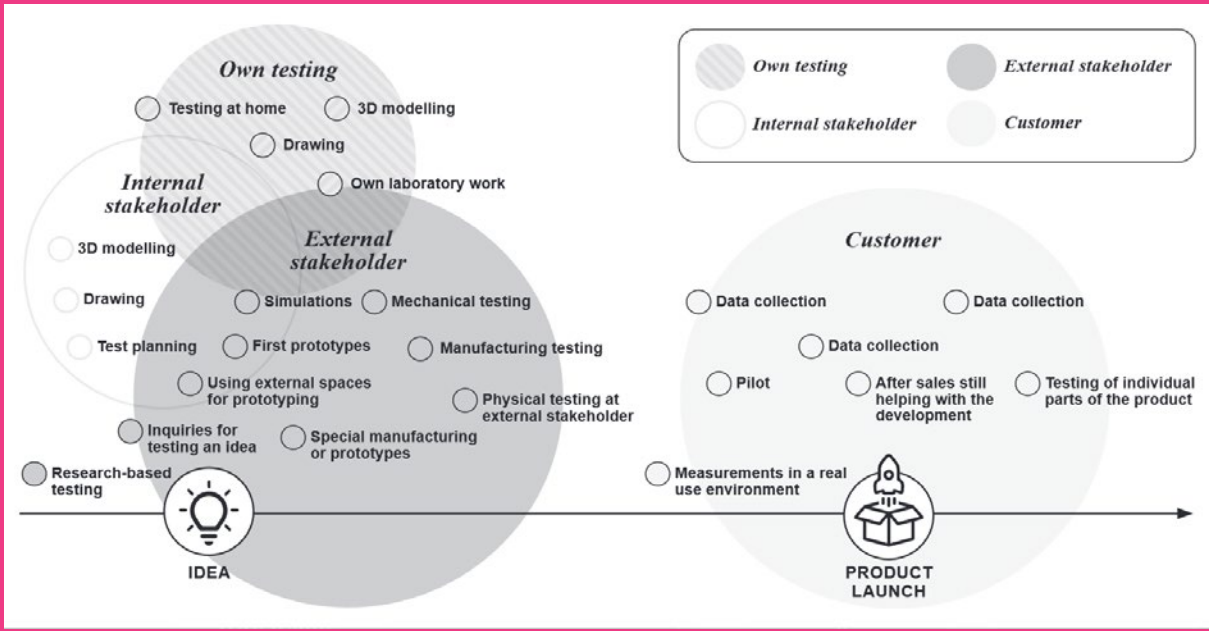

Fig. 2. Timeline displaying how different stakeholders are usually part of different development phases.

in varying stages of the development process. The stakeholder groups found were other internal units or laboratories in the company and external stakeholder groups, including customers, subcontractors and manufacturing suppliers, universities, and consulting companies.

Most of the described prototyping instances were paths of either only one step (n=23, 37%) or two steps (n=19, 31%). Longer iterative prototyping paths were in the minority, with 15 (24%) three-step paths described and only five (8%) paths with four or more steps (see examples in Figure 1).

In most paths (n=33, 53%), the first prototyping activity took place in the unit where the idea was conceived, typically by the interviewees themselves. These prototypes included drawings, 3D-models, testing in a laboratory, 3D-prints, and other types of small-scale testing. When prototyping had started as individual work, it most often continued to a second round of individual prototyping before collaborative prototyping and testing with other units, subcontractors, or customers. Especially real scale, physical, material, or manufacturing prototypes were often described to be only possible with subcontractors and customers. In these cases, the third round most often took place already with customers. Almost all paths with three or more steps started with prototyping by the interviewees.

In other instances, prototyping was immediately started in collaboration with another stakeholder (n=29 paths). In 13 instances (21%), this was an internal stakeholder, while the customer was involved in the beginning in nine (15%) instances and other identified stakeholder groups only in seven (11%) instances. When paths started in collaboration, they were very rarely described to have more than two steps - with only two such paths described, both having started with internal stakeholders.

The way these descriptions of prototyping instances were positioned relative to different development phases (see Figure 2) indicates that prototyping with the customer usually happened closer to the release of the product than other types of prototyping and partnerships. Customer involvement in prototyping was often described in cases where e.g., the first sold deal was the pilot test. Pilot testing was also described as being done in a lab or with subcontractors, illustrating “piloting” having many meanings to the interviewees.

In the early phases of development, the interviewees tested their ideas with the methods available. The early phases often included prototyping and testing mechanical designs with subcontractors and manufacturing suppliers described to be experts in specific areas and, therefore, important collaborators. The company had formed long and strong relationships with many different partners. Testing was also often moved to a customer’s location, where prototyping was described to consist of piloting, gathering data, or testing in a real-use environment. The need for collaboration was described by an interviewee as follows:

> *“Well, at least I would like it if we would have an easy access test laboratory, where one could make some crazy inventions quickly. Of course, it would be preferable, that there would be a 3D-printer that could be used or some tools that could be used to make initial models, like quick and dirty testing, that kind of opportunities would make innovating easier for sure.”*

Discussions and conclusions

How the practitioners perceived and discussed prototyping differed from how the literature discusses prototyping (e.g., Camburn et al., 2017; Lim et al., 2008). The interviewees discussing mostly testing final prototypes or piloting and rarely mentioning low-fidelity prototyping, suggested that often early steps in idea development that are regarded as prototyping activities in literature are either not considered prototyping in the practitioners' minds or then are easily skipped when moving to designing e.g., for production. Most of the prototyping paths had only one or two steps, indicating a lack of iterating in practice. Given research demonstrating iterative prototyping correlating with better chances of having new ideas and meeting the design requirements (Camburn et al., 2017), there may be missed opportunities here in the field, and we suggest that practitioners should pay more attention to early, iterative prototyping.

Second, the results highlight the significance of the personal networks of innovators. Those who had connections to external stakeholders and had collaborated with them in prototyping before turned often to their existing connections. Similarly, interviewees who had experience in in-house prototyping, using the company's laboratory units, or that had strong connections with customers reported turning to them for help. Collaborative prototyping like this supports cross-organizational knowledge sharing and designing on the go (Bogers & Horst, 2013). These paths were described as easy and quite commonly used. Conversely, interviewees lacking pre-existing connections described prototyping and testing to be hard or in some cases even impossible. The importance of networks was further emphasised by an experienced lack of funding in R&D for prototyping and testing, particularly at scale in the expensive industrial technology context. This often led developers to defer fully testing new ideas only at a paying customers' facility, a risky move. As such, examining the interconnections in networks, prototyping practices and risk offers a promising research avenue for further understanding the dynamics of how ideas are advanced in collaboration in organisations.

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References

Bogers, M., & Horst, W. (2014). Collaborative prototyping: Cross-fertilization of knowledge in prototype-driven problem solving. *Journal of Product Innovation Management*, *31*(4), 744-764.

Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., ... & Wood, K. (2017). Design prototyping methods: state of the art in strategies, techniques, and guidelines. *Design Science*, *3*, e13.

Chell, Elizabeth. (1998). "Critical Incident Technique." In Qualitative Methods and Analysis in Organizational Research: A Practical Guide, 51–72. Thousand Oaks, CA: Sage Publications Ltd.

Fayard, A. L., Stigliani, I., & Bechky, B. A. (2017). How nascent occupations construct a mandate: The case of service designers' ethos. *Administrative Science Quarterly*, *62*(2), 270-303.

Flanagan, John C. (1954). "The Critical Incident Technique." Psychological Bulletin 51 (4): 327–58. https://doi.org/10.1037/h0061470.

Houde, S., & Hill, C. (1997). What do prototypes prototype?. In *Handbook of human-computer interaction* (pp. 367-381). North-Holland.

Hölttä-Otto, K., Björklund, T., Klippert, M., Otto, K., Krause, D., Eckert, C., ... & Albers, A. (2023). Facing extreme uncertainty–how the onset of the COVID-19 pandemic influenced product development. *International Journal of Design Creativity and Innovation*, *11*(2), 117-137.

Laakso, M., & Liikkanen, L. A. (2012). Dubious role of formal creativity techniques in professional design. In *DS 73-1 Proceedings of the 2nd International Conference on Design Creativity Volume 1* (pp. 55-64).

Lim, Y. K., Stolterman, E., & Tenenberg, J. (2008). The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *15*(2), 1-27.

Micheli, P., Wilner, S. J., Bhatti, S. H., Mura, M., & Beverland, M. B. (2019). Doing design thinking: Conceptual review, synthesis, and research agenda. Journal of Product Innovation Management, 36(2), 124-148.

Paton, B., & Dorst, K. (2011). Briefing and reframing: A situated practice. *Design studies*, *32*(6), 573-587.

Rekonen, S., & Hassi, L. (2018). Impediments for experimentation in novice design teams. *International Journal of Design Creativity and Innovation*, *6*(3-4), 235-255.

Sanders, E. B.-N., E. Brandt, and T. Binder. (2010). "A Framework for Organizing the Tools and Techniques of Participatory Design." Proceedings of the Participatory Design Conference 2010, Sydney, Australia.

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Creating the conditions for innovation – a case study approach to investigate the functions of an innovation hub

Abstract

Innovation hubs have been gaining popularity in recent literature and practice due to their roles as engines for innovation and bridges between academia and industry. They are set up in various configurations that are context-specific. Nevertheless, these hubs share a common goal of promoting innovation outputs in the long term. Some innovation hubs are closely related to academic institutions; accordingly, they tend to research aspects that drive innovation best practices. At the same time, they cultivate new innovation practices. However, there is a lack of studies analysing research outputs from specific hubs to identify which type of research they do, the topics covered and potential gaps. The mechanisms of an innovation hub, specifically looking at the research they produce, provides an interesting perspective to investigate. In this study we explore the relationship between theory and practice by analysing patterns in 254 research outputs of two selected innovation hubs. Four emergent themes were identified, the most covered topics relating to the innovation process and development activities. A small percentage was related to mindset, values, community and culture, while few works analyse characteristics of space and environment that enable innovation. Given the highly contextual nature of the study, implications are discussed with a primary focus on recommendations for future research.

Key words:
innovation,
front-end innovation,
innovation hub

Introduction

Innovation hubs have been gaining popularity in recent literature and practice (Nnanna et al., 2023). Sometimes called 'living labs' (Leminen et al., 2012), they have been set up in various configurations and contexts: as public sector-based innovation hubs servicing a variety of stakeholders within business settings (Fiore & Rosani, 2018) and in university settings (Youtie & Shapira, 2008). Nevertheless, the general goal of these hubs is to foster innovation outputs through various means, such as facilitating interaction with novel technologies, enabling multi stakeholder collaboration, and providing innovation training on skills like creativity and collaboration (Nnanna et al., 2023).

While setting up an innovation hub is highly context-specific, common elements have been identified that define these spaces. Three core components of innovation hubs typically include a

physical environment, resources and facilitation (Memon et al., 2018). However, given the emergent approach of setting up an innovation hub, the staff members connected to it might make developments through trial and error, relying on existing literature and best practices and adjusting them to their local context. On the other hand, innovation hubs, specifically residing in a university context, enable staff to conduct studies *in vivo*, using the hubs as a fruitful territory for experiments, integrating research and innovation in real-life situations.

Despite the increased scholarly interest towards innovation hubs, relatively little has been published on the interplay between theory and practice in innovation hubs. For example, research has explored elements of spaces that support creativity and innovation without focusing specifically on the context of an innovation hub (Errichiello & Pianese, 2018; Moultrie et al., 2007; Thoring et al., 2019; Vignoli et al., 2018). The lack of direct comparisons between research and practice in such spaces poses an interesting inquiry into the dynamics and evolution of establishing an innovation hub, where best practices are often used as a guideline for the hub's operations. At the same time, new insights and theories may emerge through experiments and iterations, as evidenced in a longitudinal study that looks at the evolution and impact of an idea lab since its conception (Thoring et al., 2018). In addition, an innovation hub residing in a higher education context gives rise to the fertile conditions for exploring this possible virtuous cycle as a scholarly practice is inherently present, and being immersed in the daily practice may naturally spark new research questions.

We set out to examine this question through a case study by investigating the explicit scholarly activities of a network of innovation hubs housed by higher education and research institutions. As the network has grown drastically since 2008, frequent questions have emerged about the methodology of the innovation hub. Despite the hubs being established on similar values and practices, an explicit rule book emerging from literature or practice-based is yet to exist. As a result, this study aims to address the call for common practices and approaches in relation to an innovation hub within a university context by examining the research outputs of two of the most established hubs in the network. Being able to clearly articulate the purpose and core practices can promote higher legitimacy in the eyes of external audiences (Wry et al., 2011). This study is a preliminary attempt to unveil a more nuanced understanding of innovation hub operations with highly contextual insights. Avenues for further research with improved generalisations are discussed at the end of the study.

Method and data

We employed a case study research design to investigate the scholarly insights situated in the innovation hub. Specifically, we used a case study methodology to examine the operations of the innovation hub and its context (Yin, 2009). The case study methodology is particularly relevant for the explorative and descriptive nature of the study. The case in question is an example of a network of innovation hubs within education and research institutions. Identifying themselves as drivers for innovation in their own context, the first innovation hub was established in 2008 and has since spread to 39 institutions worldwide, creating a network of autonomous yet connected innovation hubs. Each hub is based on similar values and practices yet largely influenced by the local context, such as the society and culture, institution, organisational structure and disciplinary influence.

We combined the data set by collecting research outputs from two innovation hubs from the innovation network. Purposive sampling was used to reach the research goal by selecting the most productive sample (Marshall, 1996). A range of factors were considered in determining the sample. Two innovation hubs in the network were selected as they are the longest-standing network members with an active focus on research contribution. Hence, the two hubs would be best placed to provide insights into the evolution of theoretical contributions and practices. Furthermore, both hubs had a high proportion of journal and conference paper outputs. Finally, the number of hubs was limited to two, allowing the authors to develop the methodological approach used in this study and an exploratory approach in the data analysis in preparation for a future larger-scale study.

The research outputs were accessed from an existing repository maintained by the coordinating body of the network. Master's and doctoral theses, book chapters, journal articles and conference articles were included, and the time frame was inclusive of the establishment year of each of the innovation hubs respectively (2008 and 2012 until 2020). In addition, each research output was checked for its topical relevance, with works unrelated to innovation practices discarded. Altogether, 254 research outputs were included in the final data set.

We used an inductive approach in the research analysis (Maykut & Morehouse, 1994) and employed a constant comparative method (Glaser & Strauss, 1967), whereby each research output was selected, compared to other coded outputs and subsequently categorised and coded with similar units (Maykut & Morehouse, 1994). If a research output did not fit any of the existing categories, a new theme was created. During the review process, some themes evolved through renaming and regrouping. If a research output matched several themes, it was multiplied and placed to all matching themes.

Results

There was a distribution of different research outputs, with conference papers being the largest, followed by journals and master's theses, respectively. Figure 1 shows the breakdown of the type of

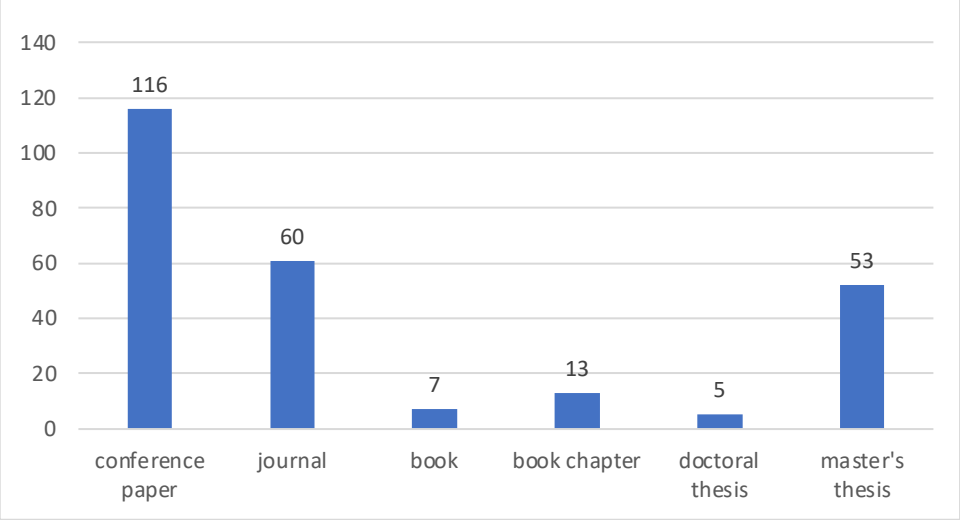

Fig 1: Breakdown of research outputs by the type of contribution.

contribution. Conference paper contributions might be deemed the most suitable output for university employees, striking a balance between theoretical exploration and practice. Master's theses seem to accomplish the same for students, providing a substantial scholarly effort with practical outcomes.

Using inductive coding and analysis, four major themes were identified in the data set. The emerging themes were defined as (a) Space and Environment - as both physical and intangible sites fostering or hindering innovation activities. Specific physical areas were mentioned and explored in relation to activities to encourage engagement, prototyping, and flexible learning spaces. (b) Process - pertained to methodologies and methods, practices, and non-routine problem-solving. A broad set of disciplinary influences were mentioned, such as design, engineering, and business, including mentions of multi, cross and interdisciplinary contexts. In addition, the 'process' theme included explorations of methodologies and isolated studies on a particular phase or a method in a process, such as ideation. (c) Mindset - targeted demonstrators and instructive practices to encourage and reward creativity, experimentation, and novel approaches to foster collaboration. Some of the studies expanded to the literature in psychology, such as the concept of self-efficacy and its role in innovation processes. (d) Community and culture – consisted of targeted events such as showcases, lectures, seminars, demonstrators and social engagements to include both local and international stakeholders to integrate a broader community of practice.

The 'process' category was by far the most recurrent theme, with 183 contributions, followed by 'mindset', 'community & culture' and 'space & environment'. Figure 2 shows the exact numbers for the breakdown. Table 1 shows the breakdown by type of contribution in each theme. All themes had a reasonable distribution of different outputs.

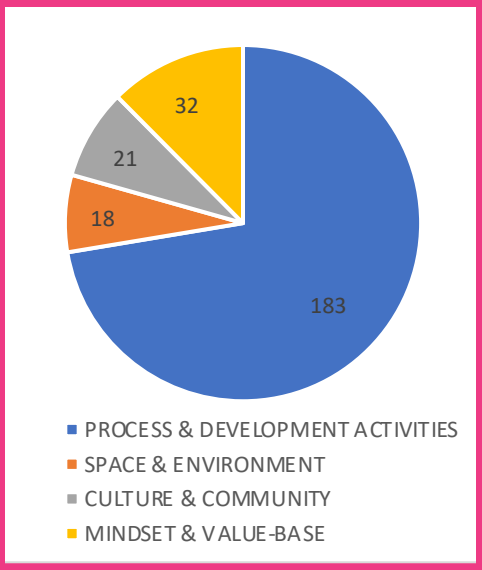

Fig 2: Breakdown of thematic areas.

DISCUSSION AND CONCLUSIONS

The emerging themes in this study correlate with the broader academic literature defining innovation hubs as spaces for education, mentoring, funding, co-working and promoting commercialisation. The analysis defined by the parameters in this study revealed four emerging themes of *Space and Environment*, *Process*, *Mindset* and *Community and Culture*. What perhaps emerges from the results is that innovation hubs and their operative dynamics is highly contextual and equally, the profile and the purpose of the hubs are nuanced. In addition, research into the practices of and activities in the hub was by far the popular topic, implying that the people interacting and working in the hub can either make or 'break' the hub. This finding is somewhat contradictory to the Dul et al. 's perspective who say that literature does not explore how experimentation and innovation takes place in creative spaces (2011). Nevertheless, human-related factors are import-

Tab 1: Breakdown of each theme by type of contribution

Theme	Journal papers	Conference papers	Books	Book chapters	Doctoral thesis	Master's thesis
Process & Development activities	40	90	3	9	4	37
Mindset & Valuebase	13	12	2			5
Community & Culture	6	6	2	3	1	3
Space & Environment	1	8		1		8

ant to complement the interdisciplinary approach to the study of these innovation spaces (Ciaramella et al., 2018). What is not yet clear and requires further analysis with in vivo research is how the practice informs the research and vice versa. Therefore, subsequent investigation is required comparing practice within these hubs benchmarked against the four themes derived from this literature thematic analysis.

We found that the emerging themes accurately represent the contextual nature of the hubs. However, we are not yet clear on whether the practices, programs, and infrastructure underpinned by the four themes are unique just to this study. Hence further investigation of other innovation hubs' outputs of research literature and evidence of practices is required. How to communicate the purpose and process of setting up an innovation hub is currently a circuitous process for the authors, who currently draw on a combination of anecdotal evidence in practice, in situ and qualification by research outputs. We acknowledge there are a multitude of factors regarding innovation hubs and that our categorisation is limited to only two innovation hubs. With the emerging topics of this study, we set to build foundations for a framework and typology to better understand the phenomenon we, as members of innovation hubs, derive research from and work in.

References

Ciaramella, A., Rossi-Lamastra, C., Rovelli, P., & Tagliaro, C. (2018). Who talks about collaborative spaces, how, and why. CERN IdeaSquare Journal of Experimental Innovation, 2(1), 3–7. https://doi.org/10.23726/cij.2018.758

Dul, J., Ceylan, C., & JASPERS, F. (2011). KNOWLEDGE WORKERS' CREATIVITY AND THE ROLE OF THE PHYSICAL WORK ENVIRONMENT. *Human Resource Management*, *50*(6), 715–734. https://doi.org/10.1002/hrm

Errichiello, L., & Pianese, T. (2018). Smart work centers as "creative workspaces" for remote employees. *CERN IdeaSquare Journal of Experimental Innovation*, *2*(1), 14–21. https://doi.org/10.23726/cij.2018.746

Fiore, A., & Rosani, G. (2018). Two questions to ask before you set up an innovation unit. *Harvard Business Review*.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine.

Leminen, S., Westerlund, M., & Nyström, A.-G. (2012). Living Labs as Open-Innovation Networks. *Technology Innovation Management Review*, *2*(9), 6–11. https://doi.org/10.22215/timreview/602

Marshall, M. N. (1996). Sampling for qualitative research. *Family Practice*, *13*(6), 522–525. http://www.ncbi.nlm.nih.gov/pubmed/9023528

Maykut, P., & Morehouse, R. (1994). *Beginning Qualitative Research - a philosophic and practical guide*. The Falmer Press.

Memon, A. B., Meyer, K., Thieme, M., & Meyer, L. P. (2018). Inter-InnoLab collaboration: An investigation of the diversity and interconnection among Innovation Laboratories. *Journal of Engineering and Technology Management - JET-M*, *47*(November 2015), 1–21. https://doi.org/10.1016/j.jengtecman.2017.11.003

Moultrie, J., Nilsson, M., Dissel, M., Haner, U., Janssen, S., & Lugt, R. Van Der. (2007). *Innovation spaces : towards a framework for understanding the role of the physical environment in innovation*. https://doi.org/10.1111/j.1467-8691.2007.00419.x

Nnanna, J., Charles, M. B., Noble, D., & Keast, R. (2023). Innovation Hubs in Australian Public Universities: An Appraisal of Their Public Value Claims. *International Journal of Public Administration*, *46*(2), 133–143. https://doi.org/10.1080/01900692.2021.1993900

Thoring, K., Desmet, P., & Badke-Schaub, P. (2019). Creative space: A systematic review of the literature. *Proceedings of the International Conference on Engineering Design, ICED*, *2019-Augus*(AUGUST), 299–308. https://doi.org/10.1017/dsi.2019.33

Thoring, K., Mueller, R. M., Luippold, C., Desmet, P., & Badke-Schaub, P. (2018). Co-creating an idea lab: Lessons learned from a longitudinal case study. *CERN IdeaSquare Journal of Experimental Innovation*, *2*(1), 30–37. https://doi.org/10.23726/cij.2018.743

Vignoli, M., Mattarelli, E., & Mäkinen, S. (2018). Experimenting with innovation in creative spaces. *CERN IdeaSquare Journal of Experimental Innovation*, *29*(2), 381–400. https://doi.org/10.1287/isre.2018.0794

Wry, T., Lounsbury, M., & Glynn, M. A. (2011). Legitimating Nascent Collective Identities: Coordinating Cultural Entrepreneurship. *Organization Science*, *22*(2), 449–463. https://doi.org/10.1287/orsc.1100.0613

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Sage.

Youtie, J., & Shapira, P. (2008). Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development. *Research Policy*, *37*(8), 1188–1204. https://doi.org/10.1016/j.respol.2008.04.012

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Making skills: how courses on digital fabrication enhance 21st century skills

Abstract

The paper elaborates on critical "design decisions" of a series of digital fabrication micro-courses offered as an optional addition to the full one- or two-semester programs on engineering design. It presents the first results of an evaluation regarding the learning outcomes and 21st-century skills acquired by the students. The evaluation indicates that the courses convey practical making skills and contribute to 21st-century skills like self-efficacy, self-initiative, and learning competence. Therefore, the courses support the overall aim of our learning space to develop our students into so-called "change agents." This result of the work can inspire other universities and design factories to set up their device-training courses similarly to gain this additional benefit.

Key words:
21st-century skills;
course design;
making;
prototyping;
digital fabrication;
challenge-based learning;
makerspace.

Introduction

With inno.space, an innovative learning space was created at the University of Applied Sciences Mannheim, which promotes the students' action competence through its learning offers, design, and furnishing. Students can develop into so-called "change agents" through innovative learning formats such as ME310 (Wiesche et al., 2018; Kohler et al., 2022) and CBI A3 (Thong et al., 2021). In transdisciplinary project teams, they develop concrete solutions for complex challenges. All courses follow the pedagogical concept of "Challenge Based Learning" (Charosky et al., 2018) and teach 21st-century skills (OECD, 2019) such as self-efficacy, learning competence, and ambiguity competence. One of the core methods is prototyping, which allows students to transform their ideas into tangible and graspable demonstrators. Access to digital fabrication devices (e.g., 3D printers) is an essential part of the space to enable students to realise these demonstrators. Students acquire the ability to operate digital fabrication devices through micro-courses.

Initially, these micro-courses on digital fabrication were conducted exclusively in presence. We realised it took much work to consider the different levels of prior knowledge and the associated learning speeds.

For this reason, a series of micro-courses was designed for students to acquire basic skills in operating a device through blended learning. These micro-courses are optional and can be chosen by the students, depending on the status and focus of the project as well as their individual experience, which

varies depending on their progress in studies and professional background. The micro-courses thus take up the "challenge and affordance character" of the room architecture and self-directed learning paradigm, which is spatially supported by group worktables and a makerspace and thus already call for prototyping through its design and promotes initiative and performance competence (Galaleldin et al., 2016).

Based on our challenge-based courses, the question arose of how to empower students in prototyping while using learning methods that can promote 21st-century skills. For this reason, we defined the following essential goals in creating the courses: G1) acquiring basic skills in digital fabrication while promoting, G2) self-efficacy, G3) self-initiative, and G4) learning competence.

Theoretical background

Modern education is challenged to enrich the next generation of engineers with 21st-century skills in addition to their technical knowledge (OECD, 2019; Kirchner et al., 2017). These include creativity, resilience, and flexibility (Byers et al., 2013). It is widely accepted that university makerspaces encourage engineering students' creativity, digital and fabrication skills that they can later apply in their work environments (Wilczynski, 2015; Forest et al., 2014). As such, makerspaces contribute to the encouragement of dedicated 21st-century skills with this skill transfer. In addition, teaching formats such as design thinking (Koh et al., 2015; Luka, 2019), challenge-based learning (Papageorgiou et al., 2021), and project-based learning (Rajendra & Patil, 2020; Ravitz et al., 2012; Shaw, 2018) have proven to promote 21st-century skills.

While there is no longer any dispute about the effectiveness of makerspaces and course formats in terms of 21st-century skills in general, there are still no results on whether smaller course formats for mastering digital fabrication devices are also able to promote self-efficacy, self-initiative, and learning competence through their course structure and design.

We were seeking an opportunity to change our micro-courses to a blended concept. In contrast to classical classroom training, blended learning concepts offer the advantages that everyone can learn at their own pace and, therefore, build up a better understanding. In addition, tasks can be repeated as often as desired, thus ensuring that the learning objective is achieved (Trapp, 2006; Rao, 2019).

While investigating the influence of our changed micro-course design on 21st-century skills, we focus on self-efficacy, self-initiative, and learning competence: Self-efficacy describes the inner conviction of successfully coping with challenging situations out of personal strength. In comparison, self-initiative is defined as the ability to motivate yourself to work on goals and tasks. Learning competence is the ability and willingness to self-direct learning and supervise learning progress. (Bacigalupo et al., 2016; Ehlers, 2019).

Course design

Our solution describes a blended learning approach to learn the handling of digital fabrication devices (3D printer, laser cutter, and vinyl cutter) through micro-courses in the context of challenge-based courses. The micro-courses are divided into three parts: The first two are accessible via the learning platform and can be worked on independently. Students learn about the device and create digital models as a requirement for the third part. Students can choose between:

- Personalising a model: Students create and personalise the given model from the tutorial,
- Creative design: Students create their own models. Therefore, they have to transfer the tutorial instructions to their own model.

For the third part, students appear in presence to finish and "produce" their workpiece as represented in the digital model on the device. They receive support from course coaches and can clarify any questions.

Structuring of the three-part micro-course content in the learning platform [processing time from the student's point of view]:

i. Self-study: Basic information on the subject areas is given through written material, pictures, and fact sheets. [~1h]

ii. Video tutorials: Three short videos introduce students to digital fabrication software. They are guided to create a digital model for a given design independently. Completing the digital model is a prerequisite to taking the third part of the micro-course. Students submit their digital model through the learning platform and choose an in-class date. [~2h]

iii. Face-to-face appointment: On-site, students can discuss their digital model with a learning coach, clarify questions, and put the device into operation. As a result, students can take home their personalised fabricated objects. [~1h]

We assume the following course design details (DD) meet the objectives (G1-G4) mentioned above.

- DD1: Learning content can be worked autonomously and independent of the location at one's own pace and depending on the level of knowledge (G2, G4).
- DD2: Digital model can be personalised, which has a motivating effect (G3).
- DD3: Students decide which devices to learn and when (G2, G3, G4).
- DD4: The micro-course short duration lowers the participation hurdle (G3).
- DD5: Submission of the created digital design (G1).

Method and data

A total of 113 students participated in the micro-courses. Of these, 29 took a challenge-based course, and 84 students completed the micro-courses voluntarily outside of a full course as an

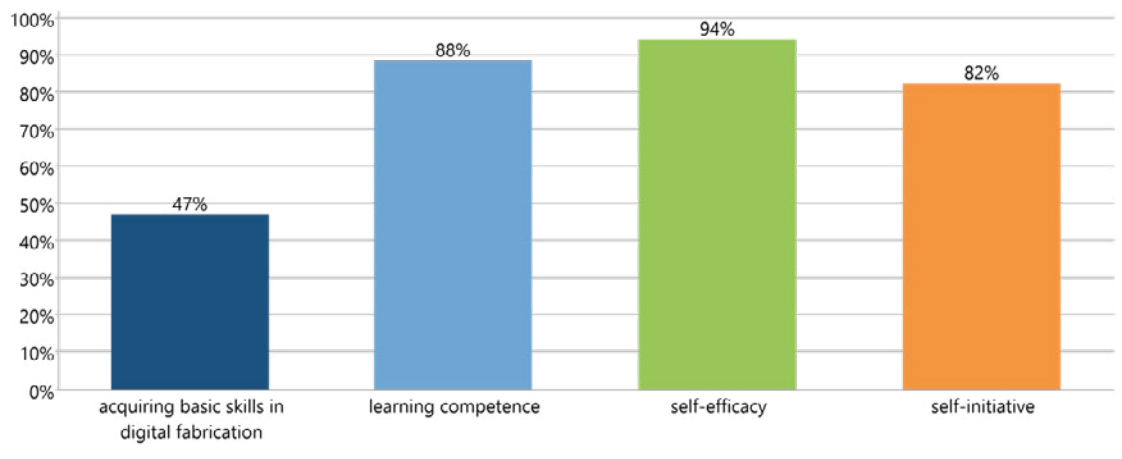

Fig. 1. Percentages of 21st century skills demonstrated in 3D printing interviews.

extracurricular skill. The data for this study were collected from this pool of students through 41 semi-structured interviews conducted in both semesters of the academic year 2022/2023. The students voluntarily participated in the interviews at the end of the third part of the course design. All interviews were conducted and recorded in person. The interview included questions about the general flow of the course and qualitative open-ended questions.

All interviews were transcribed verbatim, and all information that could be traced back to an interviewee was anonymized. The answers to the interview questions underwent a content-structured content analysis, according to Kuckartz (Kuckartz, 2012). Qualitative content analysis, according to Kuckartz, is an iterative method. For this reason, the analysis runs three times in order to refine and improve the results.

Results

Our current results show that all students who have completed the micro-courses have demonstrated during the face-to-face portion that they can operate the appropriate device by fabricating their digital models using the device (DD5, G1). Many students submitted personalised digital models; some even had creative designs (DD2, G3). 92 out of 113 students submitted their own creative design (shown in Tab. 1).

Tab. 1. Percentages of students' personalised and own creative designed model submissions divided into the three micro-courses.

	3D Printer	Laser cutter	Vinyl cutter
Total number of submissions	58	31	24
Percentage of students handed in a personalised model	18,99 %	19,34 %	16,66 %
Percentage of students handed in their creative digital design	81,01 %	80,66 %	83,33 %

In addition, we observe that self-management is working (DD3, G2, G3, G4). In the summer semester of 2022, 19 students took one of our challenge-based courses while all completed at least one of the micro-courses. In the winter semester of 2022/2023, 8 out of 11 completed a micro-course (G3). All participating students submitted a digital design. We conclude that students took the courses and understood the content (G4).

Furthermore, to the quantitative analysis, a qualitative analysis was carried out as already mentioned under Method and data. Here, the interviews of the participants of the 3D printing courses were analysed according to Kuckartz. The coding and evaluation of these interviews provided evidence of teaching 21st-century skills, as seen in Figure 1. Self-efficacy was identified in interviews with 26 out of 28 (approx. 94%).

Several text segments were found in the 3D printing interviews indicating 21st-century skills (G1-G4). One per skill is listed here as a representative example (Tab. 2). Each text segment has been translated analogously from German.

Discussions and conclusions

The quantitative analysis showed that the course teaches students how to operate digital fabrication equipment (G1). However, the qualitative content analysis showed that only 47% of the interviewees unveiled this ability. One possible explanation is that students may not feel self-confident yet to verbalise this skill after a micro-course. Also, the quantitative number of own creative digital designs shows us that the course design promotes self-initiative (G3) and learning competence (G4). The qualitative content analysis strengthened this finding. Circumstantial evidence supporting self-efficacy emerged in the qualitative content analysis (G2). It also became apparent during the interviews that the initial motivations for converting the micro-courses to a blended learning format proved to be justified. The course participants appreciate the advantages, such as free time management, that this format provides.

Tab. 2. Representative citation from the analysed 3D printing interviews for each code.

Code	Representative citation
Acquiring basic skills in digital fabrication (G1)	"We know how to make shapes. We know how to do construction lines; we have a standard on how to do circles."
Self-efficacy (G2)	"I say, if, I would fail, then at Fusion, but that would be then probably also a training thing. So, let's say the basic understanding is there now and if I then wanted to do a special rounding off or whatever, then you would just have to look at it again. But I mean, that's not what an introductory course is for, that you can design perfectly."
Self-initiative (G3)	"And then you can just try it more pleasant and even if there is a problem: On YouTube you can actually find something for everything and then you can just try it out often and then just, if you have questions, you can just write to you."
Learning competence (G4)	"I think I actually liked online better, especially because it is, let's say, interdisciplinary here. The probability is quite high that we have different previous knowledge. And I would say that someone always gets bored, either those for whom it is too fast or those for whom it is too slow. The way it is now, you can divide it up a bit more freely so that you do sometimes more of one thing and sometimes another."

This research aims to inspire other universities and design factories to set up device training courses so that 21st-century skills such as self-efficacy, self-initiative, and learning competence can be promoted in addition to the skills to operate the devices. In doing so, educators can act as a catalyst beyond their field of expertise, equipping today's generation with essential skills they need for their professional and personal lives.

Acknowledgements

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References

Bacigalupo, M., Kampylis, P., Punie, Y., & Van den Brande, G. (2016). EntreComp: The entrepreneurship competence framework. *Luxembourg: Publication Office of the European Union*, *10*, 593884.

Byers, T., Seelig, T., Sheppard, S., & Weilerstein, P. (2013). Its role in engineering education. *The Bridge*, *43*(2), 35-40.

Charosky, Guido, et al. "Challenge based education: an approach to innovation through multidisciplinary teams of students using Design Thinking." 2018 XIII Technologies Applied to Electronics Teaching Conference (TAEE). IEEE, 2018.

Ehlers, Ulf. -D., Kellermann, Sarah A. (2019): Future Skills - The Future of Learning and Higher education. Results of the International Future Skills Delphi Survey. Karlsruhe

Forest, C. R., Moore, R. A., Jariwala, A. S., Fasse, B. B., Linsey, J., Newstetter, W., ... & Quintero, C. (2014). The Invention Studio: A University Maker Space and Culture. Advances in Engineering Education, 4(2), n2.

Galaleldin, M., Bouchard, F., Anis, H., & Lague, C. (2016). The impact of makerspaces on engineering education. Proceedings of the Canadian Engineering Education Association (CEEA).

Kirchner, J., Klier, J., Lehmann-Brauns, C., Winde, M. (2017). Future Skills: Which skills are lacking in Germany. *Stifterverband* für die Dt. *Wissenschaft*.

Koh, J. H. L., Chai, C. S., Wong, B., & Hong, H. Y. (2015). Design thinking for education: Conceptions and applications in teaching and learning. Springer.

Kohler, K., Kaiser, P., Dieing, C., Walter, M., Wrobel, D. (2022) „The smaller siblings of ME310 – Commonalities and differences between three courses on interdisciplinary and international user-centric innovation" 1st Design Factory Global Network Research Conference: Designing the Future. Designing the Future.

Kuckartz, U. (2012). Qualitative Inhaltsanalyse. Methoden. Praxis, Computerunterstützung, 3, 166-169. ISO 690.

Luka, I. (2019). Design thinking in pedagogy: Frameworks and uses. European Journal of Education, 54(4), 499-512.

Organisation for Economic Co-operation and Development (OECD). (2019). OECD future of education and skills 2030: OECD learning compass 2030.

Papageorgiou, K., Hassi, L., Bragós Bardia, R., Charosky Larrieu-Let, G., Leveratto, L., & Ramos Castro, J. J. (2021). Prototyping the future of learning: reflections after seven iterations of Challenge-Based Innovation (2014-2020). CERN IdeaSquare Journal of Experimental Innovation, 5(1), 5-10.

Rajendra, S., & Patil, S. P. K. (2020). Project based learning: an innovative approach for integrating 21st century skills. Journal of Engineering Education Transformations, 33(4).

Rao, V. (2019). Blended Learning: A New Hybrid Teaching Methodology. Online Submission, 3(13).

Ravitz, J., Hixson, N., English, M., & Mergendoller, J. (2012, April). Using project based learning to teach 21st century skills: Findings from a statewide initiative. In American educational research association conference, Vancouver, Canada (Vol. 16).

Shaw, R. L. (2018). Using project-based learning to cultivate 21st century skills in STEM education. ProQuest Dissertations And Theses; Thesis (Ed.D.)--Lamar University - Beaumont, 2018.; Publication Number: AAT 13422541; ISBN: 9780438806887 Dissertation Abstracts International, Volume: 80-06(E), Section: A.; 79 p.

Thong, C., Cotoranu, A., Down, A., Kohler, K., & Batista, C. (2021). Design innovation integrating deep technology, societal needs, radical innovation, and future thinking: a case study of the CBI A3 program. CERN IdeaSquare Journal of Experimental Innovation, 5(1), 32-39.

Trapp, S. (2006). Blended learning concepts-A short overview. In CEUR Workshop Proceedings (Vol. 213, pp. 28-35). Wiesche, M., Uebernickel, F., Byler, E., Garcia-Cifuentes, J. P., Suzuki, S., Vignoli, M., ... & Krcmar, H. (2018). Teaching innovation in interdisciplinary environments: Toward a design thinking syllabus.

Wilczynski, V. (2015). Academic maker spaces and engineering design. In 2015 ASEE Annual Conference & Exposition (pp. 26-138).

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Transferable skills from multidisciplinary teamwork: insights from 5 years of courses

Abstract

This study examines the impact of multidisciplinary teamwork on the development of transferable skills among students in higher education. Inter-and multidisciplinary learning is known to enhance critical thinking, problem-solving abilities, and effective communication. The study collects survey data (n=129) from undergraduate students participating in a multidisciplinary teamwork-based project course over a five-year period. Thematic analysis of the responses uncovered recurring themes that highlight the significance of effective communication, clear roles and responsibilities, leveraging diversity, addressing challenges, and fostering personal and group learning experiences. The insights derived from this paper contribute to a deeper understanding of the impact of multidisciplinary teamwork on students' educational trajectories and can be used to inform pedagogical practices and equip students with competencies sought by employers.

Key words:
multidisciplinary teamwork, collaborative learning, transferable skills

Introduction

Multidisciplinarity in higher education is valued for enhancing student learning outcomes and preparing them for the complexities of the real world. Collaborative learning enhances critical thinking, problem-solving skills, and effective communication. While the benefits of both multidisciplinarity and collaborative learning are widely acknowledged, the connection between multidisciplinarity, teamwork, and the creation of transferable skills remains understudied. An enhanced understanding of this connection can inform pedagogical practices and provide evidence-based strategies to maximise the benefits of multidisciplinary teamwork for students.

This study aims to address the following research question: *What transferable skills do students gain from multidisciplinary teamwork?* By analysing survey data collected over five courses, this study aims to identify the transferable skills that students carry forward from their multidisciplinary teamwork experiences.

Theoretical background

Inter- and multidisciplinary learning involves integrating knowledge and perspectives from various disciplines to address complex problems. Experiences incorporating multicultural and diverse conditions provide a unique space for learning at the border of disciplinary, cultural and social groups (Klaassen 2018). Interdisciplinary majors enhance enjoyment of reading, expression in writing, and engagement in cognitive activities (Lattuca et al, 2017). According to Johnson, Johnson, and Stanne (2017), engaging students in collaborative projects that integrate knowledge from diverse disciplines enhances critical thinking, problem-solving skills, and effective communication.

Collaborative learning is an educational approach that involves groups of learners working together to solve a problem, complete a task, or create a product. Multidisciplinary teamwork enables students to learn not only from interaction with the course content but also from interaction with team members of other disciplines (van Breukelen, de Vries, and Schure 2017). Collaborative learning typically results in higher achievement, supportive relationships, and improved psychological health when compared with individualistic efforts (Laal & Ghodsi, 2012).

Transferable skills are competencies that can be applied across different contexts and disciplines, and are increasingly being sought by employers. These skills include being a team player, self-motivation, communication, problem-solving, and being proactive (McGunagle & Zizka, 2020). Scott (2015) refers to a similar set as "employability skills", including critical thinking, problem-solving, communication and collaboration, creativity and innovation, and information, media and technology literacy. Andrews and Higson (2018) emphasise the importance of developing transferable "soft" skills through collaborative learning experiences as they prepare students for the demands of the modern workforce.

Method and data

This study gathered survey data from undergraduate students enrolled in a multidisciplinary project course focused on product design for additive manufacturing. The course was conducted at Aalto University, a public research university in Finland comprising six schools. The participants' distribution across schools was as follows: Engineering (24%), Electrical Engineering (22%), Science (21%), Business (11%), Chemical Engineering (7%), and Arts, Design & Architecture (6%). 9% of participants did not disclose their affiliated school. The gender distribution was 74% male and 26% female. This elective course had no prerequisites and was open to students at all academic levels.

Students worked in multidisciplinary teams of 5 people for 12 weeks to ideate, design, and pitch a 3D-printed product. One of the intended learning outcomes of the course involved students using their own disciplinary knowledge to solve open-ended problems in a teamwork setting. This was supported by mixed method teaching from a multidisciplinary teaching team, including regular expert, user and peer feedback, and classes and workshops on teamwork and communication skills.

The voluntary survey, administered electronically, asked course participants to reflect on their learning about working in a group during the project. The data covered five years (2018-2023, excluding 2020 due to the pandemic), with a total of 129 anonymized responses. Thematic analysis was employed to identify recurring patterns in the responses. Surveys were selected as the data collection method in order to efficiently collect data over the 5 year period, with open-ended questions being used to capture nuanced reflections. Thematic analysis was chosen as the data analysis tool for its ability to uncover recurring themes, thus enhancing understanding of acquired knowledge, skills, and attitudes.

Results

Analysis revealed six major themes: scheduling and planning, diversity and team composition, communication and collaboration, roles and responsibilities, challenges and conflict resolution, and learning and growth. As each respondent discussed an average of 2.6 themes, the percentages don't add up to 100%.

Scheduling and planning

"In the next project, I would set a weekly fixed meeting from the beginning so that everyone holds this time free for the project. We had huge problems to find a time to meet all together, as we all have different course schedules." Respondent #70, 2022.

Tab. 1. Recurring themes in student responses to "What did you learn about working in a group from this project that you will carry into your next group experience?"

Theme	Respondents	%
Scheduling and planning	46	36%
Dividing work	20	16%
Working efficiently	10	8%
Regular team meetings	8	6%
Diversity and team composition	45	35%
Leveraging strengths	16	13%
Communicating expectations	11	9%
Recognizing own disciplinary expertise	9	7%
Communication and collaboration	45	35%
Listening	10	8%
Voicing opinions	9	7%
Using communication & collaboration platforms/tools	7	5%
Roles and responsibilities	34	27%
Team leadership	13	10%
Taking responsibility & initiative	9	7%
Teambuilding	8	6%
Challenges and conflict resolution	21	16%
Compromise, adaptability	7	5%
Varying levels of motivation	5	4%
Dealing with freeloaders	2	2%
Learning and growth	24	19%
Developing teamwork skills	17	13%
Learning from others	2	2%
Other	6	5%

Scheduling and planning is highlighted as a crucial factor for successful group work in 36% of the responses. Dividing work clearly by assigning tasks and responsibilities (16%), finding ways to work together effectively (8%), and having regular team meetings (6%) were seen as ways to ensure progress.

Diversity and team composition

"I learned that heterogeneity within a group can be very fruitful. All of us were from different countries, different mother tongues and big differences in age. First I was not sure how this will work out. But due to good guidance within the course it went very well I would say." Respondent #17, 2018.

Working with multidisciplinary and multicultural teams was seen as a key learning in 35% of responses. Diverse backgrounds, skills, and perspectives contributed to the success of the team. Leveraging individual strengths and resources (13%), as well as communicating expectations (9%), and recognizing personal disciplinary expertise via working with others (7%) were highlighted.

Communication and collaboration

"Everybody's different in the way we think and do things. Listening and communication is key." Respondent #15, 2018.

Effective communication emerged as a critical factor for successful group work in 29% of responses. Clear and straightforward communication, both in person and online, was emphasised. Active listening (8%), voicing opinions (7%), and utilising collaboration tools and platforms (5%) were seen as valuable for sharing tasks.

Roles and responsibilities

"I learned that a team needs some kind of coordination and a team leader. In the beginning we decided to keep working without any hierarchy and in the end it was hard to get meetings and work going, since usually nobody had any ideas or had not given the assignments any thought. My takeaway from this is that, as I think I became a de facto project manager/leader, I can be a team leader in future projects, even when I do not have the best skills in the team for the particular task." Respondent #61, 2021.

Clear roles within the team (27%) and taking responsibility and initiative (7%) are mentioned as necessary for quality work. Some teams reported a need for a dedicated project manager or team leader to ensure smooth functioning (10%), while others found success in decision-making using voting and democracy. Proactive engagement (7%) and team-building activities (6%) were mentioned as beneficial.

Challenges and Conflict Resolution

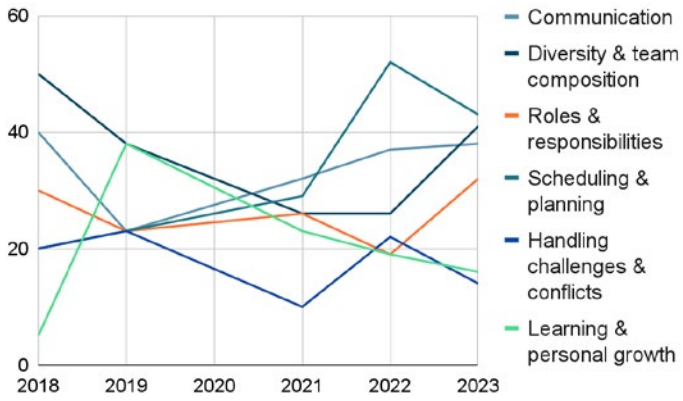
"I've learned to set some boundaries for myself. Before I would have let people take advantage of me and my work effort but not anymore. I also learned that it's important to build good relationships with the group members." Respondent #46, 2021

Participants acknowledged challenges related to differing levels of motivation (4%), freeloaders (2%), and conflicting ideas or opinions in 16% of the responses. Addressing these challenges, maintaining motivation, resolving conflicts, and establishing a supportive team environment were considered important. Compromise and adaptability (5%) and setting personal boundaries were emphasised.

Learning and Growth

"The biggest thing I learned was that if you put yourself out there you can achieve anything." Respondent #56, 2021.

Responses highlighted personal and group learning experiences throughout the project (19%). Participants mention developing teamwork and collaboration skills (13%), understanding the importance of effective teamwork, and acquiring new technical or organisational skills (2%). Reflecting on the experience, participants express a desire to apply their learnings in future group work situations.



Looking at the trends response themes over five years, some patterns can be recognized. Mentions of communication, roles and responsibilities, and addressing challenges and conflicts stay relatively stable with a 13-15% difference between the highest and lowest mentions per year, while diversity and team composition, scheduling and planning, and learning and growth fluctuate more with differences between 24-33%. This suggests a dynamic approach to multidisciplinary teamwork, potentially influenced by changes in team composition, teaching methods, and other environmental factors. One potential influencing factor could be the shift from on-site teaching in 2018-2019 to fully online in 2021, hybrid online/on-site in 2022, and returning to fully on-site in 2023 due to the pandemic, impacting communication, scheduling, and conflict management.

Discussions and conclusions

In conclusion, this study highlights the transferable skills gained through multidisciplinary teamwork in higher education. Effective communication, clear roles and responsibilities, leveraging diversity, addressing challenges, and fostering personal and group learning emerged as key themes. These skills enhance critical thinking, problem-solving, and collaboration, preparing students for the complexities of the real world. Educators can use these findings to design pedagogical practices that maximise the long-term benefits of multidisciplinary teamwork.

The limitations of this study include potential sample bias due to the specific course and voluntary participation, reliance on self-reported data with subjective perceptions and potential response bias, a small sample size (n=129) that limits generalizability, and the lack of follow-up assessments or external validation of the identified transferable skills. These limitations highlight the need for caution when interpreting the findings and suggest avenues for future research to address these limitations.

Future research in the field of multidisciplinary teamwork and transferable skills could explore the long-term impact of such experiences on professional success outcomes or investigate effective pedagogical strategies for skill development within multidisciplinary teamwork settings.

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References

Andrews, J., & Higson, H. (2008). Graduate employability, 'soft skills' versus 'hard' business knowledge: A European study. Higher Education in Europe, 33(4), 411-422.

Johnson, D. W., Johnson, R. T., & Stanne, M. B. (2017). Cooperative learning methods: A meta-analysis. University of Minnesota.

Klaassen, R. G. (2018). Interdisciplinary education: a case study. European Journal of Engineering Education, 43(6), 842-859

Laal, M., & Ghodsi, S. M. (2012). Benefits of collaborative learning. Procedia-Social and Behavioral Sciences, 31, 486-490.

Lattuca, L. R., Voigt, L. J., Fath, K. Q., Hodge, E. R., & Lange, R. E. (2017). Examining the impact of interdisciplinary programs on student learning. Innovative Higher Education, 42, 337-353.

McGunagle, D., & Zizka, L. (2020). Employability Skills for 21st Century STEM Students: The Employers' Perspective. Higher Education, Skills and Work-Based Learning.

van Breukelen, D. H., de Vries, M. J., & Schure, F. A. (2017). Concept Learning by Direct Current Design Challenges in Secondary Education. International Journal of Technology and Design Education, 27(3), 407-430.

Scott, C. L. (2015). The Futures of Learning 3: What Kind of Pedagogies for the 21st Century. Education Research and Foresight Working Papers, UNESDOC Digital Library.

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Developing expert knowledge by international product development project

Abstract

Higher education has the challenge and responsibility to educate good professionals. Cooperating with companies is important for students to gain first-hand knowledge of skills required in worklife. This study investigates students' perceptions of expert knowledge and skills development in an international product development project course organised by inno.space Design Factory Mannheim and HAMK Design Factory. The interviews of student perceptions early in the course and during the end of the course uncover students' expectations of the course and how their expert knowledge and skills developed during the course.

Key words:
Expert knowledge;
design factory;
product development project

Introduction

Higher education has the challenge and responsibility to educate good professionals (Collado et al., 2022). International and interdisciplinary product development collaboration with industry provides an authentic learning setting (Nachtigall et al., 2022) for students to develop relevant skills required by the industry. Yet, there are very few studies (Mikkonen et al., 2018; Collado et al., 2022; Figueiredo et al., 2022; Lahdenperä et al., 2023) that directly address students' skill development in interdisciplinary product development projects for companies.

The context of this study is an international product development project organised by inno.space Design Factory Mannheim and HAMK Design Factory. Häme University of Applied Science (HAMK) has approximately 8000 students and is organised into three types of units: Schools, Research Units, and a Design Factory. The role of HAMK Design Factory is to organise international and interdisciplinary courses involving students from different schools and international partners, including Design Factory Global Network and the Regional University Network – European University. HAMK Design Factory also develops and conducts research on student learning experiences, university-industry collaboration and design-based education, the educational concept applied at HAMK.

Mannheim University of Applied Sciences (HSMA) is composed of nine faculties. Inno.space, the Design Factory Mannheim, is part of the Computer Science faculty, and offers approximately 5400 students from all faculties interdisciplinary and international challenge-based courses in collaboration with global networks as well as local cooperation partners from industry, business, and society. In addition, scientific research is conducted to explore future skills, passion-based learning, and prototyping-methods.

Since design-based education and challenge-based courses tend to cultivate more skills demanded in the worklife, this study investigates students' expectations and perceptions of skills development in working to solve authentic challenges of companies. The research is guided by the following research questions: 1) What are students' expectations for an international product development project? 2) How do the students perceive skills development during the international product development project? and 3) What are the future skills according to the students?

Theoretical background

The 21st Century skills framework is often used to describe skills needed in worklife. 21st Century Skills are understood as skills that young people or students need in balancing and succeeding during their student life and worklife. The core of these skills is divided into three categories: learning and innovation skills, life and career skills, and literacy skills (Rotterham & Willingham 2010; Gonzáles-Peréz & Ramírez-Montoya 2022; Fandino 2013). Learning and innovation skills include critical thinking, creativity, communication, and collaboration skills. The development of critical thinking, collaboration, and communication has been found difficult to achieve in traditional teacher-centred learning environments (Fisher & Newton, 2014; Tynjälä, 1999). According to Tynjälä (1999) one of the most important challenges to university pedagogy is developing teaching methods that integrate formal, theoretical knowledge and more informal, practical knowledge, as well as the development of meta-cognitive and self-regulatory knowledge, which can be achieved by student-centred approaches. Student-centred approaches include problem-based learning, project-based learning, challenge-based innovation, and design-based education (Figueiredo et al., 2022; Lahdenperä et al., 2022; Joore et al., 2022; Vignoli et al., 2021; Tynjälä, 1999).

Following the aforementioned student-centred approaches, some previous studies have been conducted on students' skills development in product development project courses organised at Aalto Design Factory, UPV

Design Factory and HAMK Design Factory (Mikkonen et al., 2018; Collado et al., 2022; Figueiredo et al., 2022; Lahdenperä et al., 2023).

In a previous study on product development projects at Aalto Design Factory, the perceived significance of socio-behavioural interpersonal skills was highlighted, in which teamwork, multidisciplinarity, and communication skills formed the largest categories of student-reported learning outcomes (Mikkonen, et al. 2018). In a recent survey on product development project students, communication with multidisciplinary teams was the most prominent skill that students considered developing during the course (Figueiredo et al., 2022). In UPV Design Factory, the students perceived that teamwork and leadership, time planning, analysis and problem solving, application and practical thinking, effective communication, innovation, creativity and entrepreneurship were the soft skills that developed most by participating in Design Factory projects (Collado et al., 2022). A previous study on HAMK Design Factory product development project course suggested that students can develop their innovation capabilities already in an eight-week course (Lahdenperä et al., 2023). The results of the study also showed that working in interdisciplinary teams and solving authentic product development challenges supported students in constructing and applying knowledge, as well as collaboration and communication (Lahdenperä et al., 2023).

Method and data

The data was collected by interviews with students participating in an international product development project that was organised from February 2023 to June 2023. The students worked in international and interdisciplinary teams to solve four product development challenges provided by companies in Finland and Germany. Each team included three students from HAMK and three students from HSMA. The project started with 24 students in total, 6 students working on each challenge.

The first interview round was conducted early in the project, and all the 24 students participated in the interviews. The second interview round was conducted at the end of the project in June, and 23 students participated in the interviews. In the first interview round, we inquired students' reasons why did they choose the course and what were their expectations for the course. In the second interview round, we inquired if their expectations were met, did they learn something new, and were they surprised by something during the course. We also asked about the students' opinions on future skills, and how an international product development project could support learning future skills.

Results

From the first round of interviews, we uncovered the main reasons why the students have chosen an international product development project (iPdP) course and what were their expectations of the course. The results of the interviews help to understand what kind of skills the students wish and expect to learn. The

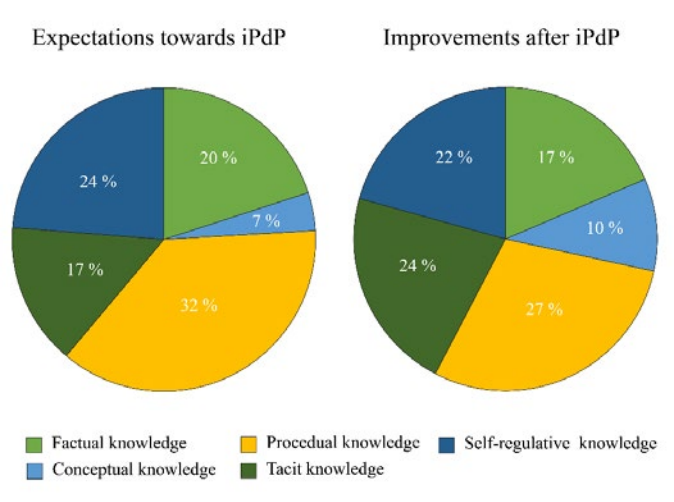

Fig. 1. Expectations of an international product development project compared to expert knowledge that have improved by participating in iPdP.

reasons for selecting an international product development course are illustrated in Table 1.

Tab. 1. Reasons for choosing and applying for an international product development project.

Reason	Answers
Internationality	15
Attractiveness	11
Supports studies	9
Multidisciplinarity	5
Future skills	5
Hands-on, not theory based	5
Creativity	4

We categorised the responses based on the frequency of certain expressions recurring in the interviews. The most frequent category included internationality, where students were talking about a trip to Finland or Germany. The second most frequent category was attractiveness that included sayings such as: "sounds cool", and "wow factor". Third most frequent category was supporting studies that included e.g., "thesis opportunity", and "opportunity to learn about prototyping".

Concerning the expectations towards iPdP and how students perceived improvements after iPdP we categorised student responses in Figure 1 based on identified expert knowledge components (Tynjälä, 1999).

For participating in the iPdP, the most often mentioned improvements to procedural knowledge included multicultural teamwork, communication skills, and technical skills. In terms of meta-cognitive and self-regulative knowledge, common responses were personal growth, time management, and flexibility-related issues.

The last part of the interviews deals with future skills students perceived as important. Most answers in Table 2 were rather self-evident, like problem solving, teamwork, and presentation skills. Interpersonal skills occurred often in the responses, e.g., as "…trustworthiness, kindness", "understanding and respecting others", "Based on the course topic, I feel mastering emotional intelligence and digital literacy are skills that will help me to stay relevant and thrive in the future."

Under theoretical skills we categorised answers like "Know where and how to get information and how to spread information", "technical skills, everything is moving quickly forward", and "Fundamental skills based on your occupation".

Tab. 2. What are the future skills that need to be learned in the future?

Future skills	Answers
Interpersonal skills	11
Theoretical skills	11
Teamwork	9
Problem solving	5
Communication	5
Technical skills	5
Presentation skills	3
Time management	3
Flexibility	3

Discussions and conclusions

The iPdP course offers students an international and interdisciplinary learning environment where students work in mixed teams to solve authentic product development challenges of industry partners. The internationality of the course was indicated by 60% of the students as the reason why they chose the course, with almost 50% of the students joining because they perceived the course as attractive. 20% of the students indicated multidisciplinarity, future skills and the hands-on approach as the reason why they chose the course.

Results highlight that although students' expectations on future skills development were not the main reasons for choosing the iPdP course, according to student perceptions, they did, however, develop during the course. Aligned with the theory of expert knowledge (Tynjälä, 1999), students perceived developing in factual knowledge, conceptual knowledge, procedural knowledge, tacit knowledge, and self-regulative knowledge during iPdP, which indicates that solving authentic problems in international and interdisciplinary teams helped students to develop sought after future skills and 21st Century Skills.

The research was limited to one international product development project course. There is a need to expand research also to other course implementations. In addition, linking 21st Century skills to European skills could bring a deeper understanding of the topic.

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References

Collado López, M. F., Villalonga Grañana, I., Giménez Carbó, E., & Gómez Martín, M. E. (2022). The UPV Design Factory. What is it good for?. In Towards a new future in engineering education, new scenarios that european alliances of tech universities open up (pp. 1892-1897). Universitat Politècnica de Catalunya.

Fandino, Y.J. (2013). 21st Century Skills and the English Foreign Language Classroom: A Call for More Awareness in Colombia. Gist Education and Learning Research Journal. No 7, Nov 2013, p. 190-208.

Figueiredo, S., Ganoo, A., Eriksson, V., & Ekman, K. (2022). Future-ready skills development through Experiential Learning: perceptions from students working in multidisciplinary teams. CERN IdeaSquare Journal of Experimental Innovation, 6(2), 12-19.

Fisher, K., & Newton, C. (2014). Transforming the twenty-first-century campus to enhance the net-generation student learning experience: Using evidence-based design to determine what works and why in virtual/physical teaching spaces. Higher Education Research & Development, 33(5), 903-920.

Gonzaléz-Peréz, L.I., Ramiréz-Montoya, M.S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. Sustainability. Vol 14, Issue 3.

Joore, P., Björklund, T., Thong, C., & Zancul, E. D. S. (2022). Co-creating the future through design-based education in innovation hubs. CERN IdeaSquare Journal of Experimental Innovation, 6(2), 1-3.

Lahdenperä, J., Jussila, J., Järvenpää, A-M., Jumisko-Pyykkö, S. 2023. Developing students' innovation capability through interdisciplinary product development projects for industry. 1st Design Factory Global Network Research Conference 'Designing the Future'5-6 October 2022.

Lahdenperä, J., Jussila, J., Järvenpää, A. M., & Postareff, L. (2022). Design Factory--Supporting Technology Students' Learning of General Competences through University-Industry Collaboration. LUMAT: International Journal on Math, Science and Technology Education, 10(1), 127-150.

Mikkonen, M., Tuulos, T., & Björklund, T. (2018). Perceived long term value of industry project-based design courses: Alumni reflections from two decades of the Product Development Project. DS 91: Proceedings of NordDesign 2018, Linköping, Sweden, 14th-17th August 2018.

Nachtigall, V., Shaffer, D. W., & Rummel, N. (2022). Stirring a secret sauce: a literature review on the conditions and effects of authentic learning. Educational Psychology Review, 34(3), 1479-1516.

Rotherham, A.J., Willingham, D.T. (2010). "21st Century" Skills: Not New, but a Worthy Challenge. American Educator, vol 34, p.17.20.

Tynjälä, P. (1999). Towards expert knowledge? A comparison between a constructivist and a traditional learning environment in the university. International journal of educational research, 31(5), 357-442.

Vignoli, M., Balboni, B., Andreea, C., Dosi, C., Noemi, G., Kirstin, K., ... & Christine, T. (2021). Inspiring the future change-makers: Reflections and ways forward from the Challenge-Based Innovation experiment. CERN IdeaSquare Journal of Experimental Innovation, 5(1), 1-4.

Theme 5

Sustainability: exploring diverse futures

Design-driven methods and mindsets are increasingly used as effective tools to address sustainability challenges. These approaches rely on humanistic approaches such as Human-Centered Design, Positive Design, and Universal design and have in common the idea of analyzing how the consequences of design choices propagate across inter-individual, social, and environmental layers. The papers belonging to this subtheme can be classified by the level at which research is done and the methods applied. Aue et al. work at the national level, investigating how the design ecosystem in Singapore is an engine for implementing progressive policies. Rafael and Peñafort investigate trust building in realizing sustainability initiatives in urban systems characterized by poor governance. Poulaillon's and Galiot's papers can be positioned at the community level.

The first paper analyzes how an innovation hub integrated UN Sustainable Development Goals into innovation projects and practices, while the second presents a case study on how social entrepreneurship students developed social innovations and addressed wicked problems through design thinking. Kuukka et al. and Coturanu et al. study how sustainability can be integrated into design-driven pedagogy. Coturanu et al. present a design-driven pedagogic approach to empower students to solve complex global problems. Kuukka et al. presents a Design+Sustainability card deck to prioritize sustainability in decision-making throughout the design process. Mardsen et al. work at the product level and present a methodology to design sustainable footwear.

“Design-driven methods and mindsets are increasingly used as effective tools to address sustainability challenges: White background, Violet and light purple, Microscopical image --c 40 --s 750.”

Image: Midjourney × Valtteri Bade, 2023

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Important discoveries for a better nation by design

Abstract

Singapore's design-driven development aims at enhancing lives and strengthening its identity as a smart nation. This study defines design in the context of Singapore, its impact, and its role. It employs a multi-method approach, including a literature review, interviews, and international benchmarking of Singapore's design ecosystem. The study reveals key aspects of the local design ecosystem, including the roles of design and designers, ecosystem conditions, the perception of the industry, and the potential of design. Design stands central to Singapore's progressive policies. While a vibrant ecosystem exists, opportunities remain for exploration and enhancement to address future challenges and realise ambitious goals.

Key words:
Design;
Design Education;
Future Designers.

Introduction

Design plays and continues to play an integral role in shaping the physical, cultural, economic, and social landscape of Singapore since its independence in 1965 (Kawakami, N. 2016). No aspects of the country, from its rapid economic growth to its international standing or its multi-racial, multi-cultural populace are happenstance – design, and human-centeredness are embedded within multiple major policies and initiatives championed by the Singapore government, such as the Creative Industries Development Strategy (CIDS) and the Design 2025 Masterplan (DesignSingapore Council, 2016). Fast-forwarding five decades later from independence, Singapore was designated as a City of Design in 2015 and joined the UNESCO Creative Cities Network (UCCN), a clear and powerful endorsement of design's importance in Singapore to develop a creative culture, a loveable city, and a sustainable future for its citizens (DesignSingapore Council, 2021).

With the discipline of design playing such a critical role in Singapore's past, present, and future, ensuring the future readiness of the local design ecosystem is critical to continue harnessing the power of design for its people and as a nation (DesignSingapore, 2019). While there are examples of analyses for design policies published by different countries around the world, there is a clear lack of a comparative review with emerging design cities like Singapore in regards to the local definition of design, the intended outcomes of design in policy-making, and the wider conditions of local design ecosystems. In light of the expanding role of design and the new challenges designers are tackling, a critical review and potential revision of the definition of design, as well as a comprehensive analysis of the local design landscape, including the role design plays in Singapore, are identified as key gaps to cover.

This is the starting point and motivation for a 3-phase landscape study, with the first phase being conducted between January and June of 2021. The study aims to conduct an in-depth analysis of the Singapore design ecosystem, understand the role of designers and design education in the Singapore context, and identify key challenges as well as opportunities for Singapore, its design, and design education ecosystem. This paper provides an overview of the key findings of the first phase of the study, focusing on the definition, impact, and role of design in the Singapore context.

Theoretical background

In an era marked by disruptive and multifaceted transformations, the interconnectedness and complexity of our world give rise to a host of challenges and opportunities on societal and economic fronts (Den Ouden, E. 2012). These challenges span a wide spectrum, encompassing issues like aging populations, the climate crisis, resource scarcity, pandemics, and global inequalities. At the heart of these transformations lies the potential for design and designers to play a pivotal role in facilitating the essential changes that can generate value for individuals, organizations, and the planet as a whole (Spitz, R., Böninger, C., Schmidhuber, S., & Frenkler, F. 2021).

Richard Buchanan's ground-breaking concept of the 'Four Orders of Design' serves as a lens through which we observe the increasing complexity of challenges that the field of design is embracing (Buchanan, R. 1992). As global dynamics drive disruptive shifts, design, its practitioners, and educators confront a moment of introspection and redefinition, illustrated by their intense engagement with the future of design education. This study aligns with two significant global research projects that explore the path of design education: the "IF Design Foundation Whitebook Designing Design Education" and "Rethinking Design Education" by the Design Lab at the University of California in collaboration with IBM's Global Design Group. These studies are dedicated to deciphering how designers can be well-prepared to handle the growing responsibilities of design, including the necessary skills, abilities, and ways of thinking.

The main aim of this investigation is to explore the role of design and designers in the setting of Singapore, learning from examples around the world. Singapore's design landscape is profoundly shaped by its distinctive cultural, historical, and geographical context, cultivating a distinctive design language and ecosystem (Zhuang, J. 2012). Moreover, Singapore's historical and contemporary status as a polyglot and interdisciplinary hub for knowledge exchange, cultural discourse, and commercial transactions further embellishes its design ecosystem (DesignSingapore Council & Ministry of Information, Communications and Arts Singapore, 2009).

Considering this complex background, understanding the bigger picture of how design is influenced by Singapore's national, cultural, and societal context becomes crucial. The scope of design now covers a wider range of domains, including strategic design, urban design, service design, and user experience design. This extended conception reflects Singapore's strategic dedication to using design as a tool for both economic advancement and societal progress (DesignSingapore Council, 2019).

Nevertheless, a comprehensive analysis and assessment of Singapore's design ecosystem in relation to the global landscape remains conspicuously absent. Furthermore, a comparative lens has not been turned toward other emerging and established design hubs across the globe. This research aims to fill this gap by investigating how Singapore uses design to create policies and how design affects its people, economy, and culture. In this mission, it is important to understand Singapore's unique approach to design to establish the foundation for creating a robust approach to teaching design in the country.

Method and data

Between January and June of 2021, a qualitative, multi-method research approach was deployed to conduct the first phase of a 3-phased design landscape study. The approach consists of a systematic literature review of local and international reports (annual, research, technical, project, etc.), working papers, government design strategy policies, white papers, and academic journal articles. The international literature review includes analyses of publicly available grey literature from aspiring international design cities in countries such as India and China in APAC, Latvia and Estonia in Europe, and Brazil in the Americas, as well as from established international design cities in countries such as South Korea and Australia in APAC, UK, Denmark and the EU region in Europe, and USA and Canada in Americas (see Table 1).

In parallel, qualitative research in the form of 24 in-depth interviews is conducted with design thought leaders, both new/aspiring and established design practitioners, design employers in small-medium enterprises (SMEs), multinational corporations (MNCs), and the public sector, design educators, and other stakeholders of the Singapore Design Ecosystem. These interviews are conducted to understand the overall conditions of the design ecosystem in Singapore. The participant profiles range across different types of organizations, roles, and years of experience, covering a broad selection of design disciplines, such as image-making, object-making, place-making, and experience-making, as defined by the Design Singapore Council (DesignSingapore Council, 2019).

Last but not least, a cross-comparative analysis is carried out to compare and analyse the insights gathered from the local and international literature review against the rich qualitative insights gathered from stakeholders in the Singapore design ecosystem (See Figure 1). From this comparison, key insights about the local context, the role, and the impact of the design ecosystem and designers are established, as well as a comprehensive and holistic understanding of the definition of design in Singapore versus international examples.

Results

The insights from qualitative interviews and strategic desk research enabled the study to examine and refine the definition of 'design' in the local context and understand the local design ecosystem, its unique drivers, potential, and challenges.

Definition of Design in Singapore

As a baseline for the study, a clear definition of 'design' in the context of Singapore must be established. Insights from qualitative interviews with actors in the local ecosystem are distilled to define design in the local context. A literature review of local and international design policy papers and other design research publications allows to extract key descriptors of design, common patterns, and unique local definitions.

The team cross-analyses the findings of the interviews with the comparative desk research. This analysis leads to a distilled definition of 'design' for the Singapore context.

"Design is a practice-based, strategic approach for problem-framing and -solving that employs empathy in order to create impact (e.g., social, behavioural, psychological, emotional, economic, cultural, environmental, etc.). It creates tangible output, drives innovation, and shapes a nation's identity." Based on this definition, further qualitative research is conducted to explore the roles of design and designers within the conditions of the local design ecosystem. The most relevant findings are:

Roles of Designers in Singapore

Designers increasingly work in non-design contexts such as healthcare, finance, or public service. Hence, designers must be able to make sense of the world outside of design (Design Council United Kingdom, 2010). Additionally, along with industry needs, a designer's skillset is constantly evolving (Meyer, M. W., & Norman, D. 2020). These insights highlight that design education must prepare designers for a rapidly changing environment, new roles, and challenges. However, design education in Singapore, and internationally, is struggling to adapt with the necessary speed (Meyer, M. W., & Norman, D. 2020).

Conditions of the Design Ecosystem in Singapore

Singapore actively utilizes design as a driver for its national identity (Lee Hsien Loong, 2018). This can be seen in policies such as the Creative Industries Development Strategy (Ministry of Communications and Information Singapore 2002) and the Design 2025 Masterplan (DesignSingapore Council, 2016). Although Singapore is actively proliferating design across the public and private sectors, it remains a risk-averse and result-oriented environment. Such an environment can limit experimentation and vibrancy in the design ecosystem.

Perception of Design in Singapore

Large organizations across sectors, such as banking, finance, or healthcare, transform to be more design-driven and user-centric. Yet decision-makers in local SMEs still lack appreciation for the transformative power of design, leading to a lack of investment (time and money) in design.

Tab. 1. Titles of design policy papers and academic papers from Singapore and internationally

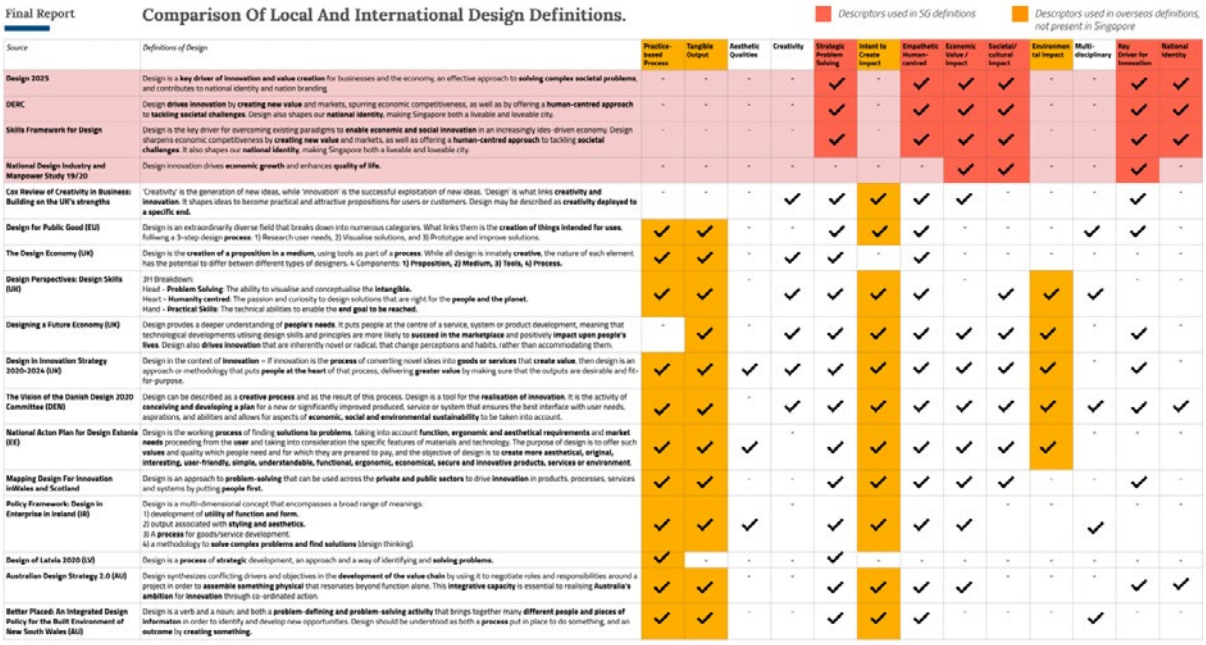
No.	Name of Publication
1	Design 2025
2	DERC
3	Skills Framework for Design
3	National Design Industry and Manpower Study 19/20
4	Cox Review of Creativity in Business: Building on the UK's strengths (UK)
5	Design for Public Good (EU)
6	The Design Economy (UK)
7	Design Perspectives: Design Skills (UK)
8	Designing a Future Economy (UK)
9	Design in Innovation Strategy 2020-2024 (UK)
10	The Vision of the Danish Design 2020 Committee (DEN)
11	National Acton Plan for Design Estonia (EE)
12	Mapping Design For Innovation in Wales and Scotland (UK)
13	Policy Framework: Design in Enterprise in Ireland (IR)
14	Design of Latvia 2020 (LV)
15	Australian Design Strategy 2.0 (AU)
16	DIA Design Education Policy 2014 (AU)
17	Better Placed: An Integrated Design Policy for the Built Environment of New South Wales (AU)
18	The History and Future of Japan's Design Policy 2008 (Japan)
19	Cool Japan, Creative Industries, and Diversity 2019 (Japan)
20	Seoul Design Survey 2009 (Korea)
21	Design, Economic Development, and National Policy: Lessons from Korea 2004 (Korea) Policy: Lessons from Korea
22	The Challenges and Transformation of Design Education in Contemporary China 2018 (China)
23	Barriers to Strategic Design 2017 (China)
24	Viewpoint Yongxiang Lu on China's Design and Innovation Policy 2016 (China)
25	Comparative Study of industrial design undergraduate education in China and USA 2020 (China)
26	National Design Policy 2011 (India)
27	Lessons from Asia: South Korea and China 2010 (South Korea, China)
28	Design 2025

The Potential of Design in Singapore

Singapore's design policies are described as ahead of other international cities due to the prominent role design plays as a driver for innovation and economic growth (Spitz, R., Böninger, C., Schmidhuber, S., & Frenkler, F. 2021). Yet Design is a relatively new practice in Singapore. Such a seeming lack of design tradition can also be seen as the ability to break new ground, as compared to more established design hubs. Based on this legacy, Singapore has untapped potential to establish its own flavor of design – system-centric, community-centric, and collaborative.

Discussions and conclusions

This study unveils opportunities for innovative practices and significant implications for the broader design ecosystem and education. Design education institutions play a pivotal role in



Final Report

Comparison Of Local And International Design Definitions.

Descriptors used in SG definitions

Descriptors used in overseas definitions, not present in Singapore

Source	Definitions of Design	Practice-based Process	Tangible Output	Aesthetic Qualities	Creativity	Strategic Problem Solving	Intent to Create Impact	Empathetic Human-centred	Economic Value / Impact	Societal/ cultural Impact	Environmental Impact	Multi-disciplinary	Key Driver for Innovation	National Identity
Design 2025	Design is a **key driver of innovation and value creation** for businesses and the economy, an effective approach to **solving complex societal problems**, and contributes to national identity and nation branding.	-	-	-	-	✓	-	✓	✓	✓	-	-	✓	✓
DERC	Design **drives innovation** by **creating new value** and markets, spurring economic competitiveness, as well as by offering a **human-centred approach** to **tackling societal challenges**. Design also shapes our **national identity**, making Singapore both a liveable and loveable city.	-	-	-	-	✓	-	✓	✓	✓	-	-	✓	✓
Skills Framework for Design	Design is the key driver for overcoming existing paradigms to **enable economic and social innovation** in an increasingly ides-driven economy. Design sharpens economic competitiveness by **creating new value** and markets, as well as offering a **human-centred approach** to tackling **societal challenges**. It also shapes our **national identity**, making Singapore both a liveable and loveable city.	-	-	-	-	✓	-	✓	✓	✓	-	-	✓	✓
National Design Industry and Manpower Study 19/20	Design innovation drives **economic growth** and enhances **quality of life.**	-	-	-	-	-	-	-	✓	✓	-	-	✓	-
Cox Review of Creativity in Business: Building on the UK's strengths	'Creativity' is the generation of new ideas, while 'innovation' is the successful exploitation of new ideas. 'Design' is what links **creativity and innovation**. It shapes ideas to become practical and attractive propositions for users or customers. Design may be described as **creativity deployed to a specific end.**	-	-	-	✓	✓	✓	✓	✓	-	-	-	✓	-
Design for Public Good (EU)	Design is an extraordinarily diverse field that breaks down into numerous categories. What links them is the **creation of things intended for uses**, following a 3-step design **process**: 1) Research user needs, 2) Visualise solutions, and 3) Prototype and improve solutions.	✓	✓	-	-	✓	✓	✓	-	-	-	✓	✓	-
The Design Economy (UK)	Design is the **creation of a proposition in a medium**, using tools as part of a **process**. While all design is innately **creative**, the nature of each element has the potential to differ between different types of designers. 4 Components: **1) Proposition, 2) Medium, 3) Tools, 4) Process.**	✓	✓	-	✓	✓	-	✓	-	-	-	-	-	-
Design Perspectives: Design Skills (UK)	3H Breakdown. Head - **Problem Solving**: The ability to visualise and conceptualise the **intangible.** Heart - **Humanity centred**: The passion and curiosity to design solutions that are right for the **people and the planet.** Hand - **Practical Skills**: The technical abilities to enable the **end goal to be reached.**	✓	✓	-	✓	✓	✓	✓	-	✓	✓	✓	-	-
Designing a Future Economy (UK)	Design provides a deeper understanding of **people's needs**. It puts people at the centre of a service, system or product development, meaning that technological developments utilising design skills and principles are more likely to **succeed in the marketplace** and positively **impact upon people's lives**. Design also **drives innovation** that are inherently novel or radical, that change perceptions and habits, rather than accommodating them.	-	✓	-	✓	✓	✓	✓	✓	✓	✓	-	✓	-
Design in Innovation Strategy 2020-2024 (UK)	Design in the context of **innovation** – if innovation is the **process** of converting novel ideas into **goods or services** that **create value**, then design is an approach or methodology that puts **people at the heart** of that process, delivering **greater value** by making sure that the outputs are desirable and fit-for-purpose.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	-
The Vision of the Danish Design 2020 Committee (DEN)	Design can be described as a **creative process** and as the result of this process. Design is a tool for the **realisation of innovation**. It is the activity of **conceiving and developing a plan** for a new or significantly improved produced, service or system that ensures the best interface with user needs, aspirations, and abilities and allows for aspects of **economic, social and environmental sustainability** to be taken into account.	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
National Acton Plan for Design Estonia (EE)	Design is the working **process** of finding **solutions to problems**, taking into account **function, ergonomic and aesthetical requirements** and **market needs** proceeding from the **user** and taking into consideration the specific features of materials and technology. The purpose of design is to offer such **values** and quality which people need and for which they are prepared to pay, and the objective of design is to **create more aesthetical, original, interesting, user-friendly, simple, understandable, functional, ergonomic, economical, secure and innovative products, services or environment.**	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	-	-	-
Mapping Design For Innovation inWales and Scotland	Design is an approach to **problem-solving** that can be used across the **private and public sectors** to drive **innovation** in products, processes, services and systems by putting **people first.**	✓	✓	-	-	✓	✓	✓	✓	✓	-	-	✓	-
Policy Framework: Design in Enterprise in Ireland (IR)	Design is a multi-dimensional concept that encompasses a broad range of meanings: 1) development of **utility of function and form.** 2) output associated with **styling and aesthetics.** 3) A **process** for goods/service development. 4) a methodology to **solve complex problems and find solutions** (design thinking).	✓	✓	✓	-	✓	✓	✓	✓	-	-	✓	-	-
Design of Latvia 2020 (LV)	Design is a **process** of **strategic** development, an approach and a way of identifying and **solving problems.**	✓	-	-	-	✓	-	-	-	-	-	-	-	-
Australian Design Strategy 2.0 (AU)	Design synthesizes conflicting drivers and objectives in the **development of the value chain** by using it to negotiate roles and responsibilities around a project in order to **assemble something physical** that resonates beyond function alone. This **integrative capacity** is essential to realising **Australia's ambition** for **innovation** through co-ordinated action.	✓	✓	-	-	✓	✓	✓	✓	-	-	-	✓	✓
Better Placed: An Integrated Design Policy for the Built Environment of New South Wales (AU)	Design is a verb and a noun: and both a **problem-defining and problem-solving activity** that brings together many **different people and pieces of information** in order to identify and develop new opportunities. Design should be understood as both a **process** put in place to do something, and an **outcome** by **creating something.**	✓	✓	-	-	✓	✓	✓	-	-	-	✓	-	-

Fig. 1. Comparison of local and International Design Definitions.

nurturing the next generation of designers, contributing to Singapore's and the region's design landscape. By adopting a broader definition of design and integrating interdisciplinary approaches and mindsets, design education equips students with skills, capabilities, and knowledge to address evolving societal challenges. Furthermore, the local design ecosystem, characterized by few rigid structures and historical confines, possesses a unique potential to shape its own region-specific culture. It leverages its regional diversity and rich history as strengths, incorporating them into a multidisciplinary approach for both regional and international collaborations.

Yet, the study has limitations.

- The study has a time limit. Evolving societal, cultural, and economic dynamics could impact the relevance of the findings. It's advisable to conduct ongoing, regular, and comparative analyses.
- The outcomes shared are just part of the larger research study. Upcoming papers will explore design education, contrasting local and global institutions and suggesting effective teaching methods across the learning journey.

In closing, Singapore has demonstrated that design can significantly contribute to envisioning a nation's future trajectory, utilizing design as a national competitive strategy. Despite being ahead in local design policy compared to numerous other markets, the local design ecosystem still has room for growth.

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References

Buchanan, R. (1992). Wicked Problems in Design Thinking, Design Issues, 8(2): pp. 5-21.

Den Ouden, E. (2012). Innovation design: Creating value for people, organizations and society (p. 196). London: Springer.

DesignSingapore Council (2016). Design 2025 Singapore by Design. https://designsingapore.org/wp-content/uploads/2022/04/Design2025Masterplan_v2.pdf

DesignSingapore Council (2019). Charting the future of design education. https://designsingapore.org/wp-content/uploads/2022/06/DERC_Report_v2_updatedJune2020.pdf

DesignSingapore Council (2021). The Loveable Singapore Project Report. https://www.designsingapore.org/ initiatives/loveable-singapore-project.html

DesignSingapore Council, & Ministry of Information Singapore, Communications and Arts (2009). Strategic Blueprint of the DesignSingapore initiative. https://designsingapore.org/wp-content/uploads/2022/06/Dsg_II_Strategic_Blueprint-1.pdf

Design Council United Kingdom (2010). Multi-disciplinary design education in the UK. https://www.designcouncil.org.uk/fileadmin/uploads/dc/Documents/multi-disciplinary-design-education.pdf

Kawakami, N. (2016). Singapore by design—Singapore's new design strategy for 2025. Axis: world design journal, (181), 90-94.

Lee, H.L. (2018). Singapore: Prime Minister's Office. https://www.pmo.gov.sg/Newsroom/pm-lee-hsien-loong-sutd-ministerial-forum

Meyer, M. W., & Norman, D. (2020). Changing design education for the 21st century. She Ji: The Journal of Design, Economics, and Innovation, 6(1), 13-49.

Ministry of Communications and Information Singapore (2002). Creative Industries Development Strategies.

Montréal World Design Summit (2017). Montréal Design Declaration.

Spitz, R., Böninger, C., Schmidhuber, S., & Frenkler, F. (2021). Designing Design Education: White Book on the Future of Design Education. Hanover: If Design Foundation.

Zhuang, J. (2012). Independence: The History of Graphic Design in Singapore Since the 1960s. Design Society.

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Acting locally on global challenges: harnessing design thinking and the pedagogy of place-based learning

Abstract

The United Nations Sustainable Development Goals present a complex challenge for college students to address. This study illustrates a pedagogical approach targeting the Clean Water and Sanitation Goal. Leveraging the concept of university campuses as 'living labs', we created a course to introduce design thinking principles among first- and second-year students, using place-based pedagogy. The course centered on the 'right-to-know water quality' challenge, prompting students to harness advanced technology for solutions. The distinctive features of the course include a narrowly defined problem scope, an interdisciplinary learning environment, access to advanced technology, and utilization of the university's natural resources, like its pond. To assess the effectiveness of this approach, reflections were gathered from 22 students and analyzed using content analysis. The results revealed students' insights into various dimensions of the water quality issue, encompassing social, environmental, technological, and legal factors. A recurring theme was the role of effective communication. Our findings suggest that this integrated pedagogical approach enables students to grasp the critical issue of public access to water quality information. By introducing such experiential learning early in students' academic journeys, universities can nurture environmentally conscious leaders, amplifying their capability to address global challenges effectively.

Key words:
design thinking;
place-based experiential learning;
sustainable development goals;
technology,
pedagogy.

Introduction

Drawing inspiration from the concept put forth by Thomas Berry in "The Great Work," (Berry, 2011), we recognize that higher education, amongst society's institutions, has the unique ability, and therefore responsibility, to be an agent of positive change. In addition, we are inspired by the concept of university campuses serving as 'living labs' or 'living systems,' as discussed by Evans et al. (2015) and Lipschutz et al. (2017) in the context of experiential learning (Kolb, 1984). Building on these perspectives, we have developed a course centred on problem-based learning that applies place-based pedagogy to teach design thinking principles while tackling the United Nations Sustainable Development Goals: Clean Water and Sanitation (UN SDG #6).

Spanning 14-weeks the course empowers students to themselves become agents of positive change early in their academic journeys. We equip them with essential skills and knowledge to solve the complex problem of right-to-know water quality through the use of technology. In the process, they also fulfil academic requirements in computing, civic engagement, and public values.

Inspired by established problem-based 'capstone' courses such as Challenge Based Innovation A3 (Thong et al., 2021)

and Product Development Project (Figueiredo et al., 2022), and informed by the design thinking curricula models (Wiesche et al., 2018), our course is distinctive in two ways. Firstly, the course stands as an introductory 'cornerstone' experience in design thinking and innovation tailored for first- and second-year students across all academic disciplines. Secondly, our pedagogical approach taps into the university's internal assets and expertise to create a rich experiential learning context. Our approach encompasses four integrated features: a narrowly defined problem scope; a learning environment that combines interdisciplinary expertise; advanced technology typically reserved for advanced and graduate students; and a 'living lab' utilising the university's campus pond, and campus drinking water infrastructure which is regulated as a "community water system" under federal law.

Theoretical background

Problem-based learning is a pedagogical approach that immerses students in real-world challenges to facilitate their learning (Barrow and Tamblyn, 1980). This approach has proved effective in developing students' competencies to solve complex problems akin to those presented by the UN SDGs. However, students often struggle with the analysis of multifaceted issues like the UN SDGs. We, therefore, narrow the problem scope to focus on a specific design challenge within UN SDG #6: the imperative to ensure the public's right of access to information about water quality. This "right-to-know" is often professed rhetorically by public officials but has yet to be guaranteed in practice (Kolar et al., 2009). In our course, students are tasked with developing a technology-based solution to tackle this challenge. While problem analysis is a crucial skill for students (Thomassen and Stentoft, 2020), its execution can be lengthy and challenging for less experienced students. By narrowing our focus, we provide students with a clear direction for their problem-solving endeavours.

Problem-based learning experiences are typically enriched by engagement with stakeholders, including domain experts and end-users. One way to foster this engagement is through collaboration with industry clients. In contrast, in this course, we create a learning environment that encourages problem exploration and solution development by leveraging the wealth of domain expertise within our university. Specifically, we collaborate with the Blue CoLab, an applied research lab on Pace University's Pleasantville campus. The Blue CoLab was founded on the principle that the assurance of clean water access, as highlighted in UN SDG #6, requires the right-to-know water is clean. The lab's research and training program includes a distributed water quality sensor network situated in the campus pond. The lab provides students with valuable resources, including access to sensing technology and systems for water quality data acquisition. Additionally, students benefit from multidisciplinary expertise in environmental studies, policy, and technology. These resources guide students throughout their learning journey by empowering them to develop solutions that better reflect the world at large, where societal activities, such as innovation and policy making, can have profound impacts on each other.

Lastly, this course incorporates elements of place-based learning (Wurdinger and Carlson, 2009), thus emphasising the significance of the 'local' dimension in cultivating active engagement within the community for our students. Specifically, we harness the university campus itself as a 'living lab,' leveraging its assets such as water bodies and water infrastructure. This approach empowers students to directly apply design thinking principles to the design challenge at hand, allowing for a deeper understanding of the complexities involved. By anchoring the design challenge within the university campus context, we enhance accessibility for first and second-year students, fostering a deeper connection and insight into the subject and encouraging them to employ these skills throughout their academic careers and beyond.

Through this blend of problem scoping, expert coaching, access to advanced technology, and place-based learning in a 'living lab' setting, we strive to equip our students with the necessary skills and knowledge to drive meaningful change in addressing the pressing issue of the public's right-to-know water quality. In this case study, we aim to assess how well our pedagogical approach enhances students' understanding of the clean water and 'right-to-know' issue while they devise solutions.

Method and data

To evaluate our pedagogical approach, we gathered written reflections from 22 students who were enrolled in this design thinking and innovation course at our private university in spring 2023. These students were pursuing studies in different academic disciplines: technology (8), business (10), nursing (3), and biology (1). There was an equal gender distribution of 11 females and 11 males.

Following the completion of the course, the students were presented with the following prompt to guide their reflection: "What insights did you gain about the issue of 'the right-to-know your water quality' through the process of designing a solution for your project?"

To analyse the students' reflections, we employed a content analysis approach (Krippendorff, 2018). Initially, we utilised words as a unit of analysis and examined the frequency of occurrence of specific words in the text. This analysis allowed us to gain insights into the students' perceptions and language usage. Additionally, we employed themes as the unit of analysis. Two instructors independently coded the students' reflections and assigned a theme to each one. Themes were first drawn from the raw text itself to further understand the data. Lastly, themes

were then drawn using the PESTLE analysis (2016) model – covering political, economic, social, technological, legal, and environmental aspects – as a framework. Subsequently, the instructors engaged in discussion to ensure a consensus on the interpretation of the identified themes and their implications.

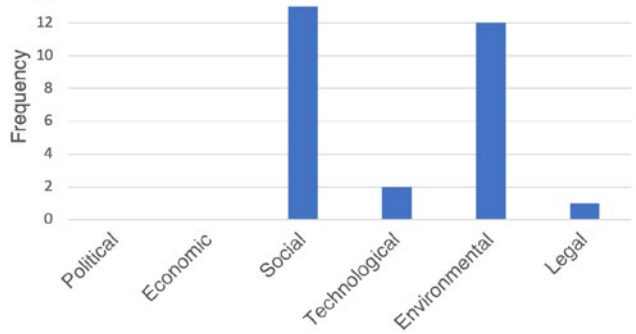
By employing these analysis techniques, we aimed to understand the students' reflections and uncover the prominent words and the recurring themes that emerged from their responses, reflecting their learning experiences.

Results

To capture the students' understanding of the course principles, we used several prominent words from the course to centre their reflections on right-to-know water quality. Among these words, the most prominent ones, listed in order of frequency, were 'water', 'quality', 'know', 'people', 'right', 'information', and 'contaminants'. Tab. 1 displays the 20 most frequent words found in the students' reflections. From the students' reflections, the instructors identified themes using PESTLE as the framework. These themes are discussed below, in order of prominence based on their frequency, and summarised in Fig.1.

Tab. 1. 20 most frequent words in students' reflections.

Word	Frequency		
water	25	information	5
learned	14	little	4
quality	11	really	4
know	8	ways	4
many	8	problem	3
issue(s)	8	come	3
people	7	time	3
right	6	contaminants	3
could	5	drink	3
		important	3



Social and Political. Thirteen students recognized the fundamental right to access water quality information, understanding its significance on both local-global and individual-society levels. They emphasised the pressing need to address this issue and to ensure a safe and sustainable future for all. While explicit mentions of political aspects such as constitutional rights, legal protections, and government actions or inactions were absent and thus not included in the thematic PESTLE count, students' reflections underscore the importance of enacting policies and regulations to ensure universal access to water information and clean water.

Environmental. Twelve students identified several environmental factors, most of them in relation to health and waterborne illnesses. These factors encompass water sources, water utilities, water infrastructure, as well as water pathogens and contaminants. The students emphasised the necessity of proactive measures to safeguard the health and well-being of individuals, especially vulnerable populations like children, older adults, and those with weakened immune systems.

Technology. Two students grasped the potential of existing technology in addressing the issue. However, they also acknowledge a technological limitation, as real-time monitoring technologies that will provide water quality data in advance are under development. Students emphasised the need for automated health warnings to be issued to individuals and the necessity of developing innovative detection technologies. They also expressed their belief that advancements in technology, both existing and forthcoming, should facilitate the development of solutions for water quality monitoring and public information dissemination.

Legal. Only one student explicitly recognized the absence of laws in the United States that safeguard individuals' right to access water quality information and to protect themselves from waterborne illnesses. Their understanding aligns with experts' assessment that real-time monitoring technologies and the public's right-to-know are not sufficient to address the issue unless recognized globally in the UN SDGs and federally with regulatory implications.

Economic. While students' reflections touched on environmental and social facets linked to water quality, there was no explicit mention of economic aspects like the costs associated with bottled water or infrastructure replacements. This omission is evident in the thematic PESTLE count.

Beyond the thematic PESTLE count, further analysis revealed that students' reflections were solution-facing. Although the prompt did not specifically encourage solution proposals, most responses implicitly or explicitly provided solutions. Moreover, the students overwhelmingly recognized the role of communication in tackling the problem. They emphasised the significance of educating individuals and communities about the issue of water quality, as well as the need to gather and share information in real time, particularly through emergency notifications. Accessibility and availability of water quality information for all were highlighted as crucial aspects by the students.

In summary, the findings reveal that students gained insights into various dimensions of the 'right-to-know your water quality' issue, encompassing mainly social, environmental, technological, and legal factors. A common theme throughout their reflections

was the importance of effective communication to raise awareness about the issue and its potential solutions among individuals and communities, both locally and globally. Moreover, the overall tone of their reflections reflects a sense of empowerment in tackling this issue, with the exploration of multiple solutions and the integration of diverse stakeholder perspectives.

Discussions and conclusions

Traditional research labs within universities, particularly in the field of technology, have primarily catered to graduate students or advanced undergraduates. In contrast, our pedagogical approach seeks to leverage the existing domain expertise within universities and extend the conversation to include first and second-year students. By doing so, we can broaden the reach of understanding and engagement among university students, empowering them to contribute creative solutions to global challenges early in their academic journeys and to embrace those principles throughout their academic careers.

Overall, the findings suggest that the course's pedagogical approach, focusing on problem scoping, expert support, and experiential learning within the campus setting, effectively empowered students to understand and tackle the pressing issue of the public's right-to-know water quality. The students' reflections capture their personal engagement, critical thinking, and readiness to contribute to creating a safer and more sustainable future for all.

Through the development of this type of place-based experiential learning experience, universities can contribute to cultivating a new generation of environmentally conscious leaders who are well-equipped to make a positive impact on the world. By embracing the place-based approach, alongside project-based learning and university-industry partnerships, universities can enhance their capacity to nurture and tap into talent necessary for addressing global issues on a larger scale.Traditional research labs within universities, particularly in the field of technology, have primarily catered to graduate students or advanced undergraduates. In contrast, our pedagogical approach seeks to leverage the existing domain expertise within universities and extend the conversation to include first and second-year students. By doing so, we can broaden the reach of understanding and engagement among university students, empowering them to contribute creative solutions to global challenges early in their academic journeys and to embrace those principles throughout their academic careers.

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References

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education* (Vol. 1). Springer Publishing Company.

Berry, T. (2011). The great work: Our way into the future. Crown.

Figueiredo, S., Eriksson, V., Björklund, T., & Ekman, K. (2022). Mapping Design Briefs and Results Over a Decade of University-Industry Student Projects. In DS 117: Proceedings of the 24th International Conference on Engineering and Product Design Education (E&PDE 2022), London South Bank University in London, UK. 8th-9th September 2022.

Evans, J., Jones, R., Karvonen, A., Millard, L., & Wendler, J. (2015). Living labs and co-production: university campuses as platforms for sustainability science. *Current Opinion in Environmental Sustainability*, *16*, 1-6.

Kolar H., Cronin J., Hartswick P., Sanderson, A. C., Bonner, J. S., Hotaling, L. Ambrosio, R. F., Liu, Z., Passow, M. L. (2009) Complex real-time environmental monitoring of the Hudson River and estuary system. IBM Journal of Research and Development. https://doi.org/10.1147/JRD.2009.5429017 #dblp

Kolb, D. A. (1984). Experience as the source of learning and development. *Upper Sadle River: Prentice Hall*.

Krippendorff, K. (2018). *Content analysis: An Introduction to its methodology*. Sage publications.

Lipschutz, R. D., De Wit, D., & Lehmann, M. (2017). Sustainable Cities, Sustainable Universities: Re-engineering the campus of today for the world of tomorrow. *Handbook of Theory and Practice of Sustainable Development in Higher Education: Volume 2*, 3-16.

Thong, C., Cotoranu, A., Down, A., Kohler, K., & Batista, C. (2021). Design innovation integrating deep technology, societal needs, radical innovation, and future thinking: a case study of the CBI A3 program. CERN IdeaSquare Journal of Experimental Innovation, 5(1), 32-39.

PESTLE Analysis. (2016). What is PESTLE Analysis? A Tool for Business Analysis. PESTLE Analysis. https://pestleanalysis.com/what-is-pestle-analysis.

Wiesche, M., Uebernickel, F., Byler, E., Garcia-Cifuentes, J. P., Suzuki, S., Vignoli, M., ... & Krcmar, H. (2018). Teaching innovation in interdisciplinary environments: Toward a design thinking syllabus.

Wurdinger, S. D., & Carlson, J. A. (2009). *Teaching for experiential learning: Five approaches that work*. R&L Education.

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Building trust and engaging in sustainability projects. A strategic design perspective

Abstract

Colombia's 2018 Resolution 1407 required industry stakeholders to coordinate their efforts across the manufacturing, consumption, and recycling systems within packaging value chains. This resolution increased manufacturers' obligation to recover packaging waste. Although such collaboration can be forced, it is considered that it needs some level of trust to function properly. The business ecosystem in Medellín, Colombia, which includes the production and recycling of plastic packaging, exhibits complexity with intricate interactions between the system's human and technical components, offering a variety of obstacles to trust-building and engagement. A significant body of work investigates, mostly in developed countries with strong institutions and good governance, the elements that influence stakeholders' rational and emotional decisions and behaviours in sustainability projects, these decisions and behaviours being influenced by individual, organisational, and system-level factors. For example, the needs and capabilities of people and organisations. However, very few research focus on engagement and trust-building in nations with poor governance. This paper stems from the author's doctoral dissertation, where the case study was the result of the review of 151 items of Colombian government legislation related to solid waste management and 27 semi-structured qualitative interviews. Stakeholders in Medellín's plastic packaging waste management system build trust and interact in projects spontaneously, progressively, and dynamically when designing solutions to sustainability challenges. They do it following the satisfaction of their material and non-material needs and motivations.

Key words:
stakeholder engagement, trust-building, design for sustainable behaviour, strategic design

Introduction

Sustainability issues in projects often arise from conflicts between stakeholder needs, capabilities, and motivations for protecting the environment. Having a better understanding of the project stakeholders' needs and motivations is critical to improving the comprehension of their relationships when ideating new solutions. Better collaboration is often related to a trust-based environment where people and organisations feel safe enough to develop joint project activities. This paper stems from the author's doctoral research that investigated stakeholder engagement and trust regarding a plastic packaging waste management system in Medellín, Colombia. The framework of design for sustainable behaviour helped better understand the influence of the material and non-material stakeholder needs and motivations in their decisions and behaviours when building trust and collaborating on sustainability projects.

Most of the reviewed literature currently understands the relationship of trust to engagement, examining how stakeholders

pursue their goals and learn to make better-informed decisions in sustainability initiatives. However, there is a critical deficit in knowledge and understanding of how this happens in unequal contexts where governance is weak, such as in the case study of this research in Colombia. Elevated levels of trust and involvement are viewed in the literature on sustainability efforts as necessary conditions for project success. However, most empirical research lacks an understanding of how differentiated material and non-material human needs influence project stakeholders' decisions and behaviours when building trust and collaborating.

The level of trust among stakeholders is seen to influence their collaboration, affected by their needs, satisfaction and capabilities when they need to overcome sustainability challenges. The implication is that projects cannot be successful without solid motivation to engage and trust and having stakeholders with their basic needs satisfied. Nevertheless, in Colombia, sustainability projects go ahead despite problematic dynamics, such as unbalanced stakeholder needs satisfaction. This paper reports partial results of the author's doctoral dissertation about a case study on what drives stakeholders to engage in unequal relationships of mistrust, serving as the basis for the doctoral research question: What drives stakeholders to engage when the motivation to trust is low and the distribution of power and resources unequal?

Theoretical background

The diversity and interconnectedness of stakeholders make their engagement in sustainability initiatives complex, needing project stakeholders to maintain their motivation and have the capabilities to work together (S. Clegg, Australian, and Pacific Researchers in Organization Studies, 2002; Liao, Chuang, and To, 2011; Morin, 1992a; Muff, 2017). Material and non-material needs are shown to be crucial to better understanding stakeholder motivations to engage (Max-Neef, 1986; Maslow, 1943; Nussbaum, 2011). It includes assessing human emotional needs and motivations (Desmet and Pohlmeyer, 2013; Niedderer, 2017). Human needs influence stakeholder decisions and behaviours and affect how they prioritise their commitment to sustainability strategies (Ceschin, 2012). When addressing sustainability challenges, not only are the technical aspects of solutions important, but also the social and cultural aspects to better understand collaboration dynamics (Ceschin, 2012; Frick, Kaiser, and Wilson, 2004; Martínez Sepúlveda et al., 2018). Here, trust-building is a key component of making better-informed project decisions (Armstrong, A. et al., 2022; Bunduchi, R., 2013; Covey, S., 2006; Fukuyama, F., 1995; Hardin, R., 2002; Jucevicius, G., and Jucevičiene, R., 2015).

The complexity of sustainability initiatives is increased by the difficulties in building trust, where trust is likely to be low due to poor governance. Here, practitioners face the challenge to design solutions to sustainability situations that adapt to diverse changing stakeholder interactions, different objects and a natural environment (Australian Public Service Commission, 2007; Kajzer Mitchell and Walinga, 2017; Rittel and Webber, 1973) Complexity theories and theories of socio-technical systems ((Foster, C. J., Plant, K. L., and Stanton, N. A., 2019; Herszon and Keraminiyage, 2014; Linger and Owen, 2020) give light on the various difficulties in such a prolonged and difficult endeavour, such as designing solutions to the plastic packaging waste management system in Medellín to comply with Resolution 1407/2018.

Method and data

According to Maloutas (2003), the nature and scope of problems in sustainability programs are highly context-dependent. Therefore, the doctoral research where this paper stems from was case-based. Here, the plastic packaging waste management system in Medellín served as the case study for the author's doctoral research. Twenty-seven semi-structured interviews with representatives from major stakeholder groups in Medellín's plastic packaging waste management system make up one of the main bodies of research data. This research nurtured the activities of an industry project called "Waste to Opportunity ‘', where the author had the chance to help in the development and facilitate three design workshops with the stakeholders, where they could identify sustainability challenges and ideate potential solutions.

The analysis of the interview data was influenced by a study of 151 pieces of legislation enacted by the Colombian government between 1973 and 2020, including the waste management policies and more general environmental protection policies that took waste management into account. To process the actual data and relate it to the goals of governmental law and the findings of the literature research, the author employed a thematic analysis approach and an iterative coding process (Braun and Clarke, 2013). To focus data collection and analysis on the effects of emergencies and stakeholder diverse qualities in impacting engagement and trust-building in the conduct of the case study, complexity theory and socio-technical systems theory were used.

Results

The research participants' individual experiences and perspectives about their challenges when designing strategies to comply with Resolution 1407/2018 put to the test the abstract concepts that define the stakeholder concept in the literature on stakeholder engagement and trust-building. Here, practitioners could benefit from their assessment of the specific attributes of the context and the network of stakeholders to keep learning about the system they design for. Project stakeholders designing solutions to their sustainability challenges could also find better opportunities when including intertwined social and technical

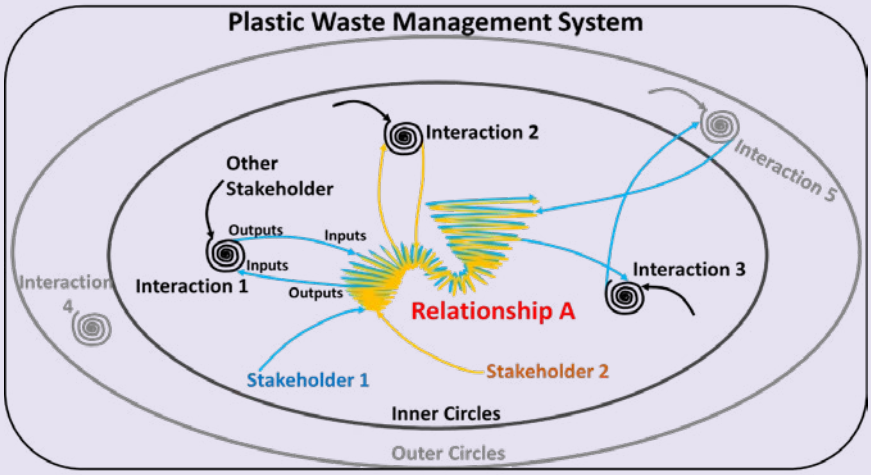

Fig. 1. A Dance of Trust between project stakeholders. Imagen taken from Ivorra, L. (2022)

initiatives in their projects (C. W. Clegg, 2000; Molleman and Broekhuis, 2001; Savaget et al., 2019)

Trust is crucial when assessing stakeholder participation in sustainability initiatives. The various motivations driving both individual and organisational stakeholders to cooperate in such initiatives illustrate the various drivers of stakeholder involvement in sustainability projects. Stakeholders competing material and non-material needs influence their incentives for participating in sustainability projects. For example, a solution aiming to improve packaging waste recovery could consider the stakeholder's need for improving the efficiency of its waste recovery process and the stakeholder's need to be recognised in society for his contribution to the protection of the environment. However, there are inherent challenges to co-designing better sustainability solutions. Trust-building and engagement are also affected by cultural differences and the complexity of Medellín's plastic packaging waste management system.

Discussions and conclusions

Medellín's plastic packaging ecosystem was challenging because of the city's poor governance, which was worsened by the asymmetry between stakeholders' needs, capabilities, and access to trustworthy information. Despite these obstacles to engaging and trusting, the interviewees did engage in collaborative initiatives, frequently in the pursuit of a purpose-filled existence. When building trust and designing joint initiatives to tackle sustainability solutions, the dynamics of these adaptability actions might be compared to dancing, as illustrated in **Fig. 1**. Senge et al.'s (1999) book Dance of Change and Echeverría's (2009) concept "Dance of the promises" inspired the use of dance as a metaphor.

Unequal needs, capabilities, and access to trustworthy information affect stakeholders' motivation to collaborate on projects, resulting in dynamics that affect engagement and trust-building. To determine whether they need to build, strengthen, or restore trust, project leaders must establish procedures for evaluating the actual and expected level of trust during a project. It is also necessary to regularly evaluate the information stakeholders utilise to make project decisions. As illustrated in **Fig. 2**, this case illustrated that stakeholders develop trust by adapting to spontaneous situations, where emergent opportunities arise, such as the "aha moment" when designing new strategies to face sustainability challenges. People and organisations progressively deepen their ties to develop trust, which could help them better know each other and formulate new projects. For example, they could test a process to convert plastic waste into new products before delving into scaling up the development of new products. They also routinely evaluate their connections to assess whether they want to continue strengthening their relationships or not. For example, after launching a new product to market, two business partners could choose to develop a whole new line of products.

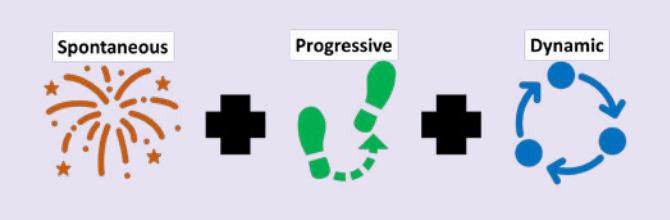

Fig. 2. Trust builds and varies spontaneously, progressively, and dynamically. Created from Ivorra, L. (2022)

The literature on stakeholder engagement in sustainability projects emphasises the value of trust-building dynamics without sufficiently illuminating the reasons why stakeholders would cooperate in situations where there is little trust. Project stakeholders must contend with a variety of obstacles and forces that push them to carry on with daily activities while adjusting to each new experience. Here, a strategic design perspective concerning the understanding of the material and non-material needs and motivations of people and organisations sheds light on how trust-building and engagement occur in sustainability projects.

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References

Armstrong, A., Flynn, E., Salt, K., Briggs, J., Clarke, R., Vines, J., and MacDonald, A. (2022). Trust and temporality in participatory research. *Qualitative Research*, 1-22.

Australian Public Service Commission. (2007). Tackling wicked problems. A public policy perspective. Australian Capital Territory.

Braun, V., and Clarke, V. (2013). *Successful qualitative research: A practical guide for beginners*. London. Sage.

Bunduchi, R. (2013). Trust, partner selection and innovation outcome in collaborative new product development. *Production Planning and Control*, 24(2-3), 145-157.

Ceschin, F. (2012). The Introduction and scaling up of sustainable product-service systems. A new role for strategic design for sustainability. Politecnico di Milano. Milán.

Clegg, C. W. (2000). Sociotechnical principles for system design. Applied Ergonomics, 31(5), 463-477.

Clegg, S., Australian, and Pacific Researchers in Organization Studies. (2002). *Management and organization paradoxes*. Amsterdam. John Benjamins Publishing.

Covey, S. M. R. (2006). *The speed of trust: The one thing that changes everything*. New York. Free Press.

Echeverría, R. (2009). *Ontología del lenguaje* (Comunicaciones Noreste Ltda., Ed.). Santiago. Lom Ediciones.

Desmet, P., and Pohlmeyer, A. (2013). Positive design: An Introduction to design for subjective well-being. International Journal of Design, 7(3), 5-19.

Foster, C. J., Plant, K. L., and Stanton, N. A. (2019). Adaptation as a source of safety in complex socio-technical systems: A literature review and model development. *Safety Science*, 118, 617-631.

Frick, J., Kaiser, F. G., and Wilson, M. (2004). Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. Personality and Individual Differences, 37(8), 1597-1613.

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity. London. Hamish Hamilton.*

Hardin, R. (2002*). Trust and trustworthiness*. New York. Russell Sage Foundation.

Herszon, L., and Keraminiyage, K. (2014). *Dimensions of project complexity and their impact on cost estimation* PMI® Global Congress 2014, Phoenix. Project Management Institute.

Ivorra, L. (2022). Weighing the importance of trust in maximising stakeholder engagement: A case study from Colombia on a plastic packaging waste management system [Doctoral dissertation, Swinburne University of Technology]. Swinburne Research Bank. http://hdl.handle.net/1959.3/470006

Jucevicius, G., and Juceviciene, R. (2015). Smart development of organizational trust: Dilemmas and paradoxes. *Procedia - Social and Behavioral Sciences*, 213, 860-866.

Kajzer Mitchell, I., and Walinga, J. (2017). The creative imperative: The role of creativity, creative problem solving and insight as key drivers for sustainability. Journal of Cleaner Production, 140, 1872-1884.

Linger, H., and Owen, J. (2020). *The Project as a Social System: Asia-Pacific Perspectives on Project* Management (Vol. 1). Melbourne. Monash University.

Maloutas, T. (2003). *Promoting social sustainability*. The case of Athens. *City*, *7*(2), 167-181.

Martínez Sepúlveda, J. A., Gómez Gutierrez, D., and Florentino Márquez Ospina, J. C. (2018). Herramientas de empoderamiento ciudadano para la sostenibilidad urbana (U. EAN, Ed. 1 ed.). Bogotá. Universidad EAN. http://editorial.universidadean.edu.co/media/pdf-ean/libro-empoderamiento-ciudadano-para-la-sostenibilidad-urbana.pdf

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370-396.

Max-Neef, M. A. (1986). *Desarrollo a escala humana. Una opción para el futuro*. Santiago. CEPAUR.

Molleman, E., and Broekhuis, M. (2001). Sociotechnical systems: Towards an organizational learning approach. Journal of Engineering and Technology Management, 18(3-4), 271-294.

Morin, E. (1992a). The concept of system and the paradigm of complexity. In M. Maruyama (Ed.), *Context and Complexity* (pp. 125-138). New York. Springer.

Muff, K. (2017). *The collaboratory: A co-creative stakeholder engagement process for solving complex problems*. London. Routledge.

Niedderer, K. (2017). Facilitating behaviour change through mindful design. In Design for behaviour change: Theories and practices of designing for change. (1 ed., pp. 104-115). Milton. Routledge.

Nussbaum, M. C. (2011). *Creating capabilities: The human development approach*. Cambridge. Belknap Press of Harvard University Press.

Rittel, H. W. J., and Webber, M. M. (1973). Dilemmas in a general theory of planning. Policy Sciences, 4(2), 155-169.

Savaget, P., Geissdoerfer, M., Kharrazi, A., and Evans, S. (2019). The theoretical foundations of sociotechnical systems change for sustainability: A systematic literature review. Journal of Cleaner Production, 206, 878-892.

Senge, P. M., Ross, R., Kleiner, A., Roberts, C., Roth, G., and Smith, B. (1999). *The dance of change: The challenges of sustaining momentum in learning organizations*. London. Nicholas Brealey.

Wu, K.-J., Liao, C.-J., Tseng, M.-L., and Chou, P.-J. (2015). *Understanding innovation for sustainable business management capabilities and competencies under uncertainty*. Sustainability, 7(10), 13726-13760.

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Transformative experiences in innovation spaces: Exploring secondary socialisation towards sustainability through UN Sustainable Development Goals integration

Abstract

This sociological study explores the impact of integrating the United Nations Sustainable Development Goals (SDGs) into projects within an innovation hub. The research investigates how this integration affects participants' values and capacity to act, with a focus on whether it leads to secondary socialisation towards sustainability.

The innovation hub, being part of the Design Factory Global Network, uses the SDGs as tools for problem-solving and systems thinking in student programmes. Participants are asked to tackle specific SDGs, understanding their targets and indicators and considering their interconnections with other societal challenges. This approach aims to broaden participants' perspectives, evaluate priorities, and inspire innovative solutions.

To understand the transformative potential of this experience, the study draws upon the sociology of knowledge, employing the concept of secondary socialisation developed by Berger and Luckmann (1966) and contemporary insights from de Singly (2022). Additionally, the notion of capability by Sen and Nussbaum (1993) is used to assess how the experience empowers participants to act.

Data collection includes semi-structured interviews with innovation hub team members and questionnaires administered to students in educational programs. The researcher also engages in participant observation as a science communicator within the innovation hub.

Preliminary results indicate that the innovation hub fosters a collaborative mindset. However, the study reveals limited evidence of strong socialisation towards sustainability. Participants tend to focus on individual-level actions, overlooking broader political, institutional, and power-related dimensions of sustainability. The SDGs themselves carry embedded values, potentially influencing participants' perspectives.

The findings highlight the need for critical thinking and a multidisciplinary approach to achieve sustainable solutions. While the innovation hub offers opportunities for non-market-based solutions, a mindset shift towards sustainability requires exposure to thought-provoking ideas that challenge worldviews and consider the interconnectedness of societal challenges. Addressing blind spots related to political and institutional dimensions is vital for socialisation towards sustainability.

In conclusion, the study emphasises the importance of broadening the focus of innovation hubs beyond individual-level actions and considering the societal and institutional aspects of sustainability. A truly multidisciplinary approach, encompassing social sciences, is essential for empowering individuals to act effectively towards achieving the SDGs' ambitious objectives. By embracing a comprehensive view of sustainability, innovation hubs can play a more significant role in fostering transformative experiences that inspire positive change towards a more sustainable future.

Key words:
Sustainability;
innovation;
innovation hub;
United Nations Sustainable Development Goals (SDGs);
secondary socialisation;
values;
capability;
collaboration;
political dimensions;
institutional level;
education.

Introduction

Sustainability has become an essential topic of discussion, with numerous governmental and non-governmental entities endeavouring to tackle it by means of the UN Sustainable Development Goals (SDGs) (Biermann et al., 2022). They are integrated into projects and programmes, and depending on how they appear there, this integration could prove to be a transformative experience for those who work with them. A stay arousing a strong commitment in an innovation hub of the Design Factory Global Network using them could expose its users to a system of values and norms different from their own, and thus result in a secondary socialisation experience.

Many studies exist on innovation spaces. Yet they are often start-up incubators, hubs that therefore practise a form of market-oriented innovation and the creation of businesses and marketable products. In the studied innovation hub, the SDGs are used as tools to innovate and think in systems, and to understand the interconnectivity of the challenges we face as a society without necessarily having the market as an end, which makes it special and particularly interesting for the analysis. More precisely, they are used in student programmes as the problem to tackle during a particular challenge. One or a limited number of SDGs are chosen, and the students are asked to elaborate on a solution around them. They are asked to look at their indicators, familiarise themselves with their objectives and be particularly attentive to how the issues that they tackle are interlinked. Working with this mindset could participate in changing people's scope of vision and making them think in new orders of magnitude, acquire new perspectives, reevaluate priorities, and open their eyes to blind spots of innovation. In other words, to internalise the 'sub world'—the set of values of a specific milieu— (Berger & Luckmann, 1966) of the innovation space and its way of integrating the SDGs into innovation. By confronting a value system different from their own, the users of the innovation space could find themselves changing theirs, or on the contrary rejecting them, depending on how they value the experience. Moreover, the experience could increase their capabilities—their positive freedom to realise what they want—(Sen & Nussbaum, 1993), by letting them realise through the SGDs that unsuspected means of action exist.

The underlying research question in this study focuses on how an innovation space can create an experience of secondary socialisation towards sustainability. It can therefore be formulated as follows: How does the inclusion of the SDGs into innovation projects impact the values and the ability to act of their participants?

Theoretical background

To study these mechanisms, the study falls within the theoretical framework of the sociology of knowledge by mobilising the concept of secondary socialisation—the adaptation of individual identities to a social system taking place in adulthood—as developed by Berger and Luckmann (1966) and complemented with de Singly's typology of secondary socializations (2022). This concept helps us understand how an individual's immersion in a new system of values and norms could change their worldview by internalising the value system of an institution through a meaningful experience. This is done by highlighting alternative worldviews and roles that participants are unfamiliar with.

The effect of the innovation space experience on people's ability to act is evaluated regarding the concept of capability developed by Sen and Nussbaum (1993). An individual could find themselves empowered by realising that they could act through indirect ways to tackle a sustainable development goal, but the opposite hypothesis—being overwhelmed by the complexity of the issue—is also questioned.

The blind spots of innovation are highlighted, with the different forms that it could take, such as imitation, innovation by withdrawal, illegal innovation, resistance to innovation, etc. This dimension is notably covered in the work of Godin & Vinck (Baya-Laffite, 2019).

The SDGs are not mobilised without a critical eye, and a particular analysis of their depoliticized dimension is made in Larsen, Haller, and Kothari's work (2022). Definitions of politicisation and political action are borrowed from Lagroye (2003).

Method and data

The studied innovation hub was chosen because of its endeavour to implement SDGs into innovation projects in its educational programmes. It is doing so by asking the students to materialise their solutions to SDGs into prototypes, adapting the specific technologies developed by the research infrastructure it is part of, to investigate how these technologies can help with sustainability, outside their usual fields of application. This way of doing innovation is particularly interesting, not only because it directly connects technology to the SDGs through a physical object, but also because the adaptation of these technologies leads students to think about the contextual needs of the stakeholders, leaving one specific domain to explore another, totally different one. They must determine what is suitable and what is not, emphasising the interconnection between all aspects affected by their solution, both technical and social. The choice was also motivated by questions of accessibility since the researcher had the possibility to work there as a full-time employee for one year.

The studied population includes all the users of the innovation hub, which are the innovation hub's team members as well as the students partaking in the educational programmes. Having the perspective of both the developers as well as the recipients of the educational programmes was necessary for the depth of the analysis.

The hub's team members are interviewed with the semi-structured method, and data about the students are collected through a questionnaire, including qualitative questions. To complement this data, the researcher uses the participant observation method by working as a science communicator in the innovation hub. First, unrecorded exploratory interviews were conducted with all members of the innovation hub team. Then, twelve semi-structured interviews were thus held with the members of the team, and the questionnaire was completed by eleven students. Observation data were recorded in a field diary. The interview grid, the questionnaire, as well as the observation grid and the field dairy, have been structured according to dimensions instigated by the theoretical framework and are as follows: innovation, SDGs, professional socialisation, capabilities, politicisation, and space. The observation data thus collected were coded according to these dimensions and more specific points such as "prototyping", "techno-solutionism", or even "climate". The data is then analysed not to be representative of all innovation hubs' experiences, but to understand the underlying mechanisms that could take place in one integrating SDGs in its projects.

Results

One of the main results is that despite the focus on sustainability, there doesn't seem to be a strong socialisation towards sustainability, but rather towards the collaborative mindset of the space and the institution in which it is located.

A second important result is that when asked about the main barriers that participants see to achieving the SDGs, the lack of information and knowledge about sustainability in society is the most cited. There seems to be a focus on the individual level. Even if a more structural or institutional level may be mentioned, it's often the action of the individual in the mentioned institutional context that is cited and not the action of institutions in themselves. Therefore, we can underline missing, or at least little present dimensions when it comes to the worldviews of interlocutors: politics, groups of interest, and power relations.

It is interesting to note that the SDGs themselves carry within them a set of values (those of the UN interpreted by the institution studied). The less politicised worldviews of the participants may reflect this. (Langford, 2016; Louis & Marteans, 2021).

The innovation hub nevertheless offers a potentially transformative experience to its users by allowing them to become aware of their power to act in relation to sustainability issues and by giving them tools to think in different orders of magnitude, by the possibility of collaborating on a large scale, and potentially by sparking new interests.

Discussions and conclusions

An innovation hub such as the one studied nevertheless offers a chance to think of solutions that are not market-based. But to achieve these solutions, critical thinking is needed, which is not possible if the focus stays at the individual level and doesn't expand to the structural and institutional levels. To have a true experience of internalising a new 'sub world', one should be exposed to thought-provoking ideas that change their worldview by offering them new perspectives that make sense to them, and by allowing them to connect the dots between societal challenges. Questioning power relations and political forces plays in that direction and seems to be an important blind spot in the data collected so far.

An innovation hub may act as a place where users have an experience of secondary socialisation, but integrating SDGs in projects will not automatically socialise participants towards sustainability. In order to achieve this, a reflection on the mindset that is communicated, through the discourses inside the space but also through the lens used in the projects, is important. If innovation is designed only for the individual level, it blinds itself to some necessary dimensions that should be considered to tackle the SDGs. It is only by taking into account all their dimensions and the complexity and interconnectivity of SDGs that individuals might be able to increase their capabilities and act to achieve these goals. More precisely, this study stresses the necessity of a truly multidisciplinary approach, including social sciences, to understand the interconnectivity of societal challenges. The multiplicity of disciplines to understand the multiple aspects of sustainability is a prerequisite.

References

Baya-Laffite, N., 2019, Critical studies of innovation. Alternative approaches to the pro-innovation bias. Godin B. & Vinck D. (eds.), 2017, Cheltenham, UK: Edward Elgar, *Revue d'anthropologie des connaissances* 13, 3, no. 3 (2019): 919–27.

Berger P. & Luckmann T., 2022, La Construction sociale de la réalité, Sociologia, Paris: Armand Colin.

Biermann F., Hickmann T., Sénit C.-A., Beisheim M., Bernstein S., Chasek P., Grob L., Kim R. E., Kotzé L. J., Nilsson M., Ordóñez Llanos A., Okereke C., Pradhan P., Raven R., Sun Y., Vijge M. J., van Vuuren D. & Wicke B., 2022, Scientific evidence on the political impact of the Sustainable Development Goals, *Nature Sustainability*, Nature Publishing Group, 5(9), pp. 795-800.

Lagroye, J., 2003, *La politisation*. Paris: Belin.

Langford M., 2016. Lost in Transformation? The Politics of the Sustainable Development Goals, *Ethics & International Affairs*, 30, pp. 167-176.

Louis M. Maertens L., 2021, *Why International Organizations Hate Politics: Depoliticizing the World*, Oxfordshire: Routledge.

de Singly, F., 2022, 'Postface. Sur la socialisation secondaire'. In *La Construction sociale de la réalité*, 3e éd.:321–34. Sociologia. Paris: Armand Colin.

Larsen, P. B., Haller T., & Kothari A., 2022, 'Sanctioning Disciplined Grabs (SDGs): From SDGs as Green Anti-Politics Machine to Radical Alternatives?' *Geoforum* 131: 20–26.

Sen, A., & Nussbaum M., 1993, *The Quality of Life*. Oxford: Clarendon Press.

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From the stories of nature and those who inhabited it

Sustainability requires an interconnected approach that transcends traditional boundaries. However, current practices often address the dimensions of sustainability separately. This experiential research investigates the concept of multiplicity in sustainability praxis by exploring speculations and fiction as a means of knowledge plurality. It investigates the phenomena of multiplicity in design praxis through a relational lens. Borrowing from the intersectional notions, it transfers the tension between oppressed and oppressor to nature and culture, and by doing so, questions the implications of the absence of nature as a stakeholder when exploring social innovations in a sustainability project. This is a multidisciplinary study grounded in social sciences and design framework, crosscutting intersectionality and critical design.

The research studies the experience of participants during a workshop with a multicultural group of social entrepreneurship students following design thinking methodologies in developing social innovations. Students are tasked with addressing wicked problems as a trigger to a new business idea that is just. After a phase of familiarization, students are challenged to explore the relationship between nature and culture through a speculative fiction activity centred on the metaphor of the tree and its rings as a temporal map. The intention was to explore identification with natural forms and, through this, the inclusion of nature in the design output.

The research question is: to what extent do fictions and speculations allow participants to occupy abstract identities such as nature? The objective is to contribute to understanding how new ways to knowledge inform the design journey seeking inclusion critically.

Keywords:
regeneration,
restoration,
inclusion,
co-creation,
nature,
original communities

References

Dunne, A., & Raby, F. (2013). Speculative Everything: Design, Fiction, and Social Dreaming. The MIT Press.

Escobar, A. (2017). Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds. Duke University Press. http://www.jstor.org/stable/j.ctv11smgs6

Crenshaw, K. W. (1991). Mapping the Margins: Intersectionality, Identity Politics, and Violence against Women of Color. Stanford Law Review, 43(6), 1241. https://doi.org/10.2307/1229039

Crenshaw, K. W. (2018). Demarginalizing the intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory, and Antiracist Politics [1989]. In Routledge eBooks (pp. 57–80). https://doi.org/10.4324/9780429500480-5

Collins, P. H., & Bilge, S. (2020). Intersectionality. John Wiley & Sons.

Megatrends - Sitra. (2023, April 27). Sitra. https://www.sitra.fi/en/topics/megatrends/

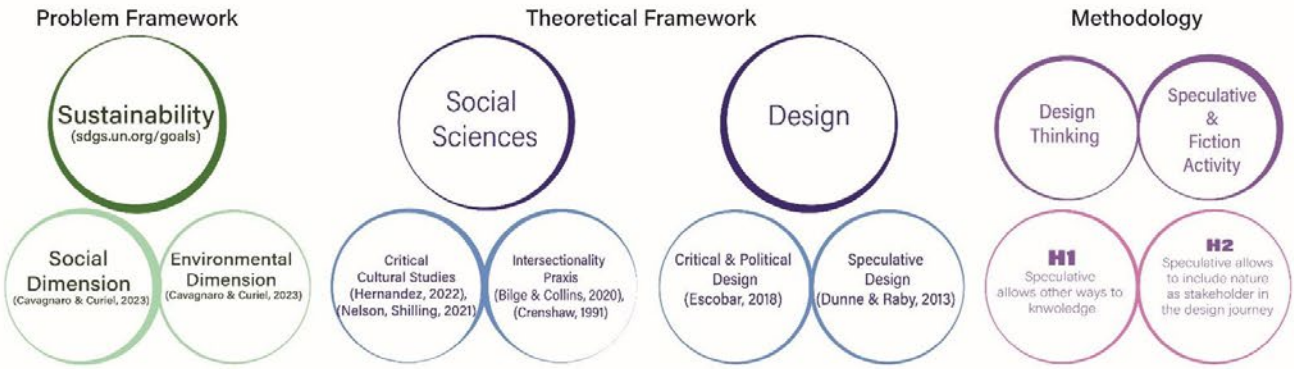
Šuran, O. (2019, September 22). Dunne & Raby: Designers need to recognise their limitations and work with them - SpeculativeEdu. SpeculativeEdu. https://speculativeedu.eu/interview-dunne-raby/

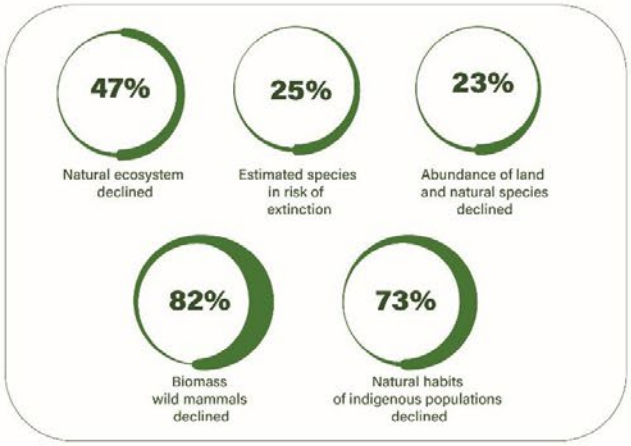
Šuran, O. (2019, August 28). Critical about Critical and Speculative Design - SpeculativeEdu. SpeculativeEdu. https://speculativeedu.eu/critical-about-critical-and-speculative-design/

THE 17 GOALS | Sustainable Development. (n.d.). https://sdgs.un.org/goals

FROM THE STORIES OF NATURE AND THOSE WHO INHABITED IT

To what extent do fictions and speculations allow participants to occupy abstract identities such as nature?





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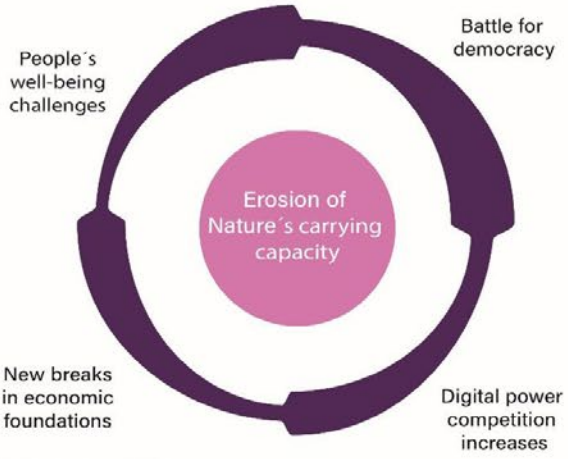

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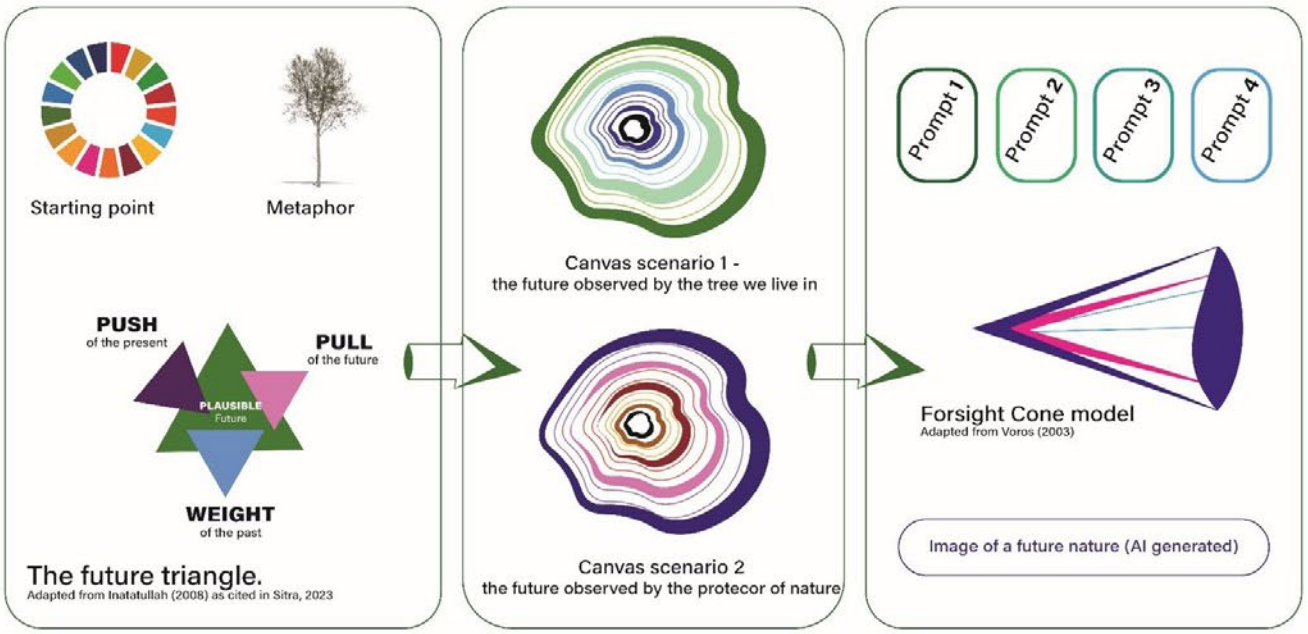

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Design & sustainability case toolkit

Product designers and engineers have a pivotal role to play in advancing sustainability. Successfully addressing sustainability challenges requires collaboration with a wide variety of professionals. However, it can be challenging to see how dimensions of sustainability and design approaches connect.

The Design+Sustainability card deck is an open-source online toolkit developed by Alto Design Factory researchers based on real-life cases and practices. Representing a range of diverse examples to support understanding, learning, and reflection, the card deck offers prompts to prioritize sustainability in decision-making throughout the design process. These decisions range from including a broader range of stakeholders when making sense of the challenge to using different types of prototyping methods to test ideas.

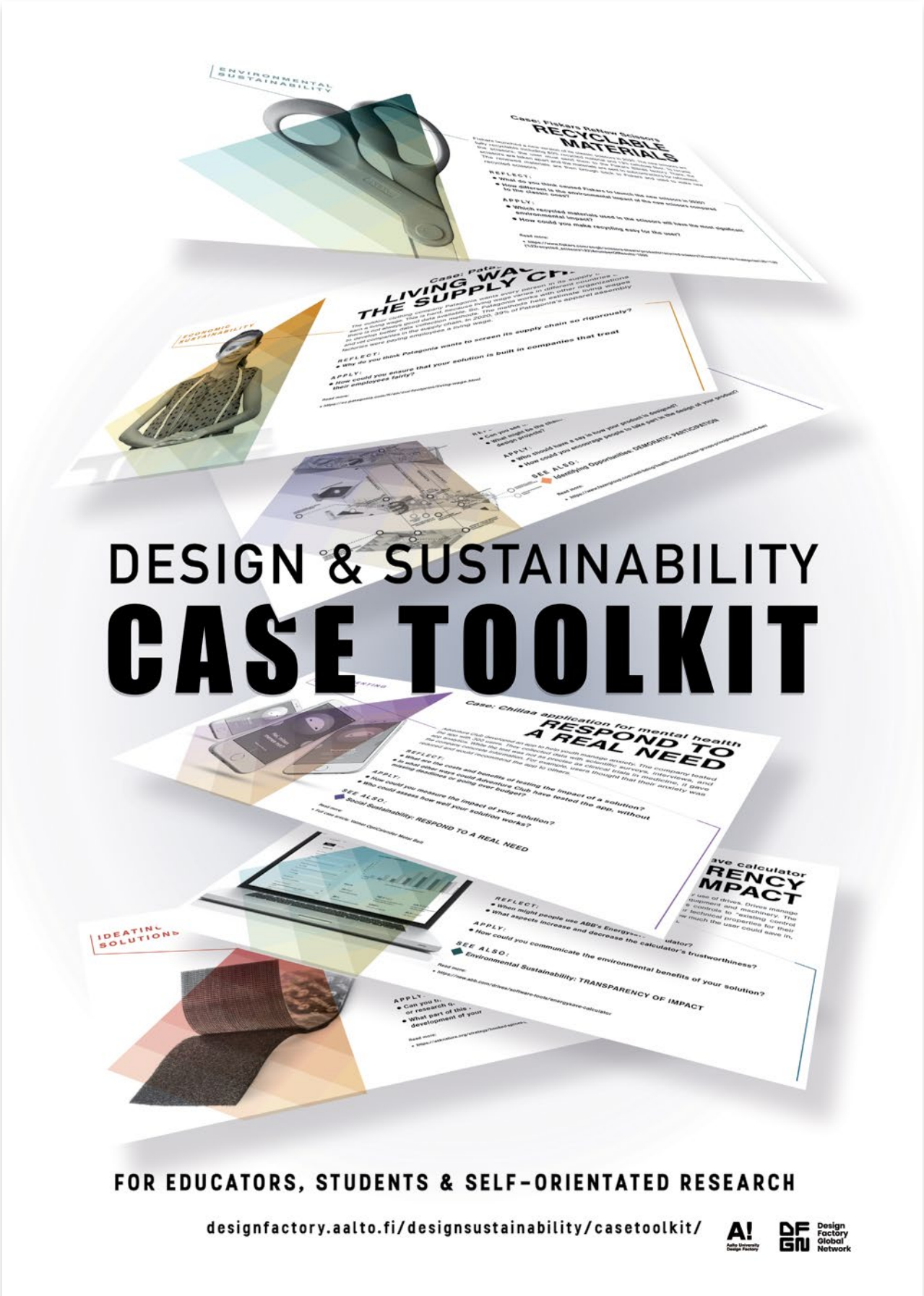
The toolkit covers design phases *Identifying opportunities*, *Ideating solutions*, *Experimenting & testing*, **and** *Producing & implementing,* **and intersects them with** *environmental*, *economic*, **and** *social* **dimensions of sustainability.**

The Design+Sustainability cards are designed to offer educators, students and anyone interested in sustainability the opportunity to learn more and reflect on how sustainability dimensions could influence their practice. The toolkit offers step-by-step instructions with activities suitable for individuals, teams as well as larger groups. For educators, the Design+Sustainability card deck offers a tool to enable sustainability-focused discussions in class and construct learning experiences that draw from real-world cases. For students and professionals in working life, it's an exciting way to learn more about the design process and the various dimensions of sustainability!

Key words:
Design; sustainability; toolkit; education; scenarios.

Access the Design+Sustainability Case Toolkit with diverse use scenario demonstrations:

https://designfactory.aalto.fi/designsustainability/casetoolkit


ENVIRONMENTAL SUSTAINABILITY
Case: Fiskars ReNew Scissors
RECYCLABLE MATERIALS
REFLECT:
What do you think caused Fiskars to launch the new scissors in 2020?
How different is the environmental impact of the new scissors compared to the classic ones?
APPLY:
Which recycled materials used in the scissors will have the most significant environmental impact?
How could you make recycling easy for the user?
Read more:
ECONOMIC SUSTAINABILITY
Case: patagonia
LIVING WA
THE SUPPLY CH
REFLECT:
Why do you think Patagonia wants to screen its supply chain so rigorously?
APPLY:
How could you ensure that your solution is built in companies that treat their employees fairly?
Read more:
SEE ALSO:
Identifying Opportunities: DEMOCRATIC PARTICIPATION
Read more:
DESIGN & SUSTAINABILITY
CASE TOOLKIT
Case: Chillaa application for mental health
RESPOND TO A REAL NEED
REFLECT:
What are the costs and benefits of testing the impact of a solution?
What other ways could Adventure Club have tested the app, without risking deadlines or going over budget?
APPLY:
How could you measure the impact of your solution?
Who could assess how well your solution works?
SEE ALSO:
Social Sustainability: RESPOND TO A REAL NEED
Read more:
ave calculator
RENCY
MPACT
REFLECT:
When might people use ABB's Energyaw... ulator?
What aspects increase and decrease the calculator's trustworthiness?
APPLY:
How could you communicate the environmental benefits of your solution?
SEE ALSO:
Environmental Sustainability: TRANSPARENCY OF IMPACT
Read more:
IDEATING SOLUTIONS
APPLY
Can you te... or research q...
What part of this ... development of your
Read more:
FOR EDUCATORS, STUDENTS & SELF-ORIENTATED RESEARCH
designfactory.aalto.fi/designsustainability/casetoolkit/
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A model for multiplicity; sustainable footwear futures

This poster illustrates how multiplicity strengthens design innovation in educational contexts and identifies the methodologies used. Combined expertise and resources dedicated to this Short Advanced Programme, SAP along with the methodologies and tools employed, allowed 3 RUN-EU partner institutions to deliver a programme that harnessed the potential of multiplicity through co-development, co-design, and co-delivery, providing a template for further progamme iterations.

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A Model for Multiplicity; Sustainable Footwear Futures

AFFILIATIONS

The combined expertise and resources dedicated to this Short Advanced Programme, along with the methodologies and tools employed, allowed 3 RUN-EU partner institutions to deliver a SAP that harnessed the potential of multiplicity through co-development, co-design & co-delivery, providing a template for further progamme iterations.

01. Introduction

Sustainable Footwear Futures
This research presents the findings of remote co-development, face-to-face and hybrid delivery of a Short Advanced Programme across 3 Institutions: TUS, HAMK & IPCA, as part of RUN-EU, a 'regional development-oriented European University network that embodies the values of sustainability, multiculturalism, and inclusiveness'

02. Objective

A. Optimise collaborative planning across 3 independent design institutions using collaborative tools.
B. Arrive at effective modes of delivery to enhace online and face-to-face engagement with students, industry experts and staff from multiple backgrounds and areas of expertise.
C. Develop a programme that can be replicated and iterated across the partner institutions

Multiplicity. Group work, Collaboration and the Individual

This poster illustrates how multiplicity strengthens design innovation in educational contexts.
Key to students from multiple institutions and with undergraduate and postgraduate degrees in design, different languages and cultures engaging with the programme effectively was designing and delivering the programme in a way that was accessible to all, while allowing the individual space to express their unique approaches to design and sustainability

03. Methodology employed in Designing a SAP

Optimising collaborative planning across 3 independent design institutions using collaborative tools.

For the planning of the short, advanced programme, the team worked collaboratively online with Miro and Teams platforms simultaneously, to map out the structure and content of the SFF course identifying core areas each could contribute to strengthen the collective offering. This proved a very efficient and enjoyable way to work together across our institutions in Ireland, Finland and Portugal.

04. Methodologies employed in Delivering a SAP

Effective modes of delivery were identified to optimise online and Face-to-Face engagement with students. Industry experts and staff from multiple backgrounds and areas of expertise contributed to the SAP.

- Week 1 industry experts from footwear sector, of small and large companies, as well as from Portuguese Footwear Technological Centre, delivered presentations and shared their insights and expertise.
- In Week 2 lecturers from Limerick School of Art and Design travelled with workshop materials to HAMK, Finland. Design workshops were delivered back-to-back, 10 participant focusing on textiles skills and techniques, while the other 10 worked in the adjoining studio on pattern cutting and prototyping. The proximity of the studios created a dynamic design exchange.
- In Week 3, to ensure engagement and the collective energy from the Face-to-Face week was retained, the programme coordinators hosted Week 3 in the Metaverse using Spatial. In culmination of the SAP, participants created their avatars and joined together again in the virtual gallery where they worked on curating their projects and presenting to staff and industry experts.

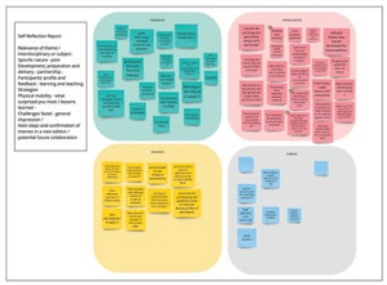
05. Results & Findings

This virtual gallery using Spatial remains live and is a space participants can continue to meet and invite other designers, host virtual events and arrange meetings with potential collaborators.

This QR code will give you access to the Sustainable Footwear Futures virtual exhibition

05. Analysis

Partners dedicated to time to gathering feedback from SAP participants at the mid-point face-to-face week and on completion of the programme. Partners then returned to Miro to complete a self reflection report. This will be used to inform future iterations.



06. Conclusion

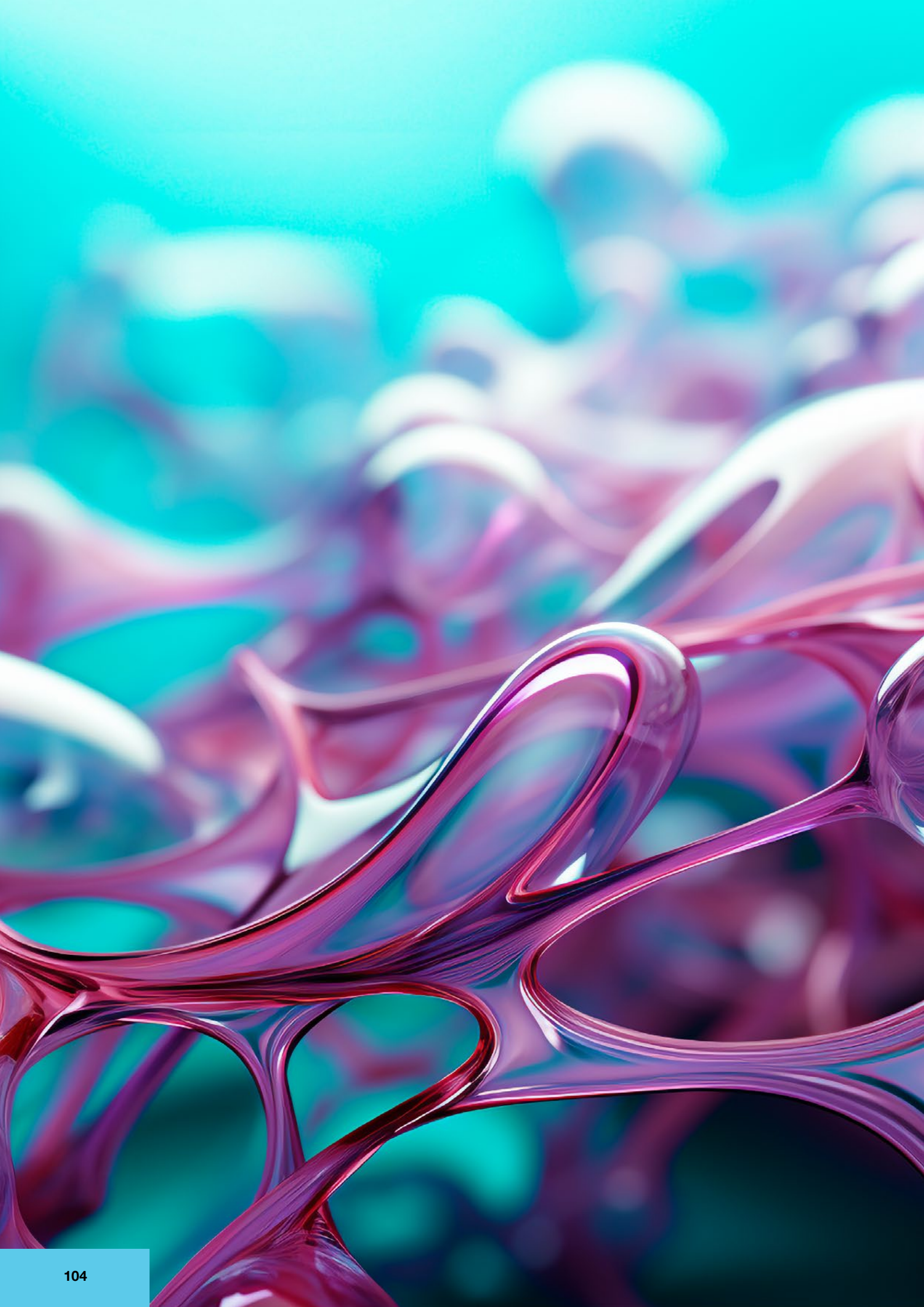
Co-design for programme development has proven a successful way of enriching the course content
Co-delivery has enabled the participants to learn from a wide range of experts and has also supported peer-to-peer learning and continued professional development and network building for tutors and guest speakers.
With the findings and programme analysis, the partners are currently developing the second iteration of this programme for 2023/24.

Theme 6

Technology adoption & transformation

The constant evolution and advancement of technology, coupled with the growing prominence of AI, have fundamentally transformed the landscape of design practices. On one hand, AI has become a valuable tool for designers, aiding them in conveying their ideas through visual means. On the other hand, integrating technology into the design process compels all involved parties to revaluate both the design processes and the principles of design thinking.

In a comprehensive study conducted by David and et.al., valuable insights were gleaned regarding how students perceive the utility of Generative Artificial Intelligence (GAI) tools within the framework of Design Thinking Double Diamond processes during an academic makeathon they organized. As technology and AI continue to assert their presence, Vignoli and et.al. pose a crucial question: how can design thinking be tailored to accommodate technology-driven projects? Their “tech-to-organization” model demonstrates how design thinking can be customized and applied to assess the integration of a given technology within an organization.



"The constant evolution and advancement of technology, coupled with the growing prominence of AI, have fundamentally transformed the landscape of design practices: White background, Cyan and light purple, Microscopical image --s 750".

Image: Midjourney × Valtteri Bade, 2023

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The use of generative AI tools in Design Thinking academic makeathon

Abstract

This paper examines the application of Generative Artificial Intelligence (GAI) tools in a Design Thinking Double Diamond (DDDT) academic makeathon. It analyses students' interaction with these tools in problem-solving scenarios, offering insights into their perceptions and usage. The research reveals that GAI, such as ChatGPT, and visual tools like Midjourney and Dall-E 2, are viewed more as assistive than solution-dictating. It emphasises the potential of GAI in fostering creativity, information gathering, and design presentation, while highlighting a need for future exploration into its deeper capacity and potential within the DDDT methodology.

Key words:
Generative Artificial Intelligence;
Design Thinking Double Diamond;
Academic makeathon.

Introduction

This paper explores the ways by which students of design and engineering use Generative Artificial Intelligence (GAI) tools to solve real-world problems. It is based on data collected during Shenkar Jamweek's Design Thinking (DT) Sprint Makeathon and aims to explore how disruptive GAI tools were used by students during the process, and how they might be incorporated to allow innovation and improve the DT methodology. Shenkar Jamweek is an annual four-day academic makeathon for interdisciplinary problem-based learning. It brings together hundreds of design, art and engineering students. Jamweek focuses on social and entrepreneurial innovation led by the Double Diamond Design Thinking (DDDT) approach.

Theoretical background

The idea of humans and GAI working together has been around since the beginning of AI. The early pioneers of AI considered its role to help users to solve difficult problems, make better decisions, and achieve goals more efficiently (Licklider, 1960). Although researchers such as Noy and Zhang (2023) claim that GAI tools serve primarily as a substitute for worker effort rather than for complementing skills, others claim that GAI tools, such as ChatGPT and Midjourney, are being increasingly adopted in various decision-making domains, including healthcare, business, military, and design (Chong et al., 2022). Other researchers add that GAI tools are also used for research, generating ideas, drafting documents and summarising information (Cardon, 2023).

Vasconcelos (2023) discusses the use of generative GAI tools, particularly ChatGPT, as "objects-to-think-with" in the context of education, and argues that it can assist in cultivating reflective and critical thinking, problem-solving skills, and concept comprehension. Jakesch, et al. (2023) argue that AI language technologies can affect the ability of what users write and think. However, According to Borji (2023), GAI tools lack a "world model" and they fail to understand the complex connections between concepts and entities. Wang (2023), though, has shown evidence of advanced models such as ChatGPT4 which demonstrates progress in "understanding the world".establishing the current level of knowledge and the research gap.

Method and data

In the makeathon there were 705 participating students: 380 of them came from the engineering faculty, and 325 came from the design and art faculty. All of them were approaching the end of their second year (out of four), just when they were concluding their core studies and starting their practitioner journey.

Each day of the four-day makeathon was dedicated to a different stage of the Design Thinking model, as follows: The first day to Research & Empathy, the second day to Problem Definition and Ideation, the third day to Ideation and Prototyping and the fourth day to Prototyping and Presentation.

The research methodology combines quantitative and qualitative data which were collected in 260 questionnaires that were filled each day (in total about 750), triangulated with documented observations, which were carried out during the makeathon.

We also encouraged students to use GAI tools such as ChatGPT and Midjourney. We provided only basic training. However, we left it open for the students to choose how to operate it (a free-style approach).

Results

1. Assisting or dictating? Around 70% of the participating students in Shankar's Jamweek stated that they have already used GAI tools in the past. However, a vast majority of them (85%) considered these tools to be merely assisting or guiding tools (on the way to a solution) rather than dictating tools.

2. The perceived link between results quality and GAI contribution: Among the students, 73% of the designers and 86% of the engineers stated that they think their final product was worthy of use as a valuable solution for the host organisation (scoring 5-7 on a 1-7 scale). Moreover, a high level of correlation was found between the students' evaluation of the project quality and their belief in the GAI effectiveness. The same correlation (between results' quality and GAI effectiveness) was also found among the students' mentors (faculty staff). Similar results appear in a study published by Amani, White et al. (2023). In this study the researchers asked both faculty members and students to evaluate the potential effects of ChatGPT on their critical thinking, problem-solving, teamwork, etc. Its conclusions show numerous commonalities in the responses provided by the two groups of participants.

3. The use manner of GAI along DDDT stages: Jamweek DDDT Sprint dedicated its first two days to research and empathy (mainly convergence work-mode, which explores the problem domain), and the two last days to ideation and prototyping (mainly divergence work-mode in creating a solution). Esling and Devis (2020) define these two work-modes as follows: convergent thinking involves applying knowledge and logic to find a single parameter answer led by a specific set of questions with only one correct answer (in our case problem definition). Divergent thinking involves a framework that encourages the generation of a diverse range of ideas in response to a given question or stimulus (in our case, finding a solution). In the Jamweek Research and Empathy stage, 70% of the students used textual AI tools (ChatGPT) while only 30% used visual GAI tools (e.g., Mid-journey and Dall-E 2), or both textual and visual tools. No significant behavioural difference was found between design students and engineering students. In the Ideation and Prototype stage, though, the adoption level of visual GAI tools increased from 30% to 50%. Here too, there was no significant behavioural difference between design and engineering students. Students used visual GAI tools for specific tasks, such as visualising ideas to quickly validate and continue developing their solution. Along this, some design students have expressed their concerns over the GAI and their unwillingness to use those tools, declaring: "They are taking our jobs."

4. Revolutionary AI or only advanced search engine? Some of the qualitative feedback suggests that students preferred textual GAI tools in the Research and Empathy stage. They reported that it facilitated their research initiation and accelerated their information gathering, and testify that they did it in order "to discover more about the challenge", "to get a broader understanding of the topic", "to get access to a lot of information across the web" and "to narrow the range of information and focus the thoughts''. Other answers referred to the unique combination of speed, accuracy and ease of use. These answers suggest that most of the students used ChatGPT as a traditional digital search engine and operated it in a conservative way, as a means to conduct classic information collection and getting direct answers. In our opinion, this manner of use misses the enormous potential of GAI. To name just a few examples, using ChatGPT in a Socratic way (Chang, 2023) can allow students to improve their creativity and learning techniques; prompting specific questions can provoke critical thinking rather than facts and information (Brown & Kelly, 1994; 2007); and conducting certain types of conversations may provide ongoing feedback about the process of learning itself (Baidoo-Anu & Owusu, 2023). While the research phase of DDDT indeed requires gathering information, we believe that using GAI

tools can expand the meaning of 'information' and 'research' in critical ways. It can also replace the usual process of information-driven use and solution-driven use. This understanding can lead to changes in the DDDT model when it is conducted by GAI tools.

5. Information veracity and user trust: *To the question "Did you validate the results provided by the GAI tools in order to ensure data reliability?" 40% of the students admitted that they had not done so. However, our survey shows a significant difference between designers and engineers: 65% of the design students did not validate ChatGPT's results compared to only 28% of the engineers. This* can come aligned with Ahmed's paper (2003), which examines the differences between the ways by which novice designers approach design tasks. It indicates that novice designers (such as our design students) tend to focus on gaining a better understanding of the challenge and adopt numerical data as accurate, without questioning it.

Discussions and conclusions

The extensive use of GAI tools by students, both prior to and during Jamweek, underscores the feasibility of integrating such technology within the DDDT methodology. This is consistent with the current research suggesting the synergy between GAI and DDDT (Bouschery et al., 2023). Furthermore, our study reveals that the incorporation of GAI into these learning environments appears to enhance student perception of their own work quality. However, the influence of these tools, particularly language models like ChatGPT, on users' creative process is not exhaustive, and it deserves further exploration. Our research shows that students perceive GAI as an assistive or guiding tool rather than a dictating-solution tool. They use ChatGPT as a search engine without exploring and exhausting its deeper capacities, and they use visual GAI to improve their presentations. This is a traditional use of an AI tool that misses its potential capacity. We also found a significant difference between engineering students, who were more sceptical and mostly challenged and cross-checked the GAI results, and design students, who mostly accepted the GAI and aligned with the results. Is it possibly related to designers' state of mind of openness to new concepts? or does it imply fear from the new disruptive technology, which aims to replace designers, as some of them expressed?

Our research suggests that GAI tools can improve some aspects of DDDT, particularly finding and gathering information rapidly and designing presentations effectively. Having said that, the integration of GAI tools has a greater potential yet to be explored in terms of their ability to radically improve the entire process of DT as a method.

References

Ahmed, S., Wallace, K. M., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. Research in engineering design, 14, 1-11.

Amani, S., White, L., Balart, T., Arora, L., Shryock, Dr. K. J., Brumbelow, Dr. K., Watson, Dr. K. L. (2023). Generative AI perceptions: A survey to measure the perceptions of faculty, staff, and students on generative AI tools in Academia. arXiv.org. https://arxiv.org/abs/2304.14415

Baidoo-Anu, D. and Owusu A. L. (2023), Education in the era of Generative Artificial Intelligence (AI): understanding the potential benefits of ChatGPT in promoting teaching and learning. http://dx.doi.org/10.2139/ssrn.4337484

Borji, A. (2023). A categorical archive of ChatGPT failures. arXiv.org. https://arxiv.org/abs/2302.03494

Bouschery, S. G., Blazevic, V., & Piller, F. T. (2023). Augmenting human innovation teams with Artificial Intelligence: exploring transformer-based language models. Journal of Product Innovation Management, 40(2), 139-153. https://doi.org/10.1111/jpim.12656

Browne, M. N., & Keeley, S. M. (2007). Asking the right questions: A guide to critical thinking. Pearson Education.

Cardon, P. W., Getchell, K., Carradini, S., Fleischmann, C., & Stapp, J. (2023). Generative AI in the Workplace: Employee perspectives of ChatGPT benefits and organisational policies. SocArxiv. https://doi.org/10.31235/osf.io/b3ezy

Chang, E. Y. (2023). Prompting large language models with the socratic method, 2023 IEEE 13th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 351-360. https://doi.org/10.48550/arXiv.2303.08769

Chong, L., Zhang, G., Goucher-Lambert, K., Kotovsky, K., & Cagan, J. (2022). Human confidence in artificial intelligence and in themselves: The evolution and impact of confidence on adoption of AI advice. Computers in Human Behavior, 127. https://doi.org/10.1016/j.chb.2021.107018.

Esling, P., & Devis, N. (2020). Creativity in the era of artificial intelligence. arXiv.org https://doi.org/10.48550/arXiv.2008.05959

Jakesch, M., Bhat, A., Buschek, D., Zalmanson, L., & Naaman, M. (2023, April). Co-writing with opinionated language models affects users' views. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (pp. 1-15).

Licklider, J. C. (1960). Man-computer symbiosis. IRE transactions on human factors in electronics, (1), 4-11.

Noy, S., & Zhang, W. (2023). Experimental evidence on the productivity effects of Generative Artificial Intelligence. Working paper. MIT.

Vasconcelos, M. A. R., & dos Santos, R. P. (2023). Enhancing STEM learning with ChatGPT and Bing Chat as objects to think with: A Case Study. arXiv.org. https://doi.org/10.48550/arXiv.2305.02202.

Wang, G., et al. (2023). Voyager: An open-ended embodied agent with large language models.

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Tech to organization. Assessing and designing technology adoption with design thinking

Abstract

This article explores how design thinking can be tailored to address projects that focus on assessing the value of technology adoption within an organisation and designing an appropriate application for the technology. Our research shows how Open.Space, the Design Factory for Open Innovation at the University of Bologna, has adapted design thinking to effectively tackle such technology-driven projects and created an ad-hoc process called Tech to Organization.

Key words:
Innovation management; Technology management; Design thinking; New product development.

Introduction

In today's rapidly evolving business environments, organisations are increasingly driven to embrace novel technologies to remain competitive and adapt to changing market dynamics (Cocchi, Dosi, and Vignoli 2023). The adoption and integration of new technologies holds substantial potential for enhancing productivity, streamlining operations, and achieving sustainable growth (Iansiti 1995). However, adopting and implementing a novel technology within a firm is not without its challenges (Parente and Prescott 1994; Magistretti, Dell'Era, Verganti 2020). Organisations often face numerous hurdles and complexities, ranging from technical and logistical issues to cultural and organisational barriers (Karlsson, Taylor, and Taylor 2010). Nevertheless, despite these challenges, many organisations are launching projects aimed at integrating specific technologies such as blockchain, internet of things, customer relationship management, or business intelligence. These projects start with a constraint on the technology to adopt, leaving the design team with the issue of identifying the value of the technology for the organisation and designing a specific application that uses it.

In particular, the successful integration of a novel technology within an organisation requires a structured process that enables a comprehensive understanding of its potential, implications, and the necessary steps to bring it inside the organisation effectively (Karlsson, Taylor, and Taylor 2010). Notably, some organisations have discovered that anchoring technology choices in a deeper understanding of the value sought by users enables them to strike a better balance among feasibility, viability, and desirability of potential solutions (Kim et al. 2020).

In this context, design thinking (Brown 2008), one of the most widely adopted approaches to problem-solving and innovation (Liedtka 2015), can empower organisations to understand what to do with a novel technology and, possibly, integrate it into their systems, products, services, and processes. Traditionally, design thinking has been regarded as a human-centred approach (Martin 2010) driven by user needs and desires in the development of products and services (Cocchi, Dosi, and Vignoli 2021). Yet, design thinking has also proven effective in contexts which are traditionally less human-centric, such as technology-driven organisations and projects (Mahmoud-Jouini, Fixson, and Boulet 2019). Existing research is not considering whether and how design thinking ought to be adapted when confronted with technology integration projects. To address this gap, this study aims to answer the following research question: *How can design thinking be leveraged to support technology integration within organisations?*

Theoretical background

Design thinking refers to "*a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity*" (Brown 2008, p.2). This definition highlights the three lenses through which design thinking approaches innovation: desirability, feasibility, and viability (Brown 2009). Desirability concerns whether users will find the product or service compelling and how they will interact with it, feasibility refers to the possibility to adapt the technology for the solution in the organisation, and viability addresses the financial and economic sustainability of the solution for the firm (Carlgren, Rauth, and Elmquist 2016).

In terms of process, design thinking can be conceptualised as encompassing three main stages (Liedtka 2015). The first stage involves data collection about users' needs. It entails empathising with the individuals who will be using the product or service to obtain a deep understanding of their needs and desires (Dell'Era et al. 2020) and thus defining the problem that requires resolution from their perspective (Beckman and Barry 2007). The second stage revolves around generating the broadest range of ideas to solve the identified problem (Micheli et al. 2019). Finally, the third stage entails prototyping the ideas by transforming them into tangible representations (McCullagh 2013) and testing the ideas with potential users to evaluate their efficacy (Beverland, Wilner, and Micheli 2015).

One inherent limitation of contemporary design thinking approaches is characterised by its "*normative and essentialist nature*" (Carlgren, Rauth, and Elmquist 2016). Design thinking is frequently portrayed as a fixed set of tools and methods, failing to acknowledge the unique nature of innovation projects and the diverse characteristics of organisational contexts where design thinking is implemented. This narrow perspective restricts our understanding of the relationship between design thinking and its impact on innovation outcomes (Seidel and Fixson 2013). Accordingly, it becomes crucial to investigate whether and how design thinking might adapt when applied to projects focused on a given technology (Cocchi, Dosi, and Vignoli 2023). Given our specific focus on the adoption and integration of new technologies within organisations, this paper explores how design thinking can be tailored to address projects that primarily revolve around assessing the value of technology integration within a firm and designing an appropriate application for the technology.

Method and data

To conduct our research, we initially selected a representative organisation (Siggelkow 2007). We employed two criteria to identify an organisation suitable for effectively addressing our research question. First, we sought an organisation that uses design thinking as its main methodology for conducting innovation projects. Second, we looked for an organisation that actively engages in technology-driven projects. The organisation chosen for our study is Oper.Space, which serves as the Design Factory for Open Innovation at the University of Bologna. Oper.Space functions as an interdisciplinary innovation hub, bringing together students, teachers, researchers, and industry partners. Oper.Space undertakes approximately 200 innovation projects each year, using design thinking to generate novel solution concepts. Additionally, Oper.Space has been actively involved in technology-driven projects for the past five years, exploring new opportunities and developing solution concepts based on emerging technologies.

Within this context, we conducted in three distinct phases a case study research (Eisenhardt 1989). In phase 1, we collected the project documentation (i.e., project brief, mid-term presentation, final presentation) related to 18 technology-driven projects carried out by Oper.Space over the period 2017-2021. In phase 2, we performed 9 semi-structured interviews with the design thinking coaches from Oper.Space who supervised and coordinated the design activities of all the 18 technology-driven projects. The interviews aimed to understand whether the design thinking coaches made any adaptations to the conventional design thinking process when dealing with technology-driven projects and, if so, why and how. We recorded and transcribed the interviews and triangulated interviewees' answers with the documentation provided (Jick 1979). In phase 3, we analysed the data collected and identified an adapted design thinking process, named "*Tech to Organization*", which Oper.Space crafted specifically for those technology-driven projects that aim to integrate a given technology within an organisation. To validate our understanding of the Tech to Organization process, we conducted a workshop involving all the design thinking coaches from Oper.Space. This workshop

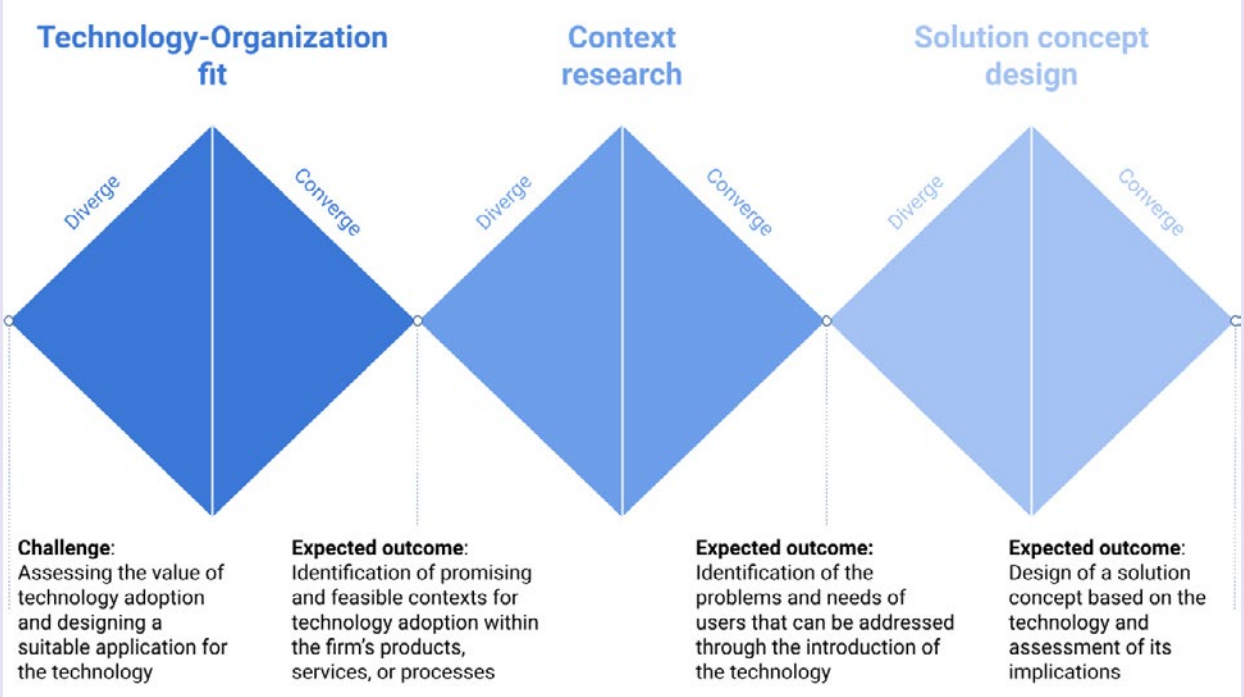


Fig. 1. Tech to Organization process

served as an opportunity to discuss and refine the process based on our collective expertise and experiences.

Results

The Tech to Organization process has been developed to facilitate the evaluation of the value associated with the adoption of a given technology within an organisation and the subsequent design of an appropriate application for that technology. The process starts with an assessment of the organisational processes, products, and services wherein the specific technology could potentially be implemented. By doing so, it allows for the identification of the most promising contexts in which the technology can be feasibly applied, while also facilitating the recognition of the problems and needs of users that can potentially be addressed through the Introduction of the technology. The process consists of three primary stages: technology-organisation fit, context research, and solution concept design. Each of these stages comprises both divergent and convergent phases. Figure 1 presents the structure of the Tech to Organization process and Table 1 a preliminary toolkit. In the full paper, we will provide a comprehensive account of a case study involving the application of design thinking tools through the Tech to Organization process in the context of drones for facility management services

Discussions and conclusions

Tech to Organization shows how design thinking might be adapted and used to assess the adoption and implementation of a given technology within an organisation, thereby contributing to the ongoing conversation about the implementation of design thinking in technology-driven projects (Mahmoud-Jouini, Fixson, and Boulet 2019). Tech to Organization holds practical implications as it offers design teams a specialised and structured approach to address projects that focus on evaluating the value of technology adoption and to develop an appropriate application for the given technology.

References

Beckman, S.L. and Barry, M. (2007), "Innovation as a Learning Process: Embedding Design Thinking", *California Management Review*, Vol. 50, No. 1, pp. 25–56. https://doi.org/10.2307/41166415

Beverland, M.B., Wilner, S.J. and Micheli, P. (2015), "Reconciling the tension between consistency and relevance: Design thinking as a mechanism for brand ambidexterity", *Journal of the Academy of Marketing Science*, Vol 43 No. 5, pp. 589–609. https://doi.org/10.1007/s11747-015-0443-8

Brown, T. (2008), "Design thinking", *Harvard Business Review*, Vol. 86 No. 6, pp. 84–92. https://hbr.org/2008/06/design-thinking

Brown, T. (2009), Change by design: How design thinking transforms organizations and inspires innovation, New York: Harper-Collins

Cocchi, N., Dosi, C. and Vignoli, M. (2021), "The Hybrid Model Matrix. Enhancing Stage-Gate with Design Thinking, Lean Startup, and Agile", *Research-Technology Management*, Vol 64 No. 5, pp. 18–30. https://doi.org/10.1080/08956308.2021.1942645

Tab. 1. Tech to Organization toolkit

Stage	Divergence/Convergence	Examples of tools
Technology-Organization fit	Diverge	Reflection around technology and their field of application, Organisational opportunities mapping, Breakdown of technology in abilities and field of application in specific activities
	Converge	Selection of the most interesting tech+field, Relevant org competences onboarding, Definition of target org processes, Specific assumption Challenge Definition
Context research	Diverge	Stakeholder mapping, Process mapping, Ethnographic interviews, Observations
	Converge	Personas, Research questions (Activity, Company, Design), Research questions ranking
Solution concept design	Diverge	Brainstorming, Rapid prototyping, Tech partner involvement, Future service envisioning
	Converge	Proof of Value, Proof of Concept, Business Case, Organisational Sharing

Cocchi, N., Dosi, C., and Vignoli, M. (2023), "Tech to Market. Finding and designing suitable technology applications with design thinking", *Proceedings of the International Conference on Engineering Design (ICED23)*, Bordeaux, France, 24–28 July 2023. https://doi.org/10.1017/pds.2023.332

Dell'Era, C., Magistretti, S., Cautela, C., Verganti, R. and Zurlo, F. (2020), "Four kinds of design thinking: From ideating to making, engaging, and criticizing", *Creativity and Innovation Management*, Vol. 29 No. 2, pp. 324–344. https://doi.org/10.1111/caim.12353

Eisenhardt, K.M. (1989), "Building Theories from Case Study Research", *Academy of Management Review*, Vol. 14, No. 4, pp. 532–550. https://doi.org/10.5465/amr.1989.4308385

Iansiti, M. (1995), "Technology integration: Managing technological evolution in a complex environment", *Research policy*, Vol. 24, No. 4, pp. 521–542. https://doi.org/10.1016/S0048-7333(94)00781-0

Jick, T.D. (1979), "Mixing qualitative and quantitative methods: Triangulation in action", *Administrative Science Quarterly*, Vol 24, No. 4, pp. 602–611. https://doi.org/10.2307/2392366

Karlsson, C., Taylor, M. and Taylor, A. (2010), "Integrating new technology in established organizations: A mapping of integration mechanisms", *International Journal of Operations & Production Management*, Vol. 30, No. 7, pp. 672–699. https://doi.org/10.1108/01443571011057290

Kim, E., Simonse, L.W., Beckman, S.L., Appleyard, M.M., Velazquez, H., Madrigal, A.S., and Agogino, A.M. (2020), "User-centered design roadmapping: anchoring roadmapping in customer value before technology selection", *IEEE Transactions on Engineering Management*, Vol. 69, No. 1, pp. 109–126. https://doi.org/10.1109/TEM.2020.3030172

Liedtka, J. (2015), "Perspective: Linking design thinking with innovation outcomes through cognitive bias reduction", *Journal of Product Innovation Management*, Vol. 32 No. 6, pp. 925–938. https://doi.org/10.1111/jpim.12163

Magistretti, S., Dell'Era, C. and Verganti, R. (2020), "Searching for the right application: A technology development review and research agenda", *Technological Forecasting and Social Change*, Vol. 151 No. 119879, pp. 1–18. https://doi.org/10.1016/j.techfore.2019.119879

Mahmoud-Jouini, S.B., Fixson, S.K. and Boulet, D. (2019), "Making design thinking work: Adapting an innovation approach to fit a large technology-driven firm", *Research-Technology Management*, Vol 62 No. 5, pp. 50–58. https://doi.org/10.1080/08956308.2019.1638485

Martin, R.L. (2010), "Design thinking: achieving insights via the "knowledge funnel"", *Strategy & Leadership*, Vol 38 No. 2, pp. 37–41. https://doi.org/10.1108/10878571011029046

McCullagh, K. (2013), "Stepping up: Beyond design thinking", *Design Management Review*, Vol 24 No. 2, pp. 32–34. https://doi.org/10.1111/drev.10238

Micheli, P., Wilner, S.J., Bhatti, S.H., Mura, M. and Beverland, M.B. (2019), "Doing design thinking: Conceptual review, synthesis, and research agenda", *Journal of Product Innovation Management*, Vol 36 No. 2, pp. 124–148. https://doi.org/10.1111/jpim.12466

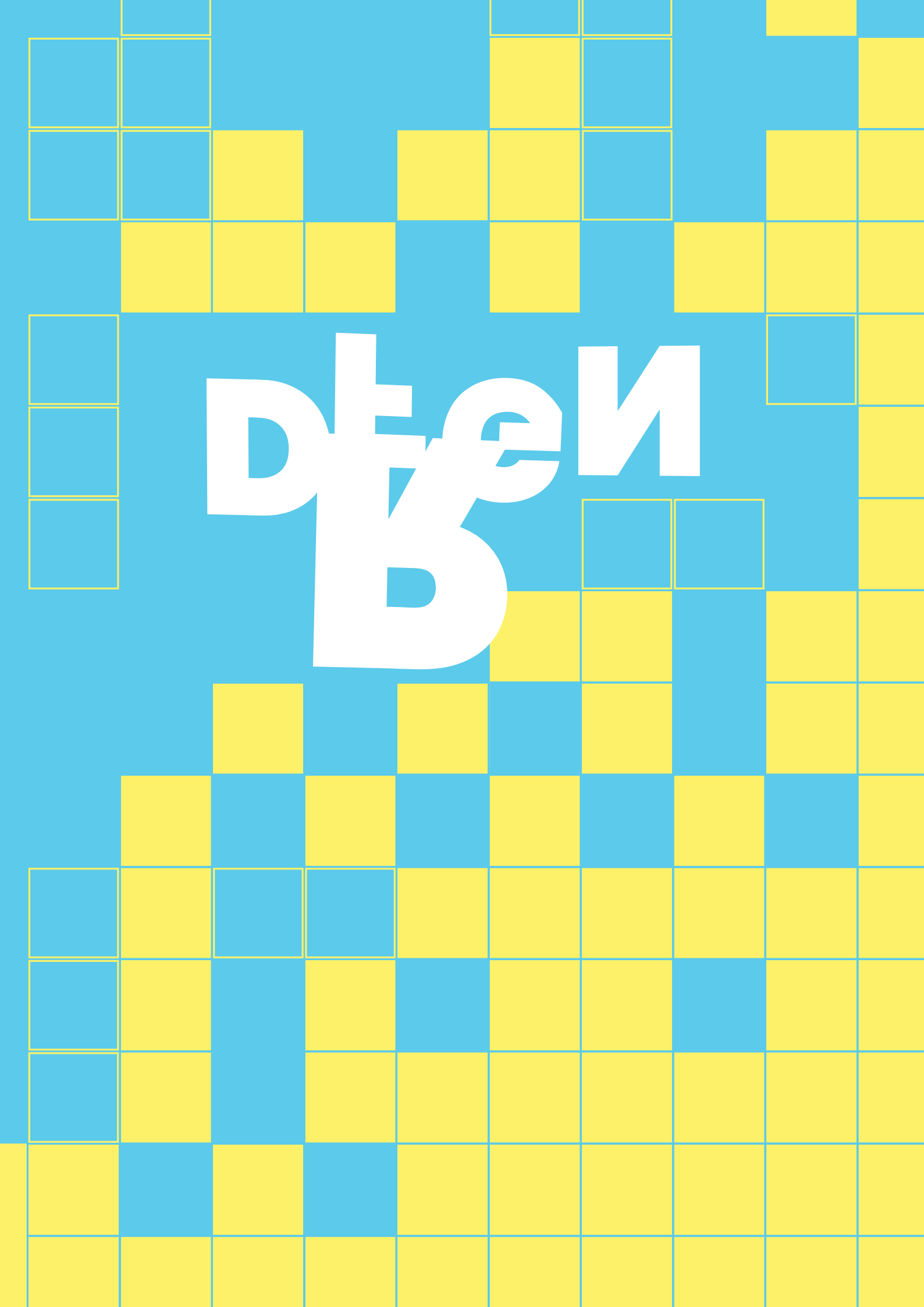
Parente, S.L. and Prescott, E.C. (1994), "Barriers to technology adoption and development", *Journal of political Economy*, Vol. 102, No. 2, pp. 298–321. https://doi.org/10.1086/261933

Schatzki, T.R. (2005), "Peripheral Vision: The Sites of Organizations", *Organization Studies*, Vol 26 No. 3, pp. 465–484. https://doi.org/10.1177/0170840605050876

Seidel, V.P. and Fixson, S.K. (2013), "Adopting design thinking in novice multidisciplinary teams: The application and limits of design methods and reflexive practices", *Journal of Product Innovation Management*, Vol 30, pp. 19–33. https://doi.org/10.1111/jpim.12061

Siggelkow, N. (2007), "Persuasion with case studies", *Academy of Management Journal*, Vol 50 No. 1, pp. 20–24. https://doi.org/10.5465/amj.2007.24160882

My notes and reflections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