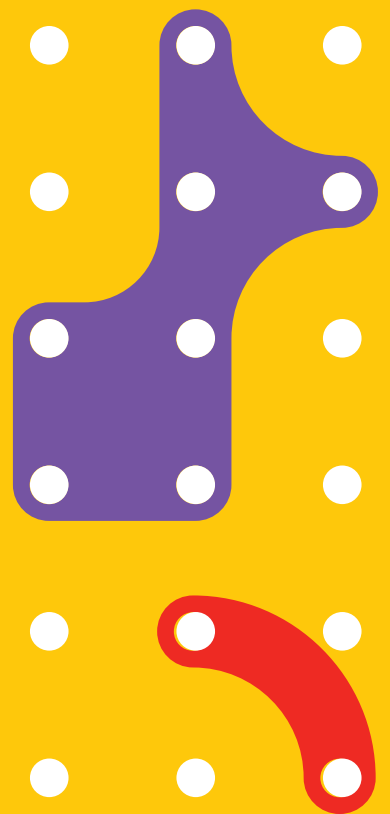# 1st Design Factory Global Network Research Conference

'Designing the Future'
5-6 October 2022

1st Design Factory Global Network Research Conference
'Designing the Future'
5–6 October 2022

Scientific Advisory Board
(in alphabetical order):

• Tua Björklund, Professor, Creative Practices in Engineering, Aalto University, Finland

• Peter Joore, Professor Open Innovation, NHL Stenden University of Applied Sciences, The Netherlands

• Saku Mäkinen, Professor Industrial Management, Tampere University, Finland

• Christine Thong, Professor of Design, Academic Director at Design Factory Melbourne, Swinburne University of Technology, Australia

• Eduardo Zancul, Professor of Engineering, The University of São Paulo, Brazil

DFGN.R 2022 –Designing the Future – is the first research conference organised by the Design Factory Global Network. The open event offers the opportunity for all like-minded educators, designers and researchers to share their insights and inspire others on education, methods, practices and ecosystems of co-creation and innovation. The DFGN.R conference is a two-day event hosted on-site in Leeuwarden, the Netherlands. The conference is organized alongside International Design Factory Week 2022, the annual gathering of DFGN members. This year's conference is organized in collaboration with Aalto University from Helsinki Finland and hosted by the NHL Stenden University of Applied Sciences.

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Acknowledgements

It is a great pleasure for us to organize the 1st Research Conference of the Design Factory Global Network.

It is a great pleasure for us to organize the 1st Research Conference of the Design Factory Global Network. DFGN is a like-minded family of 38 innovation hubs in different universities and research institutions worldwide. Shared values and practices enable us to collaborate across time zones and cultures, despite the difference in governance and setup. Design Factories are experimentation platforms, and our network moves towards an overarching goal: to create change in the world of education and learning.

This conference is taking place in unprecedented times as the global population faces enormous challenges such as climate change, resource stress, increasing inequality, and the Covid-19 pandemic. It is, therefore, timely to address how future change makers can answer these grand challenges. With this in mind, our Research Conference has constructed an extremely diversified and inspiring body of knowledge that:

- *Glimpses future practices to develop innovation capabilities through interdisciplinary higher education;*
- *Glances the methods and practices for co-creating the future; and*
- *Studies ecosystems for design-based innovation.*

This conference will expand the well-known *"Passion for Doing"*, which is core to the identity of the DFGN, to the *"Passion for Reasoning"*, which is critical in the research field. The merge of these two capstones will enable navigation in the ever-changing world, where systematic scientific research offers an objective understanding and tangible evidence of the future of education. By bringing together practitioners, researchers and students across the multidisciplinary fields to exchange knowledge, we allow trading ideas and initiating collaboration from around the world.

The 1st Research Conference DFGN.R 2022 hosted at NHL Stenden University of Applied Sciences, is organized alongside International Design Factory Week 2022. We are very excited to bring our like-minded family together after the very challenging and long previous years. We believe that this reunion and the contribution of this new body of knowledge will support building a novel future by setting new practices to educate the new generation of change-makers, equipping them to face complex challenges. The knowledge and experience detailed in these proceedings, together with the DFGN, are what we aspire to enable the Design Factory and other innovation centers to successfully contribute to creating a better Future for Design.

Preface from DFGN

Introduction from Scientific Advisory Board
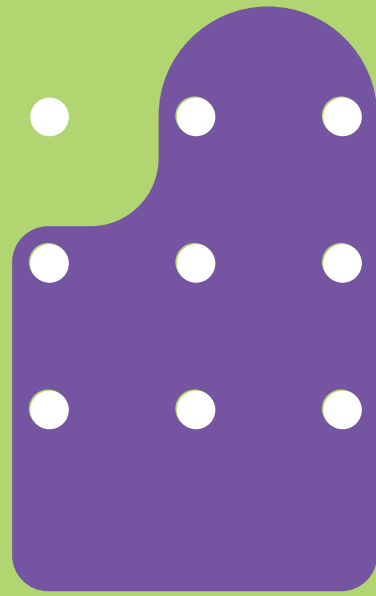
It is a great honour for us to serve as the Scientific Advisory Board for the 1st Research Conference of the Design Factory Global Network (DFGN).

The DFGN has existed for more than 10 years, bringing together people with a 'Passion for Doing' and developing higher education and institutions that are more co-creative and innovative. This emphasis on 'doing' is somewhat in contrast to regular universities, which are sometimes primarily known for their 'Passion for Thinking', or even for their 'Passion for Writing'. In one of the Design Factory (DF) annual reviews, this was discussed with some humour, by extensively mentioning everything that could be measured scientifically within the Design Factory in question. Like the number of cups of coffee drunk per year (several thousands). Or the length of plastic thread used by the 3D printing machines (several kilometres). Important information, but not really something to publish in a peer reviewed scientific journal.

Yet while the plastic thread and teaching collaboration across DFGN may be more visible, most institutions in the network also engage in academic research. The degree that this has connected to the Design Factories has varied, but we are excited to take a step forward to join forces not only in the development and education side of operations, but making connections in research. On the other side, we believe that research offers an avenue through which the 'tacit' knowledge and experience of the DFGN to become more widely available and is not merely limited to the partners within the network. Within all these unique and very different DFs, a wealth of valuable knowledge has been built up in recent years. Although some of this knowledge has been published previously, we are extremely pleased that the DFGN is experimenting with its role as a collective knowledge network, sharing its learnings through academic research.

The studies in these proceedings are primarily from institutions in the DFGN network. Most of the studies therefore deal with the process that have some connections to Design Factory activities. One of the recurring themes relates to the learning processes of students, examining innovation and creative capacity and how different experiences and factors can influence it. For example, Lahdenperä et al. look at the effect of a product development project course, Malge and Deo at the

influence of personal characteristics such as curiosity, diligence, and perseverance on the innovation capacity of students (Malge & Deo), and Torensma at experiencing art. This can be done through different methods, such as Klomp exploring how the open-mindedness of students may be mapped with transactional analysis and Figuerdo et al. look at the students' own perception of a certain capacity through interviews or questionnaires. Ylirisku and Koskela point out that capacity does not always have to involve in-depth knowledge, introducing the concept of "soft expertise as someone knowing just enough to talk about a specific subject without immediately developing in-depth expertise on it.

Numerous researchers also address collaboration specifically, examining the group process and cooperation in design teams. This may involve questions relating to the way in which people work together at a distance (Santana & Zancul), the way in which the performance of the individual is related to the performance of the team as a whole (Tan et al), the perception of staff and students regarding the importance of collaboration (Feng et al), and the way in which a collective innovation culture can be promoted (Thong et al). Sometimes the research is carried out by means of a case study (Krebs et al), but focus groups, in-depth interviews and questionnaires are also methods used by the various researchers.

Other studies zoom into specific courses and types of activities. For example, the effect of a certain type of co-creation workshop (Dieing et al). In one case, this involves a project involving more than 6 000 students (Riveros et al). The developments towards remote education, where students were taught from home, were examined in the paper by Taveter et al which examined the difference between physical and virtual co-design workshops. Research that also stems from working and learning at a distance is the paper in which Sarasvathi's Effectuation Theory is applied to an online cooking exercise to practice design-driven entrepreneurship (Iandoli & James).

Another emerging theme across the conference contributions is sustainability. For example, Lodewyckx et al. investigated the use of specific co-creation methods within the framework of the developing hydrogen economy, Ogink & Crul examine how designers can contribute to reducing the plastic soup in the ocean and Kirjavainen and Kuukka take stock of the sustainability competences that are important for designers. Others have developed a very specific methodology for working on sustainability, such as the Japanese Kintsugi approach described by (Spiegeler, Castañeda & Ackermann).

Finally, there are several studies that look at the functioning of the organisation as a whole. This can concern the degree of inclusiveness in the workplace (Keipi et al) or how ambidextrous project management can help organisations respond quickly to social change (Derksen). One of the longest existing Design Factories can even look back on an existence of more than 10 years, and in the paper its initiators try to surface the lessons learned in that time from the perspective of the Design Factory as a regional Community of Practice (Kocsis et al).

All in all, we can conclude that the very first Design Factory Global Network Research Conference has produced a diverse and inspiring body of knowledge presented in 22 studies, by 68 authors from 11 countries around the globe. As such, we're building a foundation for extending 'Passion for Doing' from education and development to research as a collaboration point across the network. By systematically reflecting on 'doing', we hope that these activities will be even more effective in the future and will contribute even more to educating a new generation of designers and innovators. With the complex questions and challenges that society faces, multidisciplinary cooperation is more essential than ever. Only when experts from different disciplines work together can we find the solutions the future demands. Which brings us back to the theme of this conference: 'Designing the Future'. Our hope and expectation are that the DFGN network, and the knowledge and expertise described in these proceedings, will help Design Factories and similar innovation hubs to make a successful contribution to the development of a smart, sustainable and inclusive future!

Peter Joore

Tua Björklund

Christine Thong

Eduardo Zancul

Saku Mäkinen
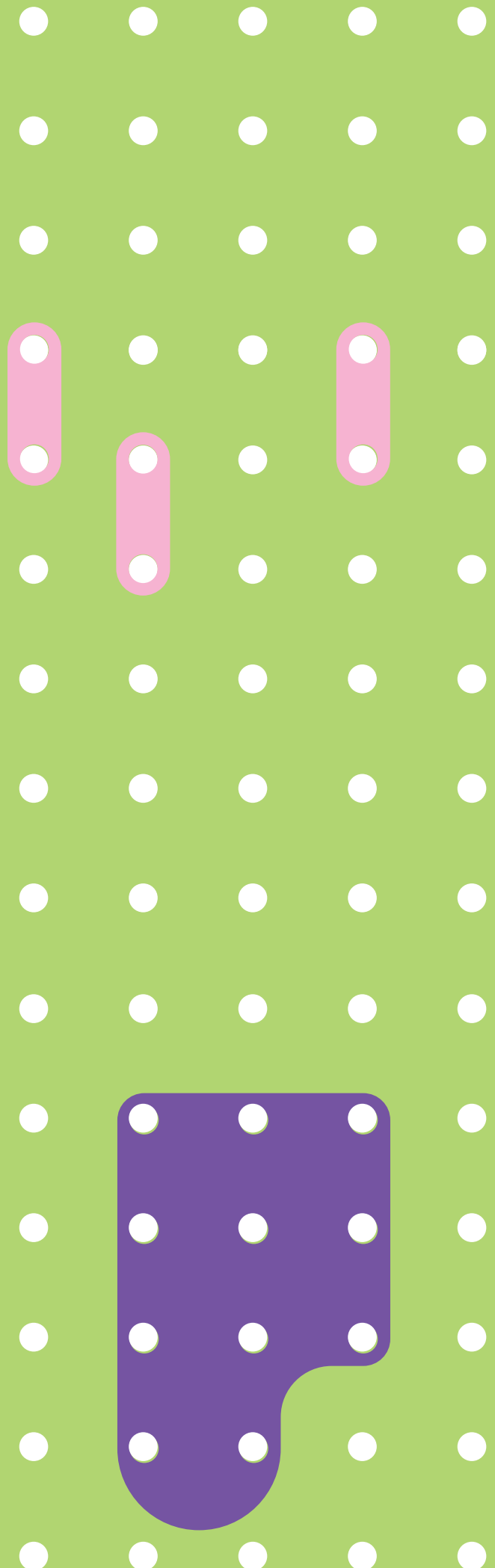
Theme 1:

Student's Learning Process
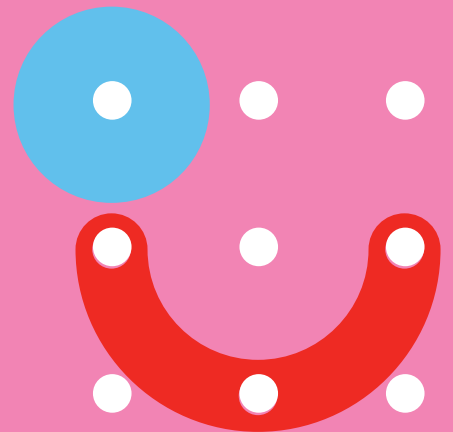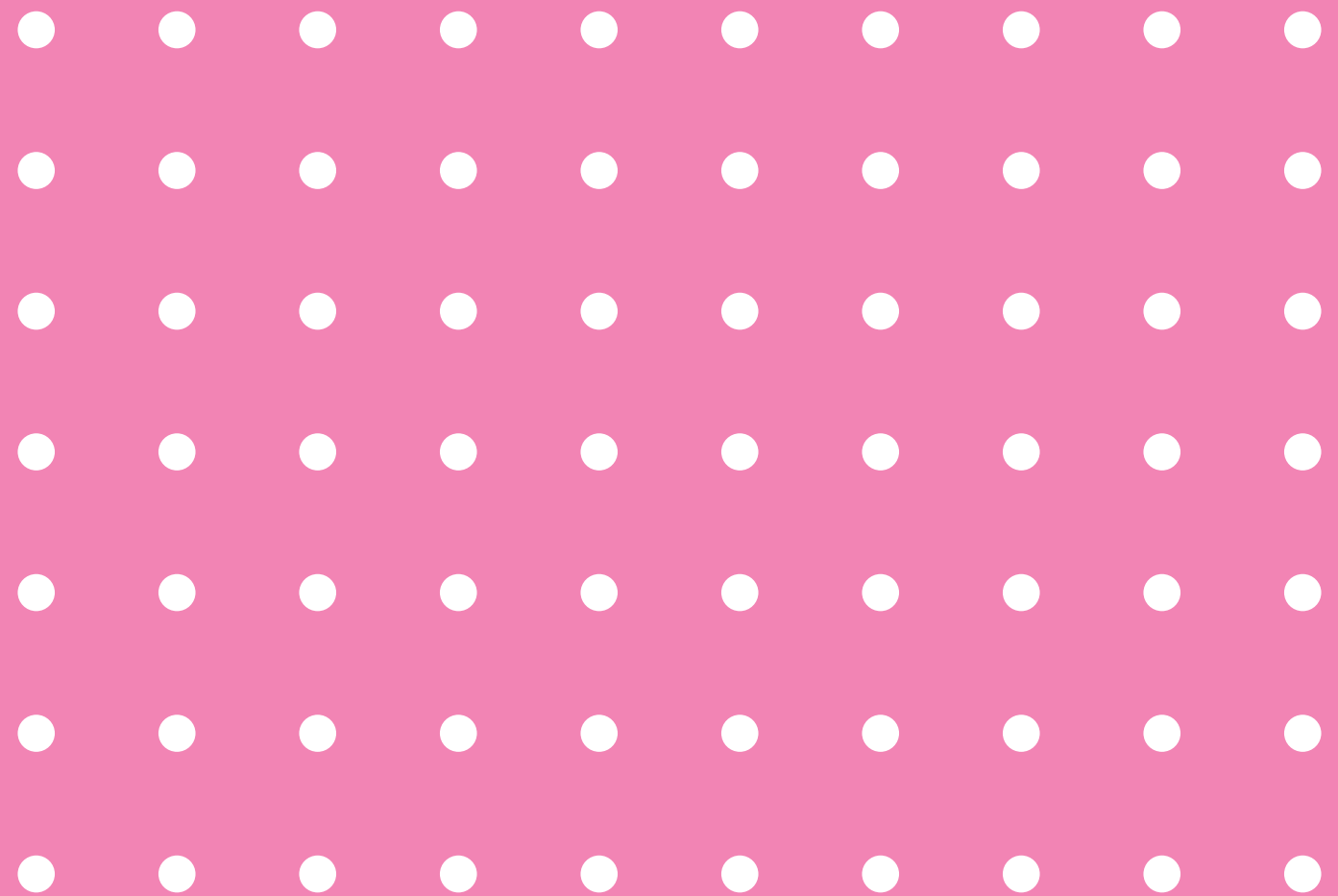
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Transactional Analysis and its impact on the open-mindedness of students

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ABSTRACT

PURPOSE

In educating our students, we are faced with the reality that the jobs we train our students for will probably no longer exist in the future. Therefore, we should teach our students skills that help them to be flexible and agile in an uncertain future and enable them to navigate unfamiliar contexts by themselves (OECD, 2019). These Future Skills are mostly general competences such as: autonomy, communication, self-efficacy, future mindset and creativity (Ehlers & Kellermann, 2019).

Research from Lahdenperä, Jussila, Järvenpää and Postareff (2022) shows that students who have developed general competences have better graduate employment prospects. These general competences are transferable into new career paths, which increases their chance of successful employment in the future. This emphasizes the importance of finding ways to support students in enhancing these Future Skills. Being open-minded seems to be an important key factor. That is also what students in one of RUN-EU's Short Advanced Programs stated. Open-mindedness refers to being receptive to other ideas and new experiences. In addition to helping you learn new things and grow as a person, it can help you become more optimistic and resilient in the face of life's challenges (Cherry, 2022). RUN-EU is an alliance of seven regional higher education institutions with the purpose to stimulate regional development (RUN-EU, 2020).

In this research we focus on the question whether Transactional Analysis (Solomon, 2018), used as a method for development of the Future Skill communication, has a positive impact on students' open-mindedness. Transactional Analysis (TA) is a practical and accessible theory concerning communication, personality and change. It provides the opportunity to learn how to communicate in an effective way by fostering and understanding peoples' motivations behind their communication, learning about communication processes and communication problems, about one's own role in communication and how to (positively) influence communication.

Research from Schaeper (2009) indicates that it is more efficient to learn general competences together with subject content than as an isolated academic competence or study skill course. In the minors of the Dutch Design Factory (DF) and the modules of a Finnish DF, we teach students the Future Skill communication by integrating the method of Transactional Analysis in the minor/module program.

RESEARCH ENVIRONMENT

The research is conducted in a Dutch and a Finnish DF. We specifically chose these two DF's, because they both practice Design Based Education (Geitz & de Geus, 2019). This prevents clouded results caused by different educational constructs. Furthermore, the two DF's already exchange experiences and information, and have the desire to further expand their collaboration in the near future. The possible differences between the two student groups are acknowledged to ensure the findings from this research are valuable for developing effective teaching approaches across the DF's. The selected students (see Research methods) in both the Netherlands and Finland are offered two TA workshops:

One at the start of the minor/module. The goal of the first workshop is to help the students get started. The session supports the process of creating a safe environment, finding common ground, and navigating differences (between different disciplines, different countries and different cultures). This workshop is about contracting, for example, making working agreements, setting learning goals, agreeing on how to work together, dividing team tasks and roles, and what to do if a problem occurs.

The second workshop is hosted when students have most likely experienced some difficulties in communication and are eager to learn how to handle difficult (communication) situations. The goal of this workshop is to help students become more open-minded, by helping them understand communication processes, get insights in the structures behind it and give them tools to steer communication in the desired direction and communicate more effectively.

METHODOLOGY

During this research study half of the students will learn about TA and the other half will not. The research is conducted in both semesters of the academic year 2022/2023. The first partial results are expected in December 2022. Table 1 shows which students will receive TA training.

The students are asked to fill in a questionnaire at the start and at the end of each minor/module. Students who took part during the first semester will be asked to complete an additional questionnaire at the end of the second semester, to note if the change is sustainable. We will use the Big Five Inventory (BFI) of John and Srivastava (1999) to measure students' general openness to experience. We chose this

questionnaire because it is scientifically validated and has proven to be reliable. We will combine the questionnaire with focus group interviews at the end of each minor/module to determine the influence of TA on changes in students' open-mindedness.

Additionally, we have asked the teachers involved to observe the students and to share their findings during future interviews.

Period	Minor/ module	With TA training	Without TA training
09/2022- 01/2023	FDP, Dutch DF	2 project groups*, **	2 project groups*, **
09/2022- 11/2023	SDS, Dutch DF	3 project groups*, **	2 project groups*, **
10/2022-01/2023	PDP, Finnish DF	40 students*	60 students*
01/2023- 07/2023	FDP, Dutch DF	2 project groups*, **	2 project groups*, **
01/2023- 04/2023	SDS, Dutch DF	3 project groups*, **	2 project groups*, **
01/2023- 03/2023	PDP, Finnish DF	40 students*	60 students*

*The definite number of participants is available at the start of the minor/module
**A project group consists of 5 students

IMPLICATIONS

If the research shows that TA indeed has a positive impact on students' open-mindedness, it is a promising method in educating our students to become flexible and agile future professionals. An interesting follow-up study could explore the effect of cultural background on open-mindedness and what that means for the way in which TA should be used. Since our research is conducted in only two, Northern European, Design Factories, we suggest that follow-up studies in DF's in various parts of the world be conducted, to achieve a more reliable measurement of possible cultural effects.

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FULL-PAPER:

Developing students' innovation capability through interdisciplinary product development projects for industry

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ABSTRACT

Innovation capability is an important skill for students in preparing for working life. Therefore, we investigated if student projects develop students' innovation capability. Data was collected from HAMK Design Factory students participating in Product Development Project (PDP) implementations. The results show that the students experienced an increase in their competences in constructing and applying knowledge, and collaboration and communication during the PDP implementations. This implies that students can develop their innovation capabilities already during an eight-week course. We argue that in PDP implementations, it is important to explicitly address students' innovation capabilities and their role in learning and knowledge creation.

KEY WORDS:

INTRODUCTION

In order to prepare the students for the world of work, the development of students' innovation capability is essential. In this study, we follow Hill and colleagues (2018) and conceptualise innovation capability as an individual's ability to engage in critical thinking and collaboration while adapting to changes and solving emergent problems.

Previous studies have addressed innovation capabilities in the Design Factory context. For example, Secundo and Moustaghfir (2016) studied innovation capabilities from the perspective of building blocks that support innovative approaches to learning. To continue, Heck (2017) investigated the impact of 'design thinking' applications in small and medium-sized enterprises' (SMEs) innovation capability. Furthermore, Munigala and colleagues (2018) propose future scenarios of Design Factory as an innovative experimental ecosystem, Kunnari and colleagues (2022) provide examples on utilising Design Factory principles in developing innovative spaces, and Freudenthaler-Mayrhofer and colleagues (2019) reflect on the Design Factory concept as an example of innovation teaching format. However, there is a lack of research directly addressing students' learning, more specifically how the Design Factory concept and learning environment support students' learning through the development of their innovation capability.

Following Soo and colleagues' (2002) sources-uses-outcomes model (see Figure 1), the theoretical underpinning of the present study is that the process of innovation capability development is closely related to students' knowledge construction, collaboration, and communication skills. This implies that in context of product development, applying knowledge acquired from benchmarking and user research is necessary for constructing new knowledge in the problem-solving process (Jussila et al., 2020). It can be reasoned that the success of this problem-solving process depends largely on the students' skills in communication and collaboration. Based on these premises, we formulated the following research question: *Do students experience that interdisciplinary product development projects develop their innovation capability?*

THEORETICAL BACKGROUND

Innovation capability has been described as "the ability of individuals to think originally and critically, adapt to change, work cooperatively and find solutions to problems as they occur" (Hill et al., 2018). Taking a process perspective on innovation capability, it can be described by a model of three phases, namely sources, uses, and outcomes (Soo et al., 2002). In this sources-uses-outcomes model, innovation is the outcome of idea generation, problem-solving, and creation of novel solutions that are based on acquired and absorbed knowledge from internal and external sources (see Figure 1). These phases can go by different names; for example, Koen and colleagues (2004) call the sources phase fuzzy front end (FFE), the uses phase new product development (NDP), and the outcomes phase commercialisation. In PDP implementations, the focus is on the two first phases, whereas outcomes and commercialization phases are something that the customer of the student project carries out after the completion of the student project.

Regarding its 'newness', an idea can vary from being new to an individual, new to the organization, new to the industry, or new to the world. Knowing whether an idea is new and how new it is requires benchmarking of existing solutions and user research (Charosky et al., 2018). Benchmarking and user research can, for example, uncover that a new idea of a product or service in one country has already been implemented elsewhere.

Student's good innovation capabilities can prepare them for the world of work. For example, widely adapted design thinking approach has both process and outcome-related value and effects in business context (see e.g., Calgren et al., 2014; McKinsey, 2018; Kujala, 2003). From the employee's perspective, the design thinking process has increased

knowledge, empowered employees as actors in process and decision making, and pushed companies towards holistic and unusual thinking (Calgren et al., 2014). Furthermore, the design thinking process has improved speed and quality of innovation process for example by enhancing collaboration between heterogeneous groups of people and team dynamics (ibid). In addition to the short-term benefits, the design thinking process can promote openness, empathy, and optimism and in that way, have a positive impact on long-term innovation process culture (ibid). In this sense, it can be argued that it is important to understand how the interdisciplinary product development projects with industry help students to develop similar innovation capabilities that are experienced in the world of work context.
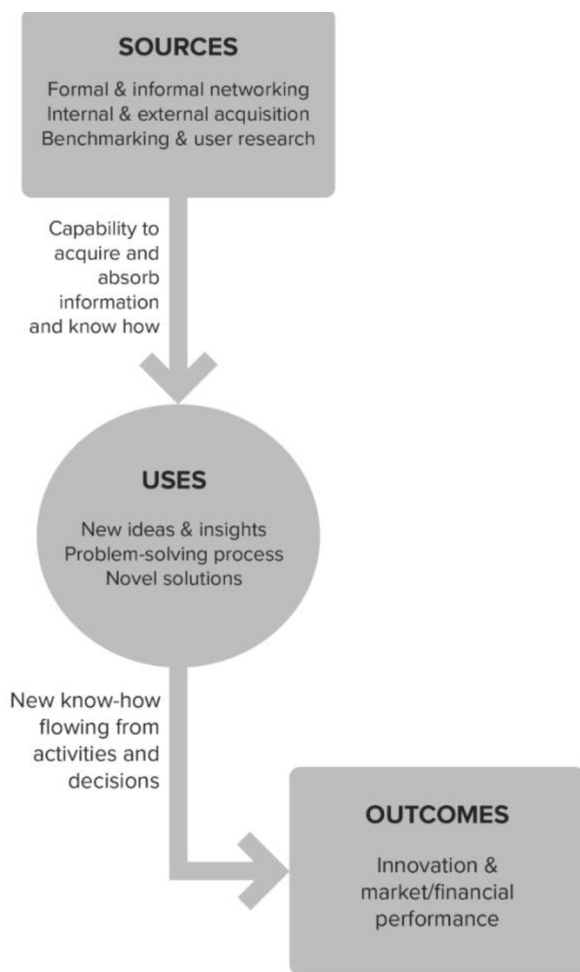

Fig. 1. The process of knowledge creation and innovation (modified from Soo et al., 2002).

METHOD AND DATA

The data was collected from students participating in two PDP implementations organised by HAMK Design Factory, Finland. The first PDP implementation was organised in Spring 2021, and the second at the turn of 2021–2022. The PDP implementations lasted 16 weeks, during which the students worked in interdisciplinary teams to solve project development challenges provided by the public sector and industry partners. For the first PDP implementation, there were 16 challenges provided by regional companies, municipalities, vocational education institutions, trade associations and research organizations. For the second PDP implementation, there were less challenges, so some student teams worked on the same challenge. These challenges were provided by cities and regional circular economy companies. Interdisciplinary teams were formed from students studying in the

Information and Communication Technology, Bioeconomy, and Sustainable Development Degree Programmes.

The students voluntarily answered an electronic questionnaire in weeks 8 (midway) and 16 (at the end). The questionnaire consisted of Likert-scale items (1 = strongly disagree, 5 = strongly agree) measuring students' experiences of the development of knowledge construction, collaboration, and communication skills. The items are from the HowULearn instrument and form two factors, constructing and applying knowledge, and collaboration and communication (see Myllykoski-Laine et al., 2022; Tuononen, 2019, 26). To further elaborate on the factors, the quantitative part was supplemented with a qualitative open-ended question (What was the most useful or important thing you experienced or learned during the study module?; see Mikkonen et al., 2018).

Because the sample sizes in this study were small, factor analysis was not conducted and instead, the factors were computed based on previous literature from the Finnish higher education context. Although drawn from the same population, the measurement points were not paired as the aim was to obtain anonymous data. The differences between the students' responses in weeks 8 and 16 were investigated using the Mann-Whitney U test suitable for independent samples and small sample sizes.

RESULTS

The results (Table 1) show that the students experience that their competences in constructing and applying knowledge, as well as in collaboration and communication increased during both investigated PDP implementations. The mean differences between the two measurement points range between .14 and .32 on a five-point Likert scale. The difference is statistically significant only in the Collaboration and communication factor in the year 2021 implementation.

To further illustrate how the two factors resonate with practice, we provide a few qualitative quotes from the students. As an example of Constructing and applying knowledge, a student stated that the most important thing they learned during the course was "finding the right information and using my theoretical knowledge [i]n practice" (Year 2022). Another student stated: "Developing indicators for [the project] taught me to seek information from various […] sources and to evaluate the qualities of a good indicator." (Year 2022). A student from the first PDP implementation reflected on collaboration and communication as they reported on the most important thing they learned during the course. The student stated: "Multidisciplinary team brought various points of view to the project; this is how I learned that it's beneficial to view things from many different perspectives." (Year 2021). Another student described their learning outcomes related to collaboration and communication as follows: "I learned that not everyone is an engineer. To the customer and even to your own team, you need to explain things much clearer, more visually, and more in detail than I had thought. I value understanding this a lot because this will save me from many embarrassing pitfalls later in life." (Year 2021).

Factor	Year	Measurement point 1		Measurement point 2		Mean difference	Mann-Whitney
		N	Mean	N	Mean		
Constructing & applying knowledge	2021	42	3.48	47	3.65	.16	U=1113.5, p=.297
	2022	20	3.44	12	3.58	.14	U=137.0, p=.526
Collaboration & communication	2021	42	3.75	47	4.07	.32	U=1238.5, p=.037
	2022	20	3.67	12	3.86	.19	U=131.5, p=.659

`Table 1.` The results from the two PDP implementations.

DISCUSSION AND CONCLUSIONS

The goal of this study was to explore if students develop their innovation capability during a short-term interdisciplinary product development project with industry collaboration. As the main observation of the present study, the results suggest that students can develop their innovation capabilities already in an eight-week course. Furthermore, the results show that working in interdisciplinary teams and solving authentic product development challenges provided by public sector and industry partners support students in constructing and applying knowledge, and collaboration and communication, both essential in knowledge creation and innovation processes. These students' innovation capabilities have similarities to the employee-related innovation capabilities studied in the business context (Calgren et al., 2014) and underline the relevance to the world of work.

There are three main suggestions for further research. Firstly, it is notable that as the sample sizes in this study are small, the conclusions can only be generalised to the investigated context. Our results are encouraging, but future research is needed to replicate the study with a larger sample, different implementation durations, and in other comparable design education contexts. Also, it would be interesting to study the long-term impact of the innovation capabilities students develop during the PDP implementations.

Secondly, in the two PDP implementations investigated in the present study, the focus was on the design thinking process with a tangible outcome, and the innovation capabilities and general competences were not made explicit to the students. We consider that the positive impact of these implementations is largely due to a mere exposure to the operational learning environment. Therefore, we suggest that it is important to explicitly address the innovation capabilities, general competences and their role in students' learning, knowledge creation, and innovation.

Thirdly, multidisciplinary collaboration is at the heart of innovation processes. Our results highlight the improved capabilities in collaboration and communication during design process, a finding also addressed in the world of work context (see e.g., Calgren et al., 2014). Building on these collaborative strengths, it would be valuable to extend development of innovation capabilities towards systems thinking. For example, Systems Intelligence has recently been shown to correlate with perceived performance, emotional intelligence, organisational learning, and wellbeing (for an overview, see Törmänen, 2021; see also Jumisko-Pyykkö et al., 2021; Jumisko-Pyykkö et al., 2022). By developing innovation capabilities parallel with Systems Intelligence, we might improve both the short and long-term quality of the process and outcome phases of the innovation processes.

ACKNOWLEDGEMENT

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ABSTRACT

INTRODUCTION AND IMPORTANCE

Can art ¬experiences contribute to students' creativity? In this article, we will discuss whether art reception can lead to an experience that fosters the creative abilities. We do this by considering a theoretical approach to art and reviewing literature on creativity enhancement. Van Heusden argues that in both making and experiencing art two cognitive skills are decisive. Those skills are imagination and reflection. It is these two skills that relate art and creativity: the imagination is by definition creative, and creativity cannot exist without imagination. Reflection is equally necessary for creativity because it enables individuals to value creative ideas. Through art, people give expression to their experiences with life. The experience after sensing of art (seeing, hearing, listening etc.) has a potential transfer effect for the imagination, reflective cognition, and use of media. Based on the literature discussed it seems plausible that imagination and reflective cognition are determining factors in creativity. In an educational setting it is these two abilities that need to be stimulated through art to foster the creative abilities of students.

KEY WORDS:
art reception, creativity enhancement, cognition, imagination, reflection

INTRODUCTION

In this paper we describe how art reception – the experiencing of works of art – might play a role in enhancing the creativity of design students in higher education. We do this by, first, presenting a theory that sketches the cultural / cognitive processes involved in art reception and, secondly, relating the theory to research on creativity and creativity enhancement. As we are interested in fostering the creative abilities of design students, we mainly deal with creativity in the context of education/ learning. We take creativity to be the ability to produce new ideas that are regarded as valuable within a social context. We thus align with the broadly held views on creativity as an individual ability but valued within a social context (Kaufman & Sternberg, 2010; Plucker, Beghetto, Dow, 2004; Ouwens, 2013; Glăveanu, 2010; Csikszentmihalyi, 1999).

The review allows us to better understand the relation between art reception and the fostering of creativity. In the context of contemporary education creativity is hailed as an important learning outcome (Supena, Darmuki, Hariyadi, 2021; Patston, Kaufman, Cropley, Marrone, 2021; Puccio, Lohiser, 2020; Grigorenko, 2019), it being one of the infamous 21st century skills (Zakiah & Fajriadi, 2020; Nurlenasari et al., 2019; Trilling & Fadel, 2009).

THEORETICAL BACKGROUND

The questionable importance of art

For centuries, arts and crafts, engineering, architecture, and design were mentioned in one and the same breath. Böröcz (2014) argues that it was only after the Second World War that what had previously been a happy marriage became a divorce: in a highly industrialised society, design and architecture were embraced, reformed, and made the property of commercial industries. Arts and crafts became a hobby. In the Netherlands, art even became known as a "linkse hobby", a leftist hobby, with which it was dismissed by a large part of society as a mere pastime for progressively oriented intellectuals. The very raison d'être of art was called into question. In the last decades research on the benefits of art appeared in educational literature (Winner, 2018; Sawyer, 2017; van Heusden, 2010; Harland, 2008) and in the field of neuroaesthetics (Brown, Dissanayake, 2018; Christensen, Gomila, 2018; Zhou, 2018; Thomson, Jaque, 2017; Leder, Markey, Pelowski, 2015). There seemed to be a desperate need to prove that art is not just for art's sake. These studies shed new light on how art works - based on empirical evidence. Below we discuss three of them.

John Harland et al. (2008) conducted extensive research into the transfer effects of art in the classroom and concluded that, among others, making art (which we do not regard to be the same as art reception) leads to an increase in creative thinking and doing. Through art education, children learn to better control materials and how to make something new with that material. To make something new, possibilities must be explored, choices are made, and a plan and schedule have to be followed. The choices may be individual but are also subject to what others think. Harland showed that art education can be seen as an exercise in creativity.

Psychologist Ellen Winner has recently collated dozens of studies on the effects of art and concluded that art is certainly not just for art's sake: it influences all kinds of cognitive and metacognitive skills. For

[1] This article is a condensed version an article that has been written for a doctoral research project in which we investigate how art can be used to foster creativity in design processes.

example, art makes people look more closely at details, helps them look more closely at themselves and at others, increases their ability to visualise ideas and leads to greater self-confidence and the courage to take risks (2013; 2018).

A third study that stands out is the one conducted under the auspices of Barend van Heusden: at several Dutch schools Van Heusden investigated art and cultural education. This study dealt with both art production and art reception in cultural education. Van Heusden tested the theoretical hypothesis that art is a process in which experiences are reflected upon through imagination. Following Donald, Van Heusden considers art to be distributed cognition or shared experiential knowledge. Art can thus be regarded as a form of metacognition. Van Heusden and colleagues argue that production and reception of art may lead to greater cultural awareness (Gielen, Van Heusden, 2015; van Heusden, 2015 a; 2015 b; 2018).

The three studies mentioned allow for a narrative on art that underlines its importance for human existence: through experiencing art people develop cognitive skills that are useful in fields outside of art and it enables them to grow into worldly citizens with a strong cultural awareness. To understand whether there is a relationship between art reception and fostering creativity, we will take a closer look at Van Heusden's approach in the next section. The three studies show that art has an effect on several dimensions: the ability to reflect, imagination and the use of or control over media. With media Harland refers to the control of material. Van Heusden also mentions body, language, and graphic media as forms of media.

Art as Reflective Imagination

When someone senses – views, hears, touches or for instance tastes – a work of art, this may lead to an experience that is different from other experiences. The making and the viewing of art is described by some as an aesthetic experience (Thomson, Jaque, 2017). Wah (2017) and Van Heusden refer to it as reflective imagination, a process whereby an observation is linked to existing memories and understood through the imagination.

According to Van Heusden (2020), art is a form of culture and cannot, therefore, be understood without a sound theory of culture. In his approach, he assumes that reality as such has no meaning and that people give meaning to it based on their experiences. They do this to hold their ground in a constantly changing reality, perhaps to get a grip on that reality. One of the ways of giving meaning to experiences of life is through art. Art can be seen as a complex cognitive process that involves reflecting on experiences through the imagination. This applies both to art production and art reception. A characteristic of culture is that it can be recursive, that it refers to itself. Art is an example of recursive culture: works of art can refer to the culture in which they were created.

Van Heusden's ideas can partly be traced back to those of Dewey who regarded art as an experience. Dewey (1934/1958) looked art as a dialectical process in which the artist and the viewer meet through a work of art and an exchange of information takes place about the mental and material environment, in short about culture. Another influence on the work of Van Heusden is Donald (1991; 2006) who takes art to be a form of distributed cognition: experiences are shared and interpreted within a socio-cultural context through artefacts such as art objects. According to Donald, human culture can be seen as a

vast network within which cognition is distributed. The minds of many are connected through these networks. Most art can also be called metacognitive and therefore by definition self-reflective: an artwork compels reflection on the mind of the artist and on the culture in which the artist emerged (Donald, 2006, 5).

Within these distributive networks artists take a "highly placed" position and they influence the cognitive activity within a social group (Donald, 2006, 4). When an artist expresses experiences, this is done through iconic and symbolic signs using movements, sounds, colours, words and, for example, narrative structures (van den Braembussche, 2000). When someone relates to a work of art, these iconic and symbolic signs are, as it were, "read". Again, this happens within a cultural context: how someone interprets the signs depends on the culture in which they life. According to Lévi-Strauss (1958/2021), every human being has the innate ability to produce and understand such signs.

Van Heusden (2009; 2010; 20115a) states that all experiences are cognitively processed through four basic cognitive skills. These skills are perceiving, imagining, conceptualising, and analysing. Van Heusden based these skills on Donald's theory (1991) in which is described how the human mind and culture evolved in three stages (mimetic, mythic and symbolic). He also partly incorporated Piaget's (1983) theory on accommodation and assimilation. Assimilation (imagination and conceptualization) is the process of using existing knowledge and skills in new situations. Accommodation (perception and analysis) is the process of adapting existing skills or knowledge to cope with a new situation. The four cognitive skills enable people to fit an experience into existing knowledge (from previous experiences) or to construct new knowledge.

Van Heusden builds further on Donald's principles and argues that all four basic cognitive skills may be involved in an art experience, but that imagination in combination with reflection are especially decisive. In education reflection is often related to the learning process itself. In our definition reflection is a process that enables one to reflect on experiences, cognition, culture, and oneself. Wah (2019) argues that the reflective imagination is unique to humans: it is this ability that enables people to create art and undergo artistic experience. Reflective imagination, Wah argues, allows humans to empathise with others and themselves through music, dance, song, visual art and spoken or written language. That humans can do this, Wah considers, brings with it a series of advantages because, she argues, the reflective imagination via an artistic experience is important to "activating memory systems, regulating emotional expression, promoting mutuality, training attentional focus, developing motor control, enabling prediction, free¬ing from actuality, sourcing identity, complexifying consciousness, and affording behav¬ioral adaptation." (Wah, 2019, 53).

METHOD AND DATA

Art and creativity are two terms that are popularly used as equivalent (Martindale, 2007), the assumption being that art is creative. This is quite plausible when we understand that art is the result of the imagination. Imagination combining memories to create something new, is by definition creative. It may therefore be worthwhile to look at what the literature on creativity says about the role of imagination and reflection. Scientific journals and books from the past five years were searched for, among other things, creativity, creativity enhancement

and imagination. This was done via Google Scholar, JSTOR and SmartCat. The search string that was entered[2] yielded 82,688 results. These were reduced to peer reviewed articles and chapters. This brought the total down to 12,044 results. The selection was narrowed down by a new added search string and the remaining 240 articles were compared and, based on presenting an original theory, relevance for the subject of this article and not being part of other domains (like management, technical engineering, and artificial intelligence). A total of 81 articles remained that seemed to give a reliable picture of current knowledge on creativity enhancement.

RESULTS

Reflective imagination in creativity

In earlier studies, creativity is explained in terms as *divergent* and *convergent thinking*, *lateral thinking* (De Bono, 1990; 1992), *category combination* and *reorganization* (Mumford e.a., 1994), *transformational* and *metaphorical thinking* (Ward & Kolomyts, 2010). In these early studies steps of the creative process are given. A systematic theory of creativity is, however, lacking. Only in the last two decades has there been theory development that takes cultural and cognitive processes into account (Glăveanu, 2010; Csikszentmihalyi, 1999). Imagination and reflection are sparsely mentioned. Rasse and Gibbs (2021) argue that divergent, convergent, and metaphorical thinking are possible because of imagination. Szczelkun (2018) states that it is imagination that enables humans to evoke images, ideas, and sensations in the mind without direct input from the senses. Razdorskaya states, "reflection brings the elements of the convergent thinking to the creative structures of thinking, in particular, divergent thinking, structuring and organizing the progression of creativity" (2015, p.435).

In recent decades, there has been an increasing focus on creativity and its enhancement within neurological research (Thomson, Jaque, 2017). In that research, too, there is increasing emphasis on both imagination and the ability to reflect. O'Mara (2019) and Heinonen e.a. (2016) name several brain networks that seem to be decisive in the creative process. They mention the Executive Attention Network or Central Executive Network, the Imagination Network also known as the Default Mode Network and the Salience Network. The Executive Attention Network is used to focus, make decisions, and pay attention to detail. The Imagination Network makes empathizing possible but is also used when people are daydreaming. The Salience Network filters the information coming in through the senses and helps people make decisions. By alternating between these networks, people can come up with new ideas and assess how valuable they are or will be in a social context. A study by Beaty and colleagues (2018) also shows that all three networks are active during a creative process. Both coming up with new ideas and determining their value are done through imagination and reflection: through imagination, people imagine themselves in situations that do not (yet) exist and what the effect of their idea will be.

[2] The first search string was: ("creativity" OR "creativity enhancement" OR "creative potential" OR "creative cognition" OR "creative thinking" OR "creative process" OR "creative environment") AND ("art" OR "art experience" OR "art reception" OR "art education") AND ("learning" OR "cognition" OR "education" OR "school" OR "enhancement" OR "development"). In a second search the string was extended with: ("imagination" OR "reflection") AND ("psychology" OR "sociology" OR "neuroscience").

Enhancing creativity

Creativity is seen as a quality that is naturally present in all of us, although in some more than in others (Hoogeveen, Bos, 2013). One characteristic of "creative persons" is that they can combine previously unrelated ideas (Guilford, 1950; Kaufman, Sternberg, 2010) and value them within a social context (Mumford, Reiter-Palmon, Redmond, 1994; Csikszentmihalyi, 1999; Glăveanu, 2010). Neurological research shows that a brain with more complex and better functioning connections is capable of greater or more diverse creativity (Kaufman, Sternberg, 2010).

The degree of creativity is determined by various factors. Guilford (1950; 1967) mentions intelligence, Glăveanu (2010) the presence of knowledge and skills offered within a social context, Csikszentmihalyi (2013) personal characteristics such as curiosity and the need to be creative. Sawyer (2012) states that a very specific form of knowledge is needed that combines knowledge of facts and procedures with a certain empathy. Sawyer describes this as knowing different perspectives. To achieve authentic, unexpected combinations, it is important that someone has a broad knowledge and a lot of experience in one or more domains. This experience can be gained by learning a lot from other people: the more people you meet, the more perspectives on life someone can get.

Research into the development of creativity in education has produced several practical insights. James and Brookfield (2014) mention three axioms that are important for student motivation in imagination: 1. skills and content to be taught must be meaningful; the imagination is stimulated when connections, patterns and new questions are addressed, 2. there must be variation in the way the skills and content are presented; students are multiple intelligent and that intelligence must be deployed in multiple ways and 3. students must be confronted with the unexpected, with something that takes them out of their daily routine; the imagination is used more strongly when there is a threat or confusion to the everyday and familiar. What these axioms make clear is that individual creativity depends on external factors: there must be a need, a contextual challenge and it must occur outside the everyday and the familiar.

DISCUSSION AND CONCLUSIONS

In conclusion, we can cautiously draw parallels between the processes of art reception and creativity. Reflective imagination seems to be the common thread:

- reflective imagination is at the heart of the artistic experience.
- reflective imagination determines the way one interacts with a work of art.
- imagination is the leading cognitive skill in the emergence of a creative idea.
- reflective imagination enables people to assess the value of a creative idea in a social context.

Harland (20080, Winner (2013, 2018) and Van Heusden (2018) have shown that art production and reception build on three cognitive dimensions: reflective cognition, imagination, and the use of media (i.e., use of body, objects, language, and symbols). These three dimensions are not exclusive to art: they are skills that are considered important in all kinds of fields. Yet in art they join forces.

Perceptual knowledge according to Sawyer (2012) is the kind of knowledge that is needed to be creative. The more perspectives

someone has, the more creative that person is. Art may very well provide these perspectives – or at least a perceptual openness of the world and a deeper insight in the complexity of our existence. The function of art is not to entertain or to dictate how we should live, but it is rather "a means to produce meaning about some aspect of the world" (Van Heusden, 2015a, 385).

Based on the discussed literature, a relationship between art reception and fostering creativity seems likely, as both are strongly determined by reflective imagination. This does not entail, obviously, that we now have a recipe telling us how to make use of art in the classroom to enhance students' creativity. After all, there are more factors that play a role, such as the kind of art and if it connects to the culture in which it is received, individual characteristics such as cultural awareness and intelligence and the need to arrive at a creative product in a social context. When students are brought into contact with art, it should be done in such a way as to create an experience that can be reflected upon and may lead to new perspectives. In a follow-up study, we will examine which art can achieve the intended effect with the target group (design students) and under which circumstances the selected art should be offered, how often this should be done, and which educational setting should be considered.

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Future-ready skills development through Experiential Learning: Perceptions from students working in multidisciplinary teams

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ABSTRACT

This paper addresses the learning outcomes and student perceptions of the Aalto University Product Development Project course (PdP), which promotes experiential learning and where multidisciplinary master student teams work on industry-based projects. These outcomes were collected through a questionnaire filled by students voluntarily, which focussed on what were the main competencies, where they were acquired and what was the core learning. The results highlight the significance of interpersonal skills, which formed the most notable category reported by students, and were perceived as critical for project success. Furthermore, the study highlights the importance of the multifaceted role that prototyping plays in communication and sense-making.

INTRODUCTION

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The future of work presents educators with a challenge: given the rapid rate of technological development, the fast-changing pace of social and environmental trends, and rapidly changing global socioeconomic positions, how does higher education empower graduates to succeed in the workplace? This question responds to the need to include 'future-ready' skills in learning experiences, equipping students to navigate future risks, complexities and opportunities (Holloway et al., 2019). Students must develop various personal and professional skills to succeed in the industry. Organisations expect new professionals to contribute not only to disciplinary knowledge, but also through communication and collaboration. This has highlighted the need for soft skills development during education and the ability to integrate different knowledge areas (Stewart et al., 2016; Nicola, et al., 2018; Succi et al., 2020).

The development of collaboration, communication, creativity and other noted 'soft skills' has been difficult to achieve within traditional formal education paradigms that place the instructor central to the learning environment (Fisher et al., 2014). More learner and learning-centred paradigms have addressed some of these challenges (Vogler et al., 2018). These approaches include problem and project-based learning, grounded in experiential learning, traditionally offered in a physical environment.

Claxton, Costa and Kallick (2016) note that curiosity "also involves a deeper pleasure in making discoveries and an openness to novelty and challenge. To develop such inclinations, students need ongoing opportunities, encouragement, and guidance in various contexts" (p. 61). The link to curiosity is specifically relevant to design and to disciplines that promote creative problem-solving as part of professional core capabilities.

Many universities have defined objectives to support the development of industry focussed core capabilities (Aliu et al., 2021). Critical skills include oral and written communication, problem-solving and the ability to collaborate (Rios et al., 2020). The same skills were considered essential by STEM graduates, along with creativity, intercultural communication and entrepreneurship (Lavi et al., 2021). This leaves the question of how to assess learner achievements and skill development in the context of Experiential learning or problem-based learning (PBL). Constructive alignment is often presented as a notion that expresses the extent to which the training programs' intended goals align with the overt and unexpected goals of the assessments (Biggs., 1996). However, Vleuten and Schuwirth (2019) assert that, if there is a discrepancy between the two, the evaluation impact frequently precedes the intended learning strategy. To properly comprehend this discrepancy, one should evaluate significant frictions surrounding evaluation in a PBL environment. Hence, PBL is believed to encourage the development of skills other than just knowledge, such as teamwork and communication, which are more domain-independent. Some initiatives to develop more adequate ways of assessment have been made in response to the apparent tension between what was normally assessed and what was intended to achieve with PBL educational approaches. Consequently, this research explores what students from a collaborative multidisciplinary course perceive as the competencies required to complete a project successfully and what their core learnings were during it. Since experiential learning-based courses tend to cultivate more work-life skills, this study collects student perceptions to understand the impact of experiential and problem-based courses, shedding light on what skills and attitudes are fostered. The study utilised two research questions:

(i) What skills do students consider important for successful project

completion within the context of experiential learning?

(ii) What do students consider to be their core learnings from successful project completion in the context of experiential learning?

The findings of this study present the students' skills development from a single course and are not intended for extrapolation into generalised understandings. Instead, they represent the first sample from a more extensive collective case study, exploring the phenomena against the backdrop of a global pandemic.

THEORETICAL BACKGROUND

Experiences incorporating multicultural and diverse conditions provide a unique space for learning, positioned at the border of disciplinary, cultural and social groups (Klaassen, 2018). There, learning occurs through experiential practice, emphasising experiences, and seeing education as a social process (Tuulos et al., 2016). Experiential learning, also known as learning by doing (Dewey et al., 1915, cited in Gentry, 1990) or experience- based learning (Wolfe et al., 1975, cited in Gentry, 1990), is defined as the act of learning from experiences. It involves a high level of engagement from participants (Lewis et al., 1994; Gentry, 1990), viewing "learners as active participants," acknowledging previous learnings as foundations for further learning, promoting "interaction with others, leading to greater understanding" (Hedin, 2010, p.109). Experiential learning theory is defined as the process whereby knowledge is created through experience transformation (Kolb, 1984). Knowledge results from the combination of grasping and transforming experience. To successfully implement those methods, the learner must go through four stages: 1) concrete experience, 2) reflective observation, 3) abstract conceptualisation, and 4) active experimentation. Therefore, experiential learning relies on the provision of an experience and reflection upon the experience (Fowler, 2008), the former being dependent on factors such as the degree of involvement of the student, subject's relevance, depth of learning achieved, proximity to real-life environments (Fowler, 2008; Mason et al., 2013; Cooper et al., 2004).

Team-based learning can be more engaging (Balan et al., 2012), and multicultural teams can strengthen global competencies (Oda et al., 2017). Bailey et al. have also indicated the advantages of cognitive diversity within team-based learning activities (2021). The benefits of multidisciplinary knowledge are not always guaranteed (Garcia-Rodriguez et al., 2012; Lüthje et al., 2006 as cited in Bailey et al., 2021) and thus, to facilitate results, developing a shared sense of purpose is deemed essential (Kayes et al., 2005). Team members need to feel included, and a sense of trust and psychological safety should also be provided (Kayes et al., 2005).

Moreover, Aronson & Patnoe (2010) present effective teams through the metaphor of a Jigsaw model whereby members should view themselves as different pieces of the puzzle, fitting together (as cited in Bailey et al., 2021). Thus, student teams within experiential entrepreneurial education should be multidisciplinary, motivated, and must be supported by facilitators and educators in a pull- based learning model. Student interactions can be a key success factor of experiential entrepreneurial education methods if the roles of managing, using, and creating new knowledge and information can be successfully organised (García- Rodríguez et al., 2012).

Eppinger and Kressy (2002) indicated student empowerment, student appreciation for other disciplines, team working skills, communicational and project management skills as lessons learned from their 10 years of interdisciplinary product development courses at MIT[1] and RISD[2]. Wiesche et al. (2018) discuss the importance of establishing interdisciplinary teams for design-oriented project courses to foster and support creativity and novelty. Moreover, interdisciplinary teams also better simulate real-world environments (Wiesche et al., 2018).

Lastly, prototyping, a crucial component of design- oriented projects, was defined as the means for the teams to not only refine and iterate their concepts, but also to communicate ideas within their teams and receive feedback (Lande & Leifer, 2009). Prototyping can be seen, for the student teams, as a valuable starting point towards grounding and directing the project, improving their working efficiency, and becoming more knowledgeable about the topic at hand (Lande & Leifer, 2009). Olsen (2015) also indicates that prototyping supports the thinking process of innovators as it allows them to build "simple models or drawing sketches before knowing the answer" to the questions at hand (p. 183).

METHODS AND DATA

This study examines the students' self-reported skills and key learnings acquired through multidisciplinary, project-based and experiential learning at the PdP (Product development Project) course at Aalto University. A questionnaire completed by 33 students from the 2021-2022 PdP course captured skills students believe they developed during the course and the core learnings attained, employing problem-based (PBL), integrative and experiential learning. Therefore, in this study, learnings are defined as the measurable aptitudes acquired as a result of participation in the PdP course. Whereas skills represent one's ability which might spring from previous knowledge and practice. The study's research instrument allowed students to share what they believed the critical skills necessary for a successful course completion were and where those were acquired.

Integrative learning is facilitated through multidisciplinary student teams' engagement as they explore and aim to understand knowledge instead of 'make sense of knowledge' (Ashby et al., 2019). The PdP course allows students to explore previously acquired methods and knowledge in practice, fostering new learning beyond their study fields. Due to the Covid pandemic, during the 2021-2022 academic programme at Aalto restrictions were being lifted, but still influenced the educational environment, leading to the adoption of online or hybrid options, where accessible content and learning experiences for isolated students were required. Thus the questionnaire was made available digitally and physically. The questionnaire included quantitative and qualitative questions and focused on reflecting on the most valuable skills used by students for the project's success and identifying their core learnings after course completion. It posed three core questions:

What were the main skills that made your PdP student project successful?
Where did you acquire the key skills for your project?
What was the core learning?

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[1] https://www.mit.edu/
[2] https://www.risd.edu/

The first and second questions were addressed by determining numerical values of perceived skills to establish the most frequently noted. The questionnaire included initial pre-listed skills from all subject areas represented in PdP groups, with multiple spaces to add individual responses. The subject areas represent the most prevalent among registered participants, namely: Design, Mechanical Engineering, Electrical Engineering, Information Technology and Business. The fields were cross-referenced with students' undergraduate fields and interviews with the primary lecturing staff and faculty within the PdP program. Active lecturing staff reflected on student deliverables (from both past projects and the 2022 cohort) and suggested the initial skill list associated with each of the various fields. To ensure students could capture additional skills, each field included open spaces to capture individual perceptions. The set of soft skills included in the questionnaire was adapted from those identified by Lippman, Ryberg, Carney and Moore (2015) for youth workforce success: social skills, higher-order thinking, self-control, communication skills, teamwork, positive attitude, and responsibility.

In the third question, the key areas of learning that students indicated the course facilitated were captured qualitatively in an open-question format. These observations provided additional insights and contextual descriptions related to the skills indicated. The questionnaire was administered after the final course evaluation, ensuring voluntary participation. In total, 33 students participated in this study, representing 60% of all course participants[3]. Table 1 presents the team role and disciplines of the participants.

Background Information	Questionnaire Respondents	Total (n)	Total (%)
Total number of respondents	PdP students	33	100%
Role in the team	Team member	29	88%
	Project manager	4	12%
Discipline	Design	4	12 %
	Mechanical Engineering	15	45 %
	Electrical Engineering	4	12 %
	Information Technology	2	6 %
	Business	3	9 %
	Other	5	15 %

Table 1. Background information of the respondents.

Student response	Assigned open codes (focussed code)	Emerging themes
"Coming from different culture, most of the time, I just studied theoretically, here beside building a physical device, I learnt about user testing, prototyping, working with very different students from different backgrounds and set a milestone"	Multidisciplinary teamwork Multicultural teamwork	Interpersonal Skills (IS)
	Product development process	Product Development (PD)
(Mechanical Engineering Student)	Management and organisation	Project Management (PM)

Table 2. Only students from Aalto University are considered in this study.

To allow students the opportunity to discuss their perceived core learning in their own words, the third question was open. Students' written responses were analysed and coded. Table 2 shows an example of the coding allocation. The open codes were reviewed to establish relationships and form focused code groups. Once all codes were reviewed, the emerging learning themes were established.

RESULTS

The questionnaire respondents identified the skills most critical for their success correlated to personal, interpersonal and team development and engagement. The skills (n=43) students selected from a pre-list were organised in a hierarchical order in Table 3. These responses show the main competencies students believed were required during the PdP course, and where they acquired them. n=5 students reported less than 20 listed skills, n=14 between 20 and 30 skills, and n=14 more than 30 skills. Most noted ten skills were the ability to communicate efficiently with team members from different backgrounds (73%, n=24 of the respondents) and working in a collaborative way that recognises different opinions (61%, n=20). The ability to resolve conflict was selected by more than half (55%, n=18) of the participants. Additional skills include managing team time effectively (61%, n=20) and communicating your challenges effectively (67%, n=22). The experimental nature of Product development contributed to creative problem-solving skills (48%, n=16) and to the personal ability to adapt to unexpected challenges (67%, n=22). The skills relating to prototyping include prototyping as a method to test ideas (70%, n=23), a form of communication (58%, n=19), and a way of thinking (52%, n=17). The relevant presence of prototyping related skills highlights that prototypes can often be useful and necessary tools for consolidating design knowledge (Menold et al., 2020), and promoting mental models or ways of thinking. Furthermore, prototypes can also be perceived as communication tools and embodiments of design thought (Lauff et al., 2019). Our study raises awareness of the role of prototyping in experiential learning and product development, placing 'making' in the centre of discovery, communication with others, and a better understanding of the challenge addressed.
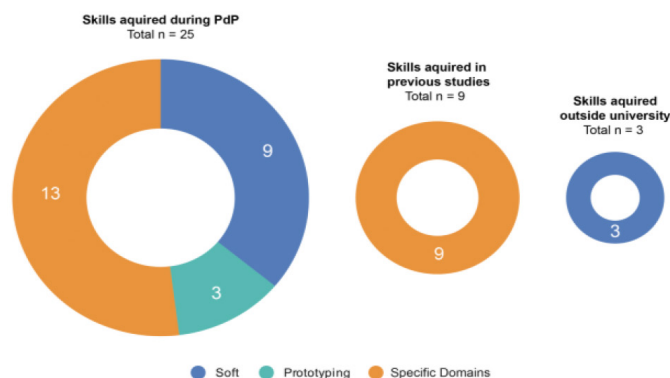
Fig.1. Assessment of where skills were acquired

Perceived skills in PdP (n=43)	Acquired during PdP	Acquired in previous studies	Acquired outside university
1. Communicate efficiently with team members from different backgrounds	73%	33%	15%
2. Quick Prototyping as a form of Testing	70%	15%	12%
3. Good adaptability towards unexpected challenges	67%	24%	39%
4. Communicate your challenge effectively	67%	27%	21%
5. Effective team time management	61%	24%	21%
6. Work in a collaborative way that recognises different opinions	61%	27%	36%
7. Prototyping as a form of Communication	58%	9%	45%
8. Resolve Conflict	55%	18%	27%
9. Thinking by Making	52%	15%	21%
10. Creative Problem Solving	48%	21%	42%
11. Effectively manage ambiguity	48%	18%	15%
12. Listen carefully and actively to the ideas of others	45%	36%	36%
13. Designing & Electrical Device Systems	42%	12%	6%

Perceived skills in PdP (n=43)	Acquired during PdP	Acquired in previous studies	Acquired outside university
14. User Experience Research UX	39%	42%	9%
15. Design Thinking - Concept & Ideation	39%	58%	27%

Table 3. Respondents' perceived skills and where those were acquired.[4]

Furthermore, the questionnaire results, presented in Figure 1, highlight that 58% (n=25) of the skills were acquired during the PdP course, 21% (n=9) in previous studies, and 7% (n=3) outside the university5. All skills acquired in earlier studies were from specific academic domains (Design, Mechanical Engineering and Business). In contrast, all skills acquired outside the university are soft or interpersonal. Whereas skills acquired during the PdP course combine specific domains, prototyping, soft and interpersonal.

The final question asked students to reflect on what was their core learning during the course as an open question. The responses reiterated the perceived development of interpersonal skills and the integration of disciplinary skills within the broader context of product development. The emerging core learnings noted, based on the responses, are indicated in Figure. 2. In total, the number of reported learning elements was 72, as some students indicated more than one core learning in their response. Figure 2 illustrates a thematic overview and analysis of the core learnings noted by the questionnaire respondents. Five main themes were identified: Interpersonal Skills (IS), Attitudes (A), Domain specific skills (DSS), Product Development (PD) and Project Management (PM). It should be noted that the learning themes introduced are an interconnected web of skills and knowledge, with IS for example, influencing A and PD. PD supports PM, while simultaneously influencing DSS. Figure 2 also enables an initial overview of the core learning themes by identifying them in a shared language of visual elements, contributing to a unified and tangible understanding of the skills and knowledge.

Responses noted the need for optimism and persistence as an attitudinal skill (A) developed. Examples of student responses below highlight the mentioned attitudes:

"Don't wait for others to do your job, just do it."
(Mechanical Engineering Student)

"It is very important to maintain a positive attitude towards the difficulties and not give up" (Mechanical Engineering Student)

Furthermore, responses perceived an integrated view of product development (PD), and the skills associated with the process (n=11), including: problem-solving, resolving product implementation challenges and prototyping as a form of learning through making and thinking through making. The following response stresses the span of

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[4] Full table available in supplementary materials.
[5] 5 skills from specific domains were acquired both in PdP and previous studies and 1 in all three environments. These 6 skills are not included in Figure 1.

different skills and learnings related to the complex process of Product Development and the resilience to resolve unexpected challenges.

"Being able to adapt to different challenges is complicated, but has to be done at some point. Sometimes it is more valuable to get things going and learn on the process than trying to come up with a perfect plan" (Mechanical Engineering Student)

Project management (PM n=13), and associated personal and project management skills were also noted. Intrapersonal skills (IS) identified (n=40) included self- awareness and self-knowledge, adaptability, creative thinking, decision-making, cultural awareness, communication and teamwork. These formed the largest group of perceived learning areas. The examples below shed light on the value of adaptability, self and cultural awareness.

"The main learning I got from PdP was to adapt and survive. Theorising and planning is very beautiful and a great tool, but reality rarely goes according to plan. And I honestly felt that I grew up as a professional enormously thanks to that particular skill. Now I feel way less afraid to go into a company and being tasked to tackle some problem I've never faced before. No matter what it is, I know I can adapt, survive and come up with a sort of solution." (Electronics and Nanotechnology Student)

"Listen to what others do not say. Finnish culture is very different from mine, be patient with undecided insecure people" (Mechanical Engineering Student)

Teamwork was often noted (n=19) as a developed skill and includes building trust, conflict resolution, fostering team relationships and working in multicultural and multidisciplinary teams. The response below emphasises why multidisciplinary and multicultural experiences promote key learnings.

"...something that PDP taught me (that my own parents nor the academia or work life has ever taught), is how to handle situations in which the viewpoints of different people are so radically different that neither can ever fully understand what the other person is thinking and why they are thinking so differently. These situations aren't easy, because they can easily cause conflict, but I think that even though we had our conflicts, we learned to handle the different viewpoints and learned to work as a team." (Economics Student)

Intriguingly, only a handful of students perceived domain-specific disciplinary knowledge skills (DSS) developed (n=5) as core learning during the course.
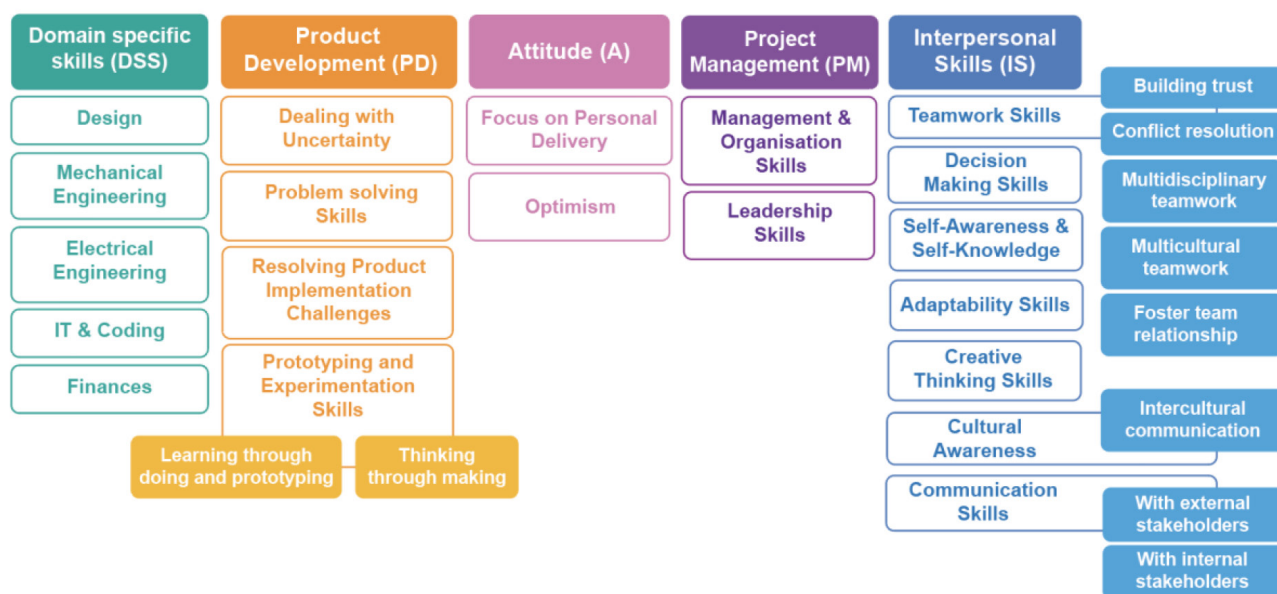
Fig.2. Core learning theme

DISCUSSION

The PDP course often represents students' first end- to-end experiential project learning opportunity, where proximity to real-life environments is critical. Previous research in the context of the PdP course (Rautavaara et al., 2014) considered the programme a good tool for developing communication and hands-on doing, in comparison with standard lecture-based courses. In the experiential context of PdP, educators aim to create situations mimicking real-life contexts, as in entrepreneurial education. Results highlight the significance of interpersonal skills during experiential learning, including self-awareness and self-knowledge, adaptability, cultural awareness, communication and teamwork. These formed the most significant category reported, students perceiving them as required for project success.

Students reported that interpersonal and attitudinal skills supported better engagement with product development processes and project management. Efficient communication within multidisciplinary teams was the most prominent skill students believed they developed during the course. Multidisciplinary teams can further support students' learning outcomes, providing better experiences and supporting diverging and converging processes within Kolb's learning cycle.

As communicative, interpersonal, and entrepreneurial skills become more critical for graduates entering the job market, providing an opportunity to learn them at university becomes imperative. Based on questionnaire responses, competencies acquired during the PdP course combine different academic domains, prototyping, soft and interpersonal skills emulating 'future-ready' skills. Therefore it can be argued that experiential learning supports the development of

these aforementioned skills through the acknowledgement that interactions with others lead to greater understanding (Hedin, 2010), depth of learning achieved (Cooper et al., 2003), and a higher level of involvement from the participants themselves (Lewis et al., 1994). Our findings also align with the views of Wiesche et al. (2018), whereby the provision of interdisciplinary teams better mimic real-life environments for the students. Previous studies reported the perceptions of course alumni (who graduated between 1999 and 2016). Findings from these 33 interviews and 239 surveys, conducted as part of the study, showed that socio- behavioural interpersonal skills contributed most to their careers; including communication, teamwork, navigating multidisciplinary environments and attitudes (Mikkonen et al., 2018). Our findings also closely resemble the learnings shown by Eppinger & Kressy (2002) within interdisciplinary product development courses.

This study also revealed that prototyping was seen as a physical form of communication, extending it into a 'makerspace' where students explain, decide and negotiate their understanding of a given context in a physical form. Based on this, one can state that our findings align with the views of Olsen (2015), who viewed prototyping as a tool that can help innovators to think. In a similar fashion, our findings indicated students viewed prototyping not purely as the skill to design, but also as a way for communicating and building their ideas from, and for supporting their thought processes. The prevalence of prototyping as a skill noted by students offers a unique insight into the experiences of the student cohort who completed the course during the global pandemic. Furthermore, it identifies the student's course perceptions very close to the completion of the course, whereas Mikkonen (2018)'s respondents had completed the course at least 1.5 years before and were reflecting on working life and memorable learning experiences based on the course.

CONCLUSION

In this study, students identified prototyping as an efficient communication tool within their project-based groups and an artefact representing collective decision- making. This finding highlights the multifaceted role that prototypes can play in sense and meaning-making: they are not only vehicles to communicate team ideas to stakeholders, but also present an opportunity to negotiate meaning and communicate through making, within the team. Prototypes represent a crucial design artefact, bridging internal mental models with external representations among individuals (Bucciarelli, 2002, cited in Nelson et al., 2020). The act of prototyping was also seen as a means to "communicate ideas, receive feedback" (Lande & Leifer, 2009: p. 1). Future research should analyse additional experiential courses to form an extensive collective case study, exploring the phenomena and the learning outcomes. It would also be prudent to conduct a follow-up study that includes a control group of students to allow for comparative analysis. Comparative studies could also be conducted across academic years or within other project- based courses. Furthermore, the empirical results reported herein should be considered in light of some limitations due to the questionnaire format. The questionnaire uses pre-listed skills for the first and second questions, which might influence students' responses and bias the answers to the third open question. Therefore, future development of research instruments should account for this limitation, and prospective studies should examine the skills utilised and learnings acquired separately.

Examining these findings from the standpoint of course design and potential curricula is equally pertinent. In this study, students identified interpersonal, managerial, and attitudinal abilities as the most important elements or prerequisites for project success and future readiness. Therefore, experiential learning is a core method for teaching and enhancing such attitudes, emphasising student-led learning and working through real-world problems. As these courses are becoming more prevalent at academic institutions, clearly defining the experiential learning outcomes in advance is essential. However, we are still in the midst of understanding how to evaluate student accomplishments, outcomes and skill development in the context of experiential learning and problem-based learning (PBL). Therefore, this study sheds light on how to assess experiential and problem- based learning from a more holistic view, where assessment not only drives learning but learning drives assessment, based on student reflections, skills recognition and identified core learnings.

SUPPLEMENTARY MATERIALS

To complement this manuscript, the authors have added an additional full data table relative to the respondents' key perceived skills in the context of the PdP course and where those skills were acquired. This supplementary table expands Table 3 and sheds light on the total (n=43) number of skills identified in hierarchical order by the questionnaire respondents. It might drive future research that is out of this study's scope.

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Soft Expertise as a Learning Goal in Interdisciplinary Course Design

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ABSTRACT

PURPOSE

This paper discusses disciplinary expertise from the perspective of multidisciplinary course design. With disciplinary expertise we refer to specialization, such as electronics, chemistry, and mechanical engineering, which require knowledge and pro-longed training within a particular domain. In a truly multidisciplinary project, the different specializations of the students in a team complement each other and enable student teams to reach such goals, which would not be possible without some disciplinary expertise. From the course design point of view, this entails the study project topic to be a perfect fit for the students' specializations which will allow them to leverage their emerging disciplinary expertise. Such a course design, however, requires someone to tailor the course precisely according to the students' expertise. In the real situation, some students will probably fall outside their home discipline because of the multiple other curricular and organisational aspects that influence the design of study courses, see e.g. (Kähkönen & Hölttä-Otto, 2021).

METHODOLOGY

Our approach is based on research-through practice methodology (Koskinen et al., 2011), which rests on the doubly involved work of researcher-practitioners. On the one hand, the practitioner is involved with their own community of practice, contributing to this field in practical terms. On the other hand, the same people are involved as researchers, contributing to the increase of knowledge related to the study in this field. The doubly involved practice relies on the reflexive iteration of the practice itself by the increased awareness of the practice that the research yields for the practitioners.

Our practice-based research uses data from the iterative development of a master-level multi-disciplinary university course to educate innovators in the context of internet-of-things (IoT) during the years 2018 to 2021. The data comprises personal notes, presentations, memories and reflections, as well as student feedback. Through five iterations of the course design, we have transitioned from building on *anticipated disciplinary expertise*, through the use of *ad hoc expert roles*, to promoting *soft expertise*. By anticipated disciplinary expertise, we refer to the simple assumption that a person coming to the course from a business school would have business expertise, from technical school technical expertise, and from a design school design expertise.

This was a way too broad categorization to be truly useful, as the students' expertise rarely related to the project at hand. A student could have deep knowledge about chemistry, accounting, or power engineering, which would not be helpful in the construction of an IoT device prototype. Thus, we developed the course to include a '3-week crash course' into different IoT-related specializations (embedded design, web design, and concept design). With this change, we intended the students to adopt a *pop-up expertise role* in their team. We employed the 3-week crash course with some variations over two iterations of the course. It did not work as intended. It was too optimistic to assume that students could learn enough about the structure and creation of, e.g., web-based applications during that short time, so that they could apply those lessons to anything useful, or to even playact in the role of a technical expert. The students were overwhelmed. This caused us to reflect on the learning goals of the course, and especially, the student profile that the course should cultivate.

FINDINGS

This is where we discovered the concept of *soft expertise*. By soft expertise, we refer to knowledge about (and understanding of) a particular disciplinary domain that enables one to engage in fruitful dialogue with the experts within that domain. A soft expert may know all the parts that are needed, and also in principle how the parts communicate with each other but lack the skill to create a technically functioning implementation in practice. Soft expertise is especially valuable for persons in managerial positions, as it enables them not only to talk in a 'shared language,' but also as it encourages them to perceive complex challenges from a richer set of points of view, and to be overall more resourceful in their creative thinking. It ideally enables students to express design requirements for an application in precise, unambiguous, and sustained terms.

Soft expertise differs from the project-specific expertise that is typically generated through so-called user studies. Through user studies, innovators develop insights into the user domain by interviews, observations, and participation in the field, and represent these insights through user personas, user journeys, flow diagrams, environment maps, etc. This kind of knowledge about a user domain is *ad hoc*, i.e. specific to the project at hand, as we must interpret all findings through the lens of the current project. Such *ad hoc* understanding is typically not generalisable beyond the current agenda, but disposable. Soft expertise, on the contrary, is likely to be useful in other projects as well. But how does this relate to course design?

IMPLICATIONS

Based on our experience, we can cultivate soft expertise through hands-on exercises, reading assignments, and exams. These are learning activities that are typically employed in traditional courses that educate expertise, such as electrical engineering. Motivated by the final exam, the students seemed to pay closer attention to the domain-specific knowledge that was taught in the course as compared to before. Using the exam also provided a stronger guideline for us to plan the lectures for the course. We had to ensure that we covered all the contents that we included in the exam. We aligned the exam questions and lectures according to our updated insights into the student profile the course should contribute to. This kind of course-design promotes particular knowledge as less disposable, as an ingredient of soft experience. However, besides these traditional learning activities, a multi-disciplinary course needs to enable students to leverage their existing disciplinary expertise. Our final project design uses a mixture of mono-disciplinary and multi-disciplinary project work to allow for students with relevant skills to train on those as well.

This paper outlines the key lessons learned through the iterative development of the multi-disciplinary course and makes proposals for effective techniques to achieve such course designs that promote the learning of soft expertise. We include discussion on how to design the course so that it not only facilitates soft expertise learning but allows for the deepening of project-related disciplinary expertise as well. The results of our work are valuable for the education of such future innovators that will go beyond their slide-shows and posters.

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problems, about one's own role in communication and how to (positively) influence communication.

Understanding engineering students' perceptions of their own curiosity, diligence, and perseverance and assessing its impact on their creativity

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ABSTRACT

Creativity has been among the most in-demand skills for many years. Previous studies have shown that being curious, hard- working, and persevering can significantly impact one's performance. This article is an exploratory study to understand engineering students' self-perception towards their own 1) Curiosity, 2) Diligence, and 3) Perseverance and how it affects their creativity. The research uses a well-curated study based on a survey, rubrics and statistics. The study found that curiosity has the highest potential to support creativity. However, it also has a rather intriguing relationship with diligence and perseverance. Awareness of the dynamic correlations between these three aspects can help educators design their pedagogical practices to support students to be more creative problem solvers.

INTRODUCTION

The ability to produce creative solutions can support students in a world of fierce competition. However, being creative could be challenging as there is no one right way to be creative, and several factors such as students' interests, backgrounds, design tasks and an individual's personality might influence creativity. Several such studies are explored in the subsequent section, but this study's primary focus is to explore the relationship between creativity and student personality traits empirically.

Although a tricky construct, creativity can still be executed using divergent and convergent thinking, according to Guilford (1967). A straightforward definition of creativity was proposed by Sternberg and Lubart (1999): "Creativity is the ability to produce work that is both unique (i.e., original, surprising) and appropriate (i.e., useful, adaptable regarding task restrictions. Creativity is expressed as Fluency, Flexibility, Novelty, and Elaboration (Torrance 1970). Several recent studies point toward the necessity to be creative from a future employment perspective since it is one of the most in-demand skills (Pate 2020, Whiting 2020). Nevertheless, to develop creativity, one must first understand the factors influencing individuals' creativity.

A study found that creative thinking is prominently affected by Contextual factors and Individual factors. The individual factors include personality, intelligence, and emotions (Utriainen and V altonen 2022).

Furthermore, Chen (2016) focused on how conscientiousness affects creativity in Chinese undergraduate students while studying the relationship between personality and everyday creativity. The association between subclinical autistic features, cognitive

(performance-based), and personality-related (self-reported) creativity was also comprehensively explored (Jankowska, Omelańczuk et al. 2019). In another study, the personality of individuals was found to stimulate their creativity (Amabile, Collins et al. 2018).

In different phases of creating something new, an individual's personality can subtly contribute. For example, it was found that performance attitude and workplace behavior results from innovation behavior (Yesil and Sozbilir 2013). Personality traits and creative success have often and predictably been connected (Prabhu, Sutton et al. 2008). Therefore, several studies exist that link the different aspects of an individual with creativity, but it was also imperative to better understand personality traits and choose appropriate aspects to explore in depth this study.

Cattell (1946) listed down 22 personality traits, further studied by Fiske (1949), wherein he categorized the 22 personality traits into five broad categories based on self-rating, rating by peers and ratings by psychological staff members. Tupes and Christal (1961) reanalyzed the five personality traits by taking eight samples from high school education to first-year graduate-level students. Tupes and Christal (1961) corroborated the five broad personality traits recommended by Fiske. Norman (1963) labeled the big five personality traits as extraversion, agreeableness, openness, conscientiousness, and neuroticism.

The Big Five personality traits—1) Openness to experience, 2) Conscientiousness (or Dependability), 3) Extraversion (Positive emotionality, level of activity, impulsivity, and risk-taking), 4) Agreeableness, and 5) Neuroticism (Emotional stability)—have been compared to perseverance (Goldberg 1992). In one study by Duckworth and Quinn (2009), the Short Grit Scale (Grit- S) and 12-item self-

report measure of grit (Grit-O) measuring grit were strongly correlated with conscientiousness. McCrae and John (1992) understood that conscientiousness is being dutiful, self-disciplined and an achiever. Lakhal and Khechine (2017) further enrich a conscientious personality trait to assess the degree of organization, perseverance, and motivation in students' behaviour toward a goal. Conscientiousness is a bigger umbrella under which diligence and perseverance are categorized. The openness and persistence of students in problem-solving were among the characteristics explored as motivational predictors of learning processes. These two categories explain students' willingness to engage in problem-solving despite impediments and include components closely related to self-beliefs, goal orientations, personality, and interests (Scherera and Gustafsson 2015).

In engineering education, Mamaril (2016) studied self-efficacy, described as self-belief in their ability to perform a specific task. The authors found that it can predict students' performance in different tasks during a course. Furthermore, the effect of perseverant grit and self-belief on academic performance and academic success has been investigated and found to be positively linked (Usher et al. 2019, Valentine et al. 2004).

A growing body of literature exists to understand creativity and link it to personality traits. Nevertheless, these studies are scattered and do not converge to paint a clear picture depicting the relationship between the two. It is because personality traits have multiple aspects, and each aspect needs to be studied separately. The current study builds on the existing literature in an effort to contribute to this growing body of knowledge and explores students' personality traits and their impact on creativity in the engineering-specific context.

Therefore, in this study, we focus on diligence and perseverance among the five personality traits from the conscientiousness category and curiosity is opted from the openness to experience category. The other broad personality categories, such as neuroticism, agreeableness, and extraversion, are essential personality traits in the context of creativity. The effect of these personality traits will be studied in the future. Therefore, in this study, we attempt to understand if personality traits viz: Diligence, Curiosity, and Perseverance can support students to become more creative, and we ask the following research questions.

Research questions * MER

1. To what extent does students' self-perception about RMA curiosity, diligence, and perseverance varies and T3 influences their ability to produce creative design solutions?
2. To what extent do students' curiosity, diligence, and perseverance, relate to each other and creativity?

THEORETICAL BACKGROUND

Creativity often demands out-of-the-box thinking to produce new solutions. One way of demonstrating creativity is by generating multiple ideas. Idea generation is the process of coming up with as many concepts as possible that are unique, useful, novel, and original. Idea promotion is the practice of involving oneself in the idea by looking for sponsors who have sway over the authorities (Agarwal 2014).

Academicians of the engineering fraternity usually focus on assessing the quality of the solution or ideas as a sign of creativity. The ideas are evaluated for key performance indicators such as uniqueness, novelty, quantity, or originality (Shah, Smith et al. 2003).

Researchers have explored several ways to generate ideas, for example, the use of different interventions, such as a course or ideas generation mechanisms, on creativity has been studied (Deo, Hölttä-Otto et al. 2020, Deo, Blej et al. 2021, Kirjavainen and Hölttä-Otto 2021). Lee et al. (2018) implemented design heuristics as an ideation tool and examined the applicability of Design Heuristics within individual and team concept generation contexts. Valentine et al. (2022) investigated the effect of using computers for idea generation on self-efficacy and performance. It was observed that using computers for idea generation did not negatively impact the students' self-efficacy.

Tiryaki, A. and Adigüzel (2021) investigated the effect of STEM-based robotic activities on the creativity and attitude of students. The study revealed that students enjoy STEM-based application problems rather than theoretical knowledge. Huang (2021) applied regression analysis and found that five types of informal workplace activities, such as learning through student interaction, colleagues' interaction, learning through media, stakeholder interaction and reflections, are positively related to teaching for creativity.

Abedini (2020) compared the creativity of students learning through the virtual classroom to those attending physical classes. The relationship between personality traits and creativity was stronger in virtual classrooms than in physical classes. Novikova et al. (2020) compared personality traits and creativity as predictors of success in foreign language acquisition (FLA). Creativity indicators have a more substantial but contradictory impact on the level of foreign language proficiency compared to personality traits. Furthermore, Toh et al. (2016) studied personality traits, risk attitudes, and idea-generation abilities that impact the promotion or filtering of creative ideas in a team setting. Teams with higher conscientiousness, agreeableness, and tolerance for ambiguity have more ability to select novel concepts. Therefore, creativity has been extensively studied; however, student personality may influence their performance in creativity; hence, it is essential to understand the aspects of personality under investigation in this study.

Curiosity, i.e., the "desire to know," is perhaps the core of this intrinsic motivation (Schiefele, Krapp et al. 1992). Walsh et al. (2021) study has developed a new framework that defines and drives the innovation process with phases of curiosity, creativity, and clarity. Intrinsic motivation helps the individual think about the solution to an anticipated problem before the situation worsens and warrants a crisis. Curiosity is the crux of inherent motivation; thus, curious thinkers are better divergent thinkers (Alberti and Witryol 1994). Earlier studies show that newcomers in an organization score high as they have a good appetite to seek new knowledge and gain more information by socializing with colleagues (Reio Jr and Wiswell 2000). Curiosity is related to cognitive thinking, intellectual engagement, and the ability to think of out-of-the-box solutions (Mussel 2010). Plamondon (2000) observed that curious people welcome change and have more endurance to handle stress than less curious individuals. Further, Celik, Storme et al. (2016) argued that curiosity is not only limited to intrinsic motivation or knowledge seeking but also fosters innovative performance. These studies inspired us to explore the potential relationships between engineering students' personality traits and creativity.

John and Srivastava (1999) presented 44 item inventory that assists in measuring the Big Five Inventory personality of students. However, this

study focuses on curiosity instead of all five traits John and Srivastava mentioned. Kashdan et al. (2018, 2020) devised a Five-Dimensional Curiosity Scale Revised (5DCR) that featured Joyous Exploration, Deprivation Sensitivity, Stress Tolerance, Social Curiosity, and Thrill Seeking. This is a validated tool and provided an opportunity to evaluate curiosity, and hence we deployed this tool.

Nowadays, perseverance has become one of the vital personality traits. Earlier Galton (1892) found that ability alone cannot bring success, wherein success is the outcome of zeal, relentless hard work, and an individual's ability. Howe (2001) asserted that perseverance is a necessary trait of intelligence in a person. Tenacity and perseverance are two non-cognitive traits that are critical for success (Shechtman, DeBarger et al. 2013). Perseverance and, openness, creativity is positively correlated, but individuals' perception greatly varies across different countries (Scherer and Gustafsson 2015). Duckworth (2007) mentioned the effort of perseverance as grit, an essential requirement to achieve an individual's vision. Christensen and Knezek (2014) have successfully used the Grit scale to capture students' perception of their perseverance. It is a proven instrument that we opted to use for this study.

A Diligent personality trait indicates that an individual is actively working and not seeking to delegate responsibilities. In this way, adopting diligence is a wonderful liberator (Grow 2017). In several fields, the effect of diligence on academic and student performance has been studied. For example, Studies have shown that diligence supported students in enhancing their academic performance in tedious tasks (Galla, Plummer et al. 2014). Galla et al. (2020) conducted two field tests to investigate the effect of mindfulness on academic diligence and boredom. It was observed that students with high mindfulness were more prone to boredom but had high academic diligence. Fladljeiv et al. (2020) studied the effect of temporal behavior on diligence. It was observed that slow students are considered to be more diligent in getting more correct answers. Wu and Wu (2020) investigated differences between high- and low-creativity learners regarding cognition, personal motivation, and personality traits.

In industries, employee diligence is essential from the future employment point of view (Eisenberger, Fasolo et al. 1990). However, this aspect has not been studied much in engineering education, where students deal with complex, tedious problems of nebulous nature. Corgnet et al. (2016) found that overthinking can negatively affect creativity, and people with high diligence skills are hard to find. We adopted the diligence instrument Arthur (2000) used to assess diligence and further correlate it with creativity. It is a closed-end questionnaire that captures students' diligence using a simple Likert scale survey.

Several creativity assessment instruments are available, each focusing on a specific aspect of creativity or can be used in particular circumstances (Shah, Smith et al. 2003, Kershaw, Bhowmick et al. 2019). We used the Organisation for Economic Co-operation and Development's (OECD) creativity rubrics (1= Dormant to 5 = Outstanding) to assess creativity. These rubrics assess creativity aspects such as inquiring, imagining, doing, and reflecting and categorize them into products and processes (Vincent-Lancrin, González-Sancho et al. 2019).

METHODS AND DATA

In this study, out of 92, 69 first-year Mechanical Engineering students from an autonomous engineering college, MIT Academy of Engineering, India, opted to participate during the academic year 2021-22. Participants were briefed in class about the purpose of the study without revealing too much information about the study, and they were verbally informed that participation was voluntary and that this study was not directly related to the course nor would affect their grades in this course. Students were attending a mandatory Design thinking course. We followed the experimental procedure shown below in Fig. 1.
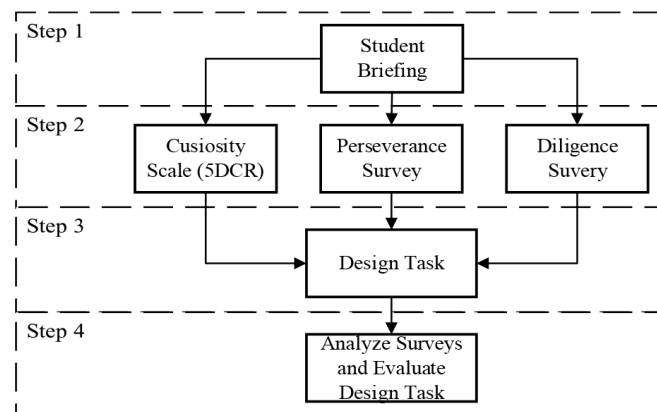
Fig.1. Experimental approach

For this study, students had a design task to propose safe-to-use multipurpose cutting tool concepts for a prototyping lab. Each student did this task separately for 10 min. A few sample concepts are shown in Fig. 2. We trained two raters to use the OECD's creativity rubrics: a professor and a doctoral student. One rater evaluated all the concepts when they achieved an acceptable kappa of 0.76 after two rounds (Cohen 1960).
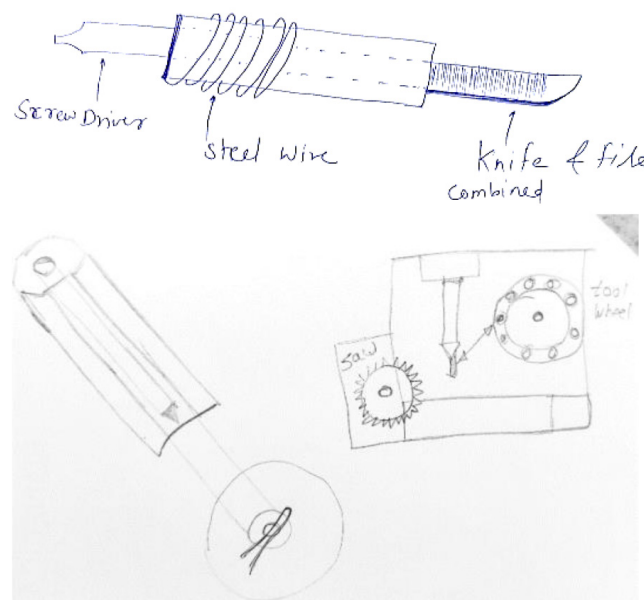
Fig.2. Sample concepts produced by students

The participants completed three self-reported surveys reporting their perception of curiosity, perseverance, and diligence. First, participants completed the Five-Dimensional Curiosity Scale Revised (5DCR) by Kashdan et al. (2020). This was on a 7-item Likert scale from 1 = Does not describe me at all to 7 = Completely describes me (α = .82). To capture * perseverance toward a meaningful long-term goal, we MER deployed (Duckworth and Quinn 2009) short grit scale GEFO using five items Likert scale from 1= very much like me RMA to 5 = not like me at all. (α = .75). Furthermore, to T3 measure diligence, a

revised diligence survey by Arthur (2000) was deployed with a 5-item Likert scale from 1= Never/Rarely 2= Occasionally 3= Sometimes 4= Usually 5= Almost Always (α = .72). For all the surveys used, their internal consistency of reliability was established, and Cronbach's alpha coefficients were above the acceptable level of 0.70 (Cronbach 1951, Tavakol and Dennick 2011). Students completed these surveys online in Moodle.

RESULTS

Exploratory Data Analysis

At first, descriptive statistics were studied (Table 1), and based on the mean score, students believed that they were quite curious (M= 4.47, SD= 1.40); however, the standard deviation is also the highest among the dataset, indicating a wide range in students' perception about curiosity. For diligence and perseverance, a similar mean score of (M= 2.89, SD= 0.818) and (M= 2.91, SD= 0.876) implies that the students had similar perceptions about these aspects and the responses had less deviation than curiosity.

Items	N	Min	Max	Mean	Std. Dev.
Curiosity	69	2.20	6.50	4.47	1.405
Diligence	69	1.20	4.50	2.89	.818
Perseverance	69	1.25	4.63	2.91	.876
Creativity	69	1.50	4.50	2.78	.867

Table 1. Descriptive Statistics.

Furthermore, the data were analyzed to identify any visible patterns and trends in student responses toward curiosity, diligence, and perseverance. Fig. 3 shows three pairs of student responses. The X axis is students, and the Y axis is survey-based scores. The graphs show that students reported a certain degree of opposite perception towards curiosity and diligence. It means curious students reported lower diligence. A similar pattern is visible in a graph with curiosity and perseverance, but results indicate that highly curious students do not show higher perseverance.

No such pattern is distinguishable from the diligence and perseverance graph, and results indicate students' mixed perceptions towards diligence. We explored data further to gain better insights into how these aspects and creativity interacted.

Creativity Analysis

Here, we first measured the number of solutions produced by each student, as Shah et al. (2003) recommended. Students produced a total of 110 concepts (refer to Fig. 2). However, no statistical test was done on students' concepts since we did not have student groups to conduct comparative statistical analysis.

We calculated a creativity score for each concept using the OECD's creativity rubrics. It helped to identify concepts that can be classified as 'radically different', meaning highly creative concepts. In a previous article, Kershaw (2019) suggested that a concept scoring above 75% score was a radically different concept. In this study, we looked into creativity scores to identify radically different concepts and presented our findings in Fig 4. These concepts have creativity scores equal to and above 75%.
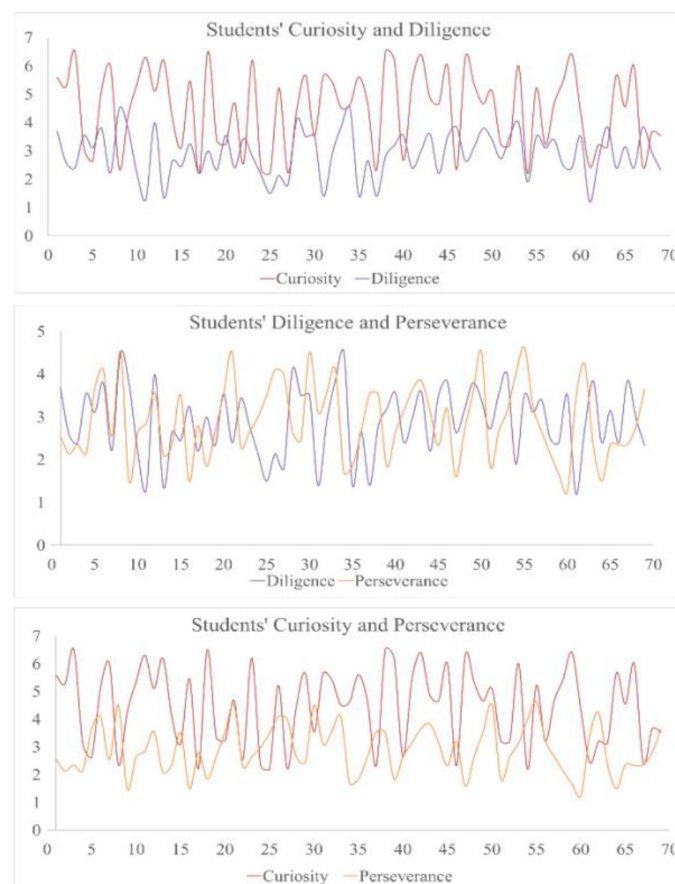
Fig.3. Student perception of their curiosity, diligence and perseverance

This study had 11 such concepts. Fig. 4 shows a bar chart with a standard deviation. In most cases, high curiosity appears to be a consistent factor among students who produced radically different concepts. However, the two students reported similar curiosity and diligence (e.g., ID34 and ID60) and produced radically different concepts. The remaining students who did not produce radically different concepts had a lower self-reported curiosity than the ones who produced radically different concepts, and all three characteristics followed a mixed pattern, unlike the one shown below in Fig. 4.
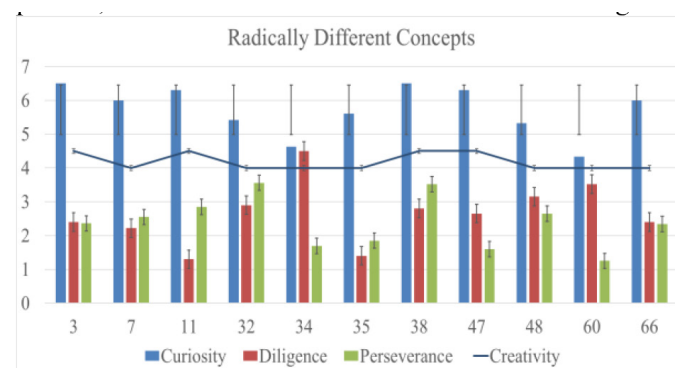
Fig.4. Radically different concepts

Furthermore, Fig. 5 shows how each student's creativity compares to their perception of curiosity, diligence and perseverance. As shown in the graphs, to a certain extent, curiosity shows positive,

and perseverance shows negative patterns with respect to creativity. Diligence does not show any noticeable trend with creativity. Additional analysis was performed in the next section to further affirm these initial visual observations.

Fig.5. Creativity mapping with curiosity, diligence and perseverance

Correlation Analysis

We checked data normality and computed Pearson's correlation coefficient in SPSS to understand if there is any relationship between curiosity, perseverance, diligence, and creativity. Results are tabulated in Table 2. The results show a statistically significant negative correlation between curiosity and perseverance, $r(67) = -.294$, $p = .014$, as well as creativity and perseverance, $r(67) = -.324$, $p = .007$.

However, there is a very significant positive correlation between the other two variables, creativity and curiosity, $r(67) = 0.568$, $p = .001$. Diligence showed either a negative or positive correlation with the remaining variables; however, it was not significant ($p > 0.05$).

Sr. No.	Curiosity	Diligence	Perseverance	Creativity
Curiosity	1	-0.038	-0.294*	0.568**
	-	.755	0.014	0.001
Diligence	-0.038	1	0.007	-0.025
	.755	-	0.956	0.839
Perseverance	-0.294*	0.007	1	-0.324**
	0.014	0.956	-	0.007
Creativity	0.568**	-0.025	-0.324**	1
	0.001	0.839	0.007	-

* Correlation is statistically significant at the 0.05 level (2-tailed)
** Correlation is statistically significant at the 0.01 level (2-tailed)

Table 2. Correlation between curiosity, perseverance, diligence, and creativity.

ISCUSSION AND CONCLUSIONS

In this study, we aimed to understand a potential relation between students' self-perception towards curiosity, diligence, and perseverance and their influence on creativity. We answer two research questions during this study.

Research Question 1

Exploratory Data Analysis (EDA) and creativity analysis helped to answer the first research question. The results indicate that students' self-perception about their curiosity, diligence and perseverance greatly vary. Especially cu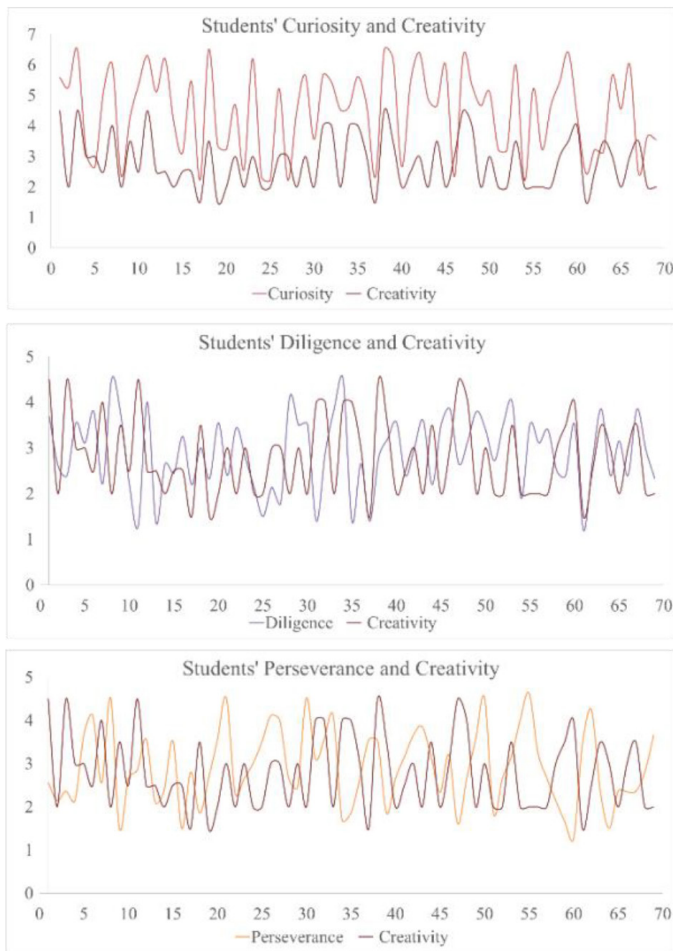riosity and perseverance show a negative relationship (refer to Fig. 3). The quantitative analysis also confirmed this observation. On the other hand, diligence does not show any apparent connection with the other variables.

Interestingly, when we looked into the creativity MER scores of all concepts, the students with high curiosity GEFO produced radically different concepts. A complementing RMA finding was visible in a positive correlation between T3 curiosity and creativity. This finding was similar to the one by Amabile et al. (2018), in which student personalities stimulate their creativity. Perhaps in this study, it was the curiosity of the student which stimulated their creativity. Additionally, Shah and Smith (2003) found that a higher quantity of solutions may lead to higher creativity, but we did not see that pattern implying a sheer number of concepts is not always the primary determinant. However, another parameter to consider could be the lack of domain knowledge. Previous studies have found domain knowledge as an important variable in creative problem-solving (Benjamins, Fensel et al. 1996, Mayer 2006). The participants did not have any engineering knowledge that could have affected the quantity or creativity scores of solutions produced.

Previous studies have found that intrinsic motivation and perseverance are correlated, and perseverance leads to higher creativity (McGraw and Fiala 1982, Eisenberger and Shanock 2003). Although we saw less perseverance than curiosity, it resulted in more creative solutions, contrary to the above finding. Mrazek, Ihm et al. (2018) trained students in perseverance. Perhaps repeating the creativity exercise after training students to enhance perseverance would be interesting.

In both methods we used, the lack of evidence on the relation between diligence and creativity is in line with the previous study that people with high diligence are hard to find (Corgnet, Espín et al. 2016). Perhaps the given design task was not suitable to demonstrate diligence which could be one of the reasons for the lower correlation between diligence and creativity. Repeating the study with different design tasks might help shed light on this aspect in the future.

Research Question 2

The second research question explored how the dynamics between curiosity, diligence, perseverance and creativity work. The results indicate that the students have quite different perceptions of their curiosity, perseverance, and diligence.

We also found that curiosity and creativity had the strongest positive correlation, confirming the previous findings (Schutte and Malouff 2020). Evidence from the study (Table 2) strongly suggests that students with higher curiosity produce solutions with higher creativity. At the same time, students who believed to have lower perseverance had higher creativity which is opposite to the previous findings (McGraw and Fiala 1982, Eisenberger and Shanock 2003). Diligence and perseverance did not indicate any specific relationship; diligence seemed to have the weakest link with creativity.

Since perseverance requires consistent efforts, curiosity leads to better divergent thinking (Alberti and Witryol 1994). Perhaps, if students are expected to solve a single complex problem requiring long-term efforts, more self-belief in perseverance might be suitable, but if students are expected to produce radically different solutions, students with higher curiosity might perform better. We did notice a positive effect of higher curiosity on student creativity.

FUTURE WORK

The study had a couple of limitation that needs to be addressed in the future, such as the limited sample size. Students reported that all three questionnaires were too long (70 questions). More optimized versions must be developed and validated in the future. In the future, it would be interesting to swap the personality aspects, for example, curiosity with motivation or diligence with confidence to study their impact on creativity. Also, this study was conducted in one country and in one engineering institute, so it would be interesting to repeat the study in a different country to see if and how culture or other contexts affect the results.

CONCLUSION

Overall results indicate intricate dynamics between these aspects. The aspects under study either correlate positively or negatively or, in some cases, do not correlate. Although the results of this study showed promising aspects, they also imply the need to conduct more research to understand students' lower or higher perceptions of their curiosity, diligence, and perseverance. Leveraging the understanding of such dynamics while designing courses, assignments and pedagogical practices can support teachers in designing a better learning ecosystem promoting students' creativity.

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Theme 2:

Team Work
& Cooperation

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Numerous researchers also address collaboration specifically, examining the group process and cooperation in design teams. This may involve questions relating to the way in which people work together at a distance (Santana & Zancul), the way in which the performance of the individual is related to the performance of the team as a whole (Tan et al), the perception of staff and students regarding the importance of collaboration (Feng et al), and the way in which a collective innovation culture can be promoted (Thong et al). Sometimes the research is carried out by means of a case study (Krebs et al), but focus groups, in-depth interviews and questionnaires are also methods used by the various researchers.

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INTRODUCTION

Shenkar Jamweek is a four-day academic makeathon for interdisciplinary problem-based learning. Jamweek brings together more than 600 students and lecturers from Shenkar's Design & Arts and Engineering faculties. This makeathon is presented in collaboration with outside organisations from academia, industry, and non-profit sectors. The makeathon heavily emphasizes social and entrepreneurial innovation using the design thinking (DT) Double Diamond sprint methodology. The structure of Jamweek includes a digital online course through pre-recorded video lessons for each DT stage (empathy, definition, ideation, prototyping). The videos are uploaded to a collaborative Miro platform and accompanied by various assignments. During the event, the students work simultaneously on campus and online. Local and international experts from various adjacent fields (e.g., gerontology, business, psychology, UX/UI) provide the students with professional support upon request. A particular emphasis is given to interdisciplinary teamwork of students from different backgrounds in design (visual communication, industrial design, fashion design, textile design, interior building and environment, art, and jewelry design) and engineering (electrical engineering, polymer materials engineering, software engineering, industrial engineering and management, and chemical engineering).

Jamweek 10 took place in February 2022. Its rationale was to address and solve contemporary social challenges and educate the next generation of designers and engineers about how to deal with socially innovative leadership and ethical thinking. An additional DT goal of Shenkar Jamweek was to promote the values of interdisciplinarity and teamwork amongst both students and lecturers.

AIMS & METHODOLOGY

This paper explores the key success factors of interdisciplinary teamwork for effective development and deployment of innovation in higher education. The division between university disciplines creates disconnected silos that prevent students from achieving the meaningful skills needed in their future careers. Nevertheless, interdisciplinarity can help designers and engineers expand their knowledge, skills, and ability to address complex challenges creatively. In recent years it seems that universities and academic institutions have finally come to understand interdisciplinarity's crucial function for innovation and research (McDonald et al., 2018). There is much evidence on the benefits of interdisciplinarity for design research (Barnes & Melles, 2007) and on the role of DT in engineering and science, technology, engineering, and mathematics education (Chang & Yen, 2021). Indeed, the value and volume of interdisciplinary research in achieving funds are higher than the discipline-specific. However, since the evaluation system is still rather conservative, this is true only in the long run. (Sun et al., 2021).

This paper explores how interdisciplinary DT affects the creative expertise of design and engineering students who work in multidisciplinary teams. It focuses on the gaps between different experiences of design and engineering students. It inspects the evaluation of these different groups regarding the advantages (or disadvantages) of the interdisciplinary DT to assist in solving given challenges. The research is based on a questionnaire that was circulated during Jamweek 10. The survey was designed to explore how students felt about various issues related to interdisciplinarity teamwork, assess student collaboration techniques, and evaluate the contribution of the DT methodology to the overall process. The questionnaires also included a qualitative section, which posed open questions. This paper analyses 103 fully completed questionnaires (out of 600 participants) sent by the students from the design and the engineering faculties.

THEORETICAL BACKGROUND & LITERATURE REVIEW

Recent studies have shown that DT methodology promotes active and collaborative learning relationships. Students from various disciplines state that this methodology is useful if taught alongside their majors (McDonald et al., 2019). Charosky et al. (2018) show how using DT increases the awareness of information and communication engineering students to users' needs. In this regard, DT usage enhances students' ability to tackle complex challenges. The use of DT also seems to improve students' ability to undergo a successful ideation process while helping them achieve disruptive and high-impact solutions by understanding the bigger picture. These competencies are further improved by interacting with students from different disciplines – design and business management (ibid.). Indeed, the success of the HPI and Stanford d.school DT programs shows that this methodology has great potential in higher education and multidisciplinary curriculum. Using

DC seems to improve not only mental capabilities, such as empathy, among students but meaningful inter\meta-disciplinary collaboration and creative competencies as well (Levy et al., 2021; Panke, 2019). Glen et al. (2015) assert that DT complements the analytical approach of business education and shows how the seemingly 'messy' process of DT can lead to the desired outcome.

Dym et al. (2013) compare DT methodology characterizations to skills usually associated with designers. They refer to the ability to work in ambiguous and uncertain surroundings, to think as part of a team, and to work and communicate across various design languages. In their research, Dym et al. (2013) argue that when it comes to engineering students, design contents (i.e. a course or other format that contains elements such as teamwork, a project focus, and communication – all of which characterise DT as well) can 'produce very positive changes in engineering student retention rates' (ibid.). The 'design contents' argument is based on having a course or other format that contains elements such as teamwork, project, and communication – all of which characterise DT as well). Producing the same results is possible not only for engineering students. Holzer et al. (2018) represents a case study of a DT course for 35 bachelor students of different backgrounds, such as computer science, engineering, architecture, mechanics, business, humanities. The participants in this study used DT to develop solutions for innovative learning spaces on campus, combined with agile curricular innovation. The students' evaluations of teaching showed a high appreciation of the interdisciplinarity group work and a strong appreciation of collaboration in general. Nonetheless, more than half the students felt that their disciplinary skills were not valued enough in the course.

Indeed, interdisciplinary use of DT has shortcomings: sometimes, it is ineffective in enhancing students' creative self-efficacy and leads to frustration, shallow ideas, and misalignment regarding learning content. In addition, this methodology may lead to tension inside teams and creative overconfidence (Gestwicki & McNely, 2012; Glen et al., 2015; Taheri et al., 2016). Lynch et al. (2021) studied the DT education experience through students' reflections. Their findings indicate that teamwork and collaboration are rather challenging ingredients and create numerous conflicts, power struggles, and communication difficulties among the team members. In addition, the teams' flat structure in their research lacked the leadership to direct the team and thus created frustration.

Nevertheless, some feedback showed that despite the difficulties, the DT process conveyed important knowledge and provided an opportunity to develop teamwork and communication skills. The students' academic discipline also seemed to affect the methodology's success. McDonald et al. (2019) surveyed students who had DT as a minor rather than a major. These students were asked to rate how useful they thought the DT methodology would be if taught along with their majors. The results showed that students with science- oriented majors had the smallest proportion of positive ratings, while students from other disciplines believed the process to be useful. However, students with a design background sometimes find it difficult to resist the temptation to transform the DT process into a conventional design brief, which undermines the methodology's creative outcome (Melles et al., 2012).

Using DT in interdisciplinary teamwork has many advantages for students, promoting skills crucial for their future careers. As shown by Lynch et al. (2021), while science and engineering students gain their education through strong technical knowledge, their expectations as future employees require problem-solving capabilities, creativity, teamwork, and more. Using DT is also effective in entrepreneurial education when challenges are provided by industry partners (Penaluna & Penaluna, 2019, Ranger & Mantzavinou, 2018). The DT skills are related not only to the content of the DT process but also to its nature as interdisciplinary teamwork.

Shenkar Jamweek gave us a unique opportunity to explore interdisciplinary teamwork using the DT methodology, which aims to solve real-world challenges provided by industry partners. This study explores the Jamweek from the student's point of view; we hope it can shed light on its perception among students from different disciplines.

FINDINGS

Interdisciplinarity: the findings of this research in the field of interdisciplinarity show that 52% of the students felt that working in an interdisciplinary team enabled better outcomes than 'regular' projects (rankings 4/5 and 5/5). The position of the engineering students (46/103) was widely positive (73%), compared to only 38% among the Design & Art students. The main qualitative arguments that support interdisciplinarity included: 'diversity of views', 'different knowledge creates common solutions', 'various thinking perspectives improve creativity'. The main qualitative negative arguments were: 'the final outcome was not very successful', 'the Jamweek orientation is design rather than engineering', and 'most of the work was burdened on the shoulders of the design students'.

Methodology: when asked to estimate the effectiveness of the DT methodology, only 31% of the students felt that it enabled better results than other 'regular' projects in which no DT methodology was applied. The engineering students also felt slightly more positive here than the design & art students. The main qualitative arguments that support the use of DT methodology included: 'effective', 'contributive', and 'step-by-step creativity'. The main qualitative negative arguments were: 'limited', 'determined too hermetically', 'the process steps are too long'.

Collaboration: regarding collaboration through Miro Boards, 52% of the students felt that this platform enabled better results compared to projects in which this platform is not in use. Here, engineering students also felt more positive than design & art students. Generally, although some qualitative arguments have included negative references such as 'unfamiliar' or 'not controllable', most references reflected confidence and effectiveness. This position of confidence and effectiveness held true when considering fundamental-conceptual pros such as co-creation and immediate reflection and tactical-technical pros such as convenience, documentation ability, and intuitiveness. In addition, the students ranked statements by empathy degree (from 1 - absolutely disagree, to 5 - absolutely agree). For the statement 'I have enriched my team colleagues with my knowledge', nearly 80% ranked 'agree' or 'absolutely agree'. It was quite similar among both engineers and designers. For the statement 'I was granted with valuable knowledge from my team colleagues', 63% ranked agree or absolutely agree. Only 51% of the designers felt this way compared to 78% of the engineers. Regarding the overall estimation of Jamweek methodology and the interdisciplinary teamwork, for the statement 'I feel that my creativity has been improved during the Jamweek sessions', only 48% ranked agree or absolutely agree. The gap between the two different

disciplinary groups was wider here: only 34% of the design students felt this way compared to 68% of the engineers. For the statement 'I understand better the importance and relevance of my current studies in relation to product development', 58% ranked agree or absolutely agree, with no significant difference between the two groups.

INSIGHTS & CONCLUSIONS

A fair share of students felt that Jamweek's interdisciplinarity was effective, although the study does raise concerns about the interdisciplinarity nature of Jamweek. The overall teamwork functioned appropriately, but engineering students estimated that they gained more knowledge and capabilities than what designers evaluated, as some of the cited literature suggests. Sonalkar et al. (2016) argue that multidisciplinary teamwork is a key required element in the DT approach regarding innovation. The multidisciplinary teams have contributed to interdisciplinarity by sharing complementary knowledge between the students. Their qualitative explanation indicates the reasons for the diversity of thoughts, building mutual confidence, and enhancing creativity. This case shows that the whole was greater than the sum of its parts.

Moreover, this approach becomes more effective only when teamwork is enriched with different areas of expertise, enabling leverage concepts, analysis, synthesis, and new ideas (Melles et al., 2012). A big challenge in this approach (as stated by the Jamweek participants) is finding the right balance between the engineering-orientated tasks and the design ones. It seems that in our Jamweek, the orientation of the tasks was asymmetric (i.e., designers had more to do because of their prior relevant knowledge). The possession of prior relevant knowledge is probably why engineers were more satisfied than designers, as they gained more significant knowledge. As mentioned above, there are many similarities between the process of DT and designers' way of working and thinking (e.g., empathising with the customers, thinking in creative ways, and embracing uncertainty). Here, designers are accustomed to a process that, although not as structured as DT, has many lines of imagination. Another possible explanation can be related to the technical separation between the stages in DT and its overall rigid structure, which contrasts with the creative thinking flow of many design students. Their statements also support this feeling that technical separation underlies how they interact with their engineering colleagues.

Only one-third of the students felt that the DT methodology was contributive. Although we must bear in mind that this particular DT process was a four-day sprint, the students' feedback still raises some questions. When we look at their reflections (most of them, but the designers more significantly), we can find some possible explanations. The students claimed that the DT methodology is limiting and too closed to new ways of thinking. Therefore, we must ask ourselves whether this method does not canalise the participants too much and captivate their mindset, especially the designers, who wish to 'fly' without grounding cords. In her 2019 article, Design Thinking in Education, Stefanie Panke mentions a study conducted by Liedtka (2015) in which he expressed his concern that in the empathy stage, the fact that 'people often project their world view onto others, limit the options considered, and ignore disconfirming data'. Panke offers, in return, a few ways to reduce bias. Still, following our students' feedback and Liedtke's remark, a question remains: does innovation need a processed consensus-based methodology or wildly creative design

individuals? This possible conclusion is even sharper regarding the DT prototyping divergent stage. Is it possible to compose a recipe book to cook creative ideas? Can creative innovation be managed within a closed process? Laursen & Haase (2019) argue that DT fundamentally aims to create a shortcut to designers' mindset. However, the DT methodology never directs HOW to create disruptive ideas, perhaps because such ideas cannot be processed in the first place.

Interestingly, engineers might find this method valuable, contrasting to designers who regularly apply critical thinking and often do not share the paradigm with engineers. The approaches of these two groups do not stand on the same pillars. Their viewpoints differ, as do their beliefs, concepts of reality, scientific ideals, ethics, and aesthetics.

Regarding knowledge contribution, most students from both disciplines felt that the Jamweek experience was enriching. Furthermore, most of the students felt that they gained a better understanding of the importance and relevance of product development to their academic studies. As researchers and educators, we were left with open questions regarding the DT methodology. We believe that this methodology poses problematic boundaries for many students, and people in general: for those who feel they lack creativity and ideation, the DT process does not help, as it does not provide any tools for developing these deficiencies. For those who feel that they have a profusion of imagination, inspiration, and creativity, the DT process places barriers and forces them to structure a process whose nature is free and fluid.

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EXTENDED ABSTRACT:

Activating Innovation Culture; practices surrounding the design-doing of interdisciplinary collaboration

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ABSTRACT

PURPOSE

Design Factories around the globe have a multitude of different flavours; their purpose and portfolio of activities influenced by the vision and strategy of their home institution. What unites us is a shared, core set of values that shape attitude and culture for innovation, emerging from Aalto Design Factory. Our innovation culture and value system is expressed in many ways, to communicate with different internal and external stakeholders; students, staff, researchers and industry as they visit or become part of the community. For example, guiding principles explicitly signal values that may inform people's behaviour: 'your parents don't work here', 'talk to strangers', 'safety comes first', 'all people have potential', and 'fail fast to succeed sooner' or 'all you need is love, design, business and engineering'. However, facilitating people to translate innovation culture and values into action can be challenging, as the nature of this knowledge is more tacit than explicit. Innovation culture is concerned with mindset and conditions for applying more concrete design inspired innovation tools and processes (UK Design Council, 2019). How can we activate, demonstrate and support the conditions for innovation as part of learning programs that foster capability in interdisciplinary collaboration and design-inspired innovation? And how do we do this in a world where virtual operations and distributed teams have become a normalised part of most workplaces?

METHODOLOGY

This paper focuses on how innovation culture is activated in Design Factories in Australia and New Zealand. The three Design Factories in this region act as Innovation Labs within their institutions building capacity in internal and external stakeholders, be it students, researchers, start-ups or corporate partners. Aligned with Bundura's (1977) Social Learning Theory, that assumes individuals learn through observing their peers, the Design Factories in this study seek activation methods that demonstrate and model behaviours for innovation culture.

We conducted a focus group with 14 facilitating staff from all three Design Factories to understand what interventions are used to activate innovation culture in both face-to-face and virtual settings. The staff ranged from 1 to 10 years of experience in working at Design Factories, and represented a range of positions from coaches, professors, department heads and coordinators with different backgrounds including design, engineering, science, business and commercialisation. To position our findings to be useful to anyone facilitating design-inspired innovation practices or capability building, we used the UK Design Council's evolved Double Diamond (2019) as a framework to thematically map our practices to facets of *Engagement and Leadership* that surround design innovation processes, principles and methods. We then did further thematic analysis to understand the characteristics of our practices for activating innovation culture and how these differed in virtual and physical settings.

To map our practices, we separated the UK Design Councils description of *Engagement* into facets; building relationships, inter-personal skills and collaboration, and *Leadership* into facets; conditions for innovation, culture change and mindset. Interventions are often featured across multiple facets and across both Engagement and Leadership, suggesting that behaviours for innovation culture are not siloed actions, rather they are integrated and complex. We found that all facets of Engagement and Leadership categories were being supported quite evenly with multiple interventions supporting each facet. Everything could be mapped to the facet 'conditions for innovation', and there were many practices that required an 'other' category suggesting that additional facets of behavioural, spatial and material-based cues could be made more explicit in such a framework.

FINDINGS

Thematic analysis showed characteristics of innovation culture included practices that were: inclusive, celebratory, open, informal and acknowledging of an individual as a whole person, not just as a representative of their discipline knowledge. Further these characteristics are demonstrated or reinforced by cues that come from people and/or facilities (such as materials and built environment) with cues spanning sound, text, visual, spatial, objects, movement and verbal activation techniques. Again, many practices would involve multiple characteristics, and activation techniques, suggesting that consistency and reinforcement of behaviours and values of innovation culture is important.

Practices for physical and virtual settings were evenly represented across facets, however there were over twice as many physical practices identified than virtual. This may be representative of the staff having more experience in physical settings, however virtual activation spanned less characteristics of innovation culture suggesting there are limitations in the opportunity and mechanisms to model as wide a range of activation cues online. Often there were 'mirror' activities for virtual and physical practices, where the same purpose was being

achieved with the same characteristics but some varied cues or activation techniques, e.g., ideation activities to prompt an open mind-set, physically and online both use sound cues, but physical practices use bodystorming and collective prototyping feature and online practices use digital collage or individual sketching.

IMPLICATIONS

The study has built on understanding of activating innovation culture that surrounds methods, frameworks and principles for design-inspired innovation, by delving deeper into identifying characteristic and types of activation cues that are combined to reinforce behaviours and values of innovation culture in action. We propose expanding the UK Design Council's evolved Double Diamond (2019) description of conditions surrounding design-inspired innovation to cover the built environment (be it digital or physical), which is equally applicable to the Net Zero Framework for responsible innovators (UK Design Council, 2021) that does not explicate spatial factors. Through our thematic mapping, we leave our audience with a matrix of practices (presented visually at the conference) for achieving different facets of innovation culture that may enhance, inspire or evolve their own practices in facilitating or teaching design inspired innovation.

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ABSTRACT

This study describes how a multidisciplinary team at an Australian university's innovation hub developed their research targets and capacity. The process through which research teams establish their research targets and strategies for achieving them is often tacit, which makes process sharing challenging. Referencing *Situated Learning Theory* (Brown et al., 1989) and using the *Design and Development Research* (DDR) framework (Richey and Klein, 2007) we document the process of how researchers negotiate to develop team research targets in this study. Our workshop data suggests that if researchers want to leverage the research abilities of others in their team, their targets must remain flexible. Additionally, a range of individual and organisation hinderers, barriers and enablers of conducting research were identified, that can inform practical actions to realise research strategy targets for innovation hubs.

KEY WORDS:

AIMS & METHODOLOGY

A team's ability to produce research within innovation hubs is fundamental to enhance innovation practices with evidence-based findings. In our experience, when researchers can apply their findings in their hub's innovation practices, they 1) experience first- hand how their work engages and impacts practice, 2) validate their findings in practice, 3) develop more rigorous research, and 4) provide clearer insights to further improve innovation processes. Therefore, it can be argued that the ability to produce research, also referred to as an individual's research capacity, is crucial in advancing innovation practice. While it may appear logical that having more researchers in a team will boost a team's research capacity, this is not always true. In multidisciplinary teams, members have less shared knowledge and research training (Tobi & Kampen, 2018), which may instead diminish the team's overall research capacity. To overcome this reduction, researchers must find ways to increase their team research capacity, such as leveraging one another's research capacity so that they can achieve more than what they each could accomplish alone.

Yet, such strategies are often kept tacit and shared within the researchers' organisation. As a result, there is a scarcity of empirically based information to guide teams in boosting their research capacity. Compared to research in allied health professionals (see e.g. Cooke, 2020; Iles-Smith & Ersser, 2019; Matus et al., 2018) and teacher education (see e.g. Hammad & Al-Ani, 2021; Murray & Vanassche, 2019; Tatto, 2021), where building research capacities have been documented in literature, this topic is underexplored in design and innovation studies. And much more so in teams comprised of researchers with diverse levels of experience and disciplinary backgrounds.

Our study responds to this gap by documenting and analysing the ongoing *Team Research Strategy Project* at an Australian university's innovation hub. The *Team Research Strategy Project* is a programme that aims to help the participants 1) identify and capture their team members' unique research skills and expertise, 2) uncover a research strategy that represents the teams' distinctive abilities and 3) maximises each members' research capacity. This innovation hub has a strong focus on applying research to industry projects and frequently collaborates with industry clients to identify and develop innovation prospects into concepts and prototypes. The team in this innovation hub is made up of multidisciplinary academics and professionals that research, teach, and service industry clients. Due to the lack of existing research to guide the *Team Research Strategy Project*, this study is guided by two research questions. Firstly, how can researchers integrate their individual research needs into a team's research target? This question seeks to identify insights into how the team set their research targets. Secondly, what factors do teams perceive as enhancing or diminishing their capacity to achieve their research target? This question seeks to identify factors that are perceived to obstruct the team's ability to reach their targets and potential mechanisms that can bolster their pursuit of the targets. In doing so this study provides evidence-based guidance to help teams in other innovation hubs improve their research capacity.

THEORETICAL BACKGROUND

This study is informed by Situated Learning Theory (SLT) (Brown et al., 1989; Cobb & Bowers, 1999; Greeno, 1998; Lave & Wenger, 1991). In SLT, an individual's environment and context, which includes the ideas, tools, and physical resources available to them, shape how they learn and what they know. Brown et al. (1989) argued that an

individual builds new knowledge through their activities, situation and culture. Additionally, Greeno (1998) argued that people's interactions with each other within the situation is key to initiate learning within the individual. These two arguments, though part of SLT, are different, for the former is based on an individual perspective and the latter on a collective perspective (Cobb & Bowers, 1999). Nonetheless, both perspectives are necessary to describe how SLT is examined in practice. Through this SLT theoretical lens, learning and knowing can only occur in a context. In other words, only when individuals acknowledge their environment and engage with the people within that environment can they begin learning and knowing. Within our study context, team members must first become aware of their context to 1) contribute what they know, 2) learn from other members, and finally, be able to 3) create a team-based research strategy project. Through this theoretical perspective, the team research strategy emphasises processes where team members share inquiry and learn from one another, to become aware of one another's 1) research interests, 2) research targets, and 3) research needs and obstacles. Only when these factors are made clear to each other the team members can work to leverage one another's research experience and, ultimately, boost their team research capacity. The project uses Design and Development Research (DDR) framework (Richey & Klein, 2007) to execute the situated learning perspective. Unlike the general design and development process, in which designers and innovators iteratively prototype an idea into a solution, DDR focuses on identifying insights in current processes and offering solutions to address obstacles identified in present practices. According to Richey and Klein (2007), DDR is used in the field of instructional design to specifically generate new knowledge and validate existing practices. There are two types of research studies that can achieve both goals, 1) research on products and tools and 2) research on design and development models (Richey et al., 2004). This study adopts type 1 and focuses on a tool to facilitate a group of researchers develop their own team research targets (to answer RQ1) and examine their existing research practices (to answer RQ2). This framework also enables the participants to 1) create a team-based knowledge and generate new understanding of the participants' research targets, and 2) examine their existing research target setting practices. Finally, this specific explorative study enables us to further develop our tool to improve the process of setting team research targets.

METHOD AND DATA

The project uses a case study methodology (Yin, 2018), with data from action-researcher observations triangulated with written workshop outcomes analysed using thematic analysis. To ensure team inclusivity, we invited all staff in the innovation hub (n=11) to participate in this study. Nine staff expressed interest, and six staff participated in the study. We note that the staff that did not participate in the study were mostly professional staff (non-academic roles). Thus, they had limited career and institutional incentives to conduct research. The six participants held different academic positions, from research assistant to hub directors. In academic positions, the university expects staff to frequently produce research outputs. These participants also worked in the hub for different lengths of time, ranging from one year to ten years.

Data collection
We collected qualitative data using an intervention workshop. The two-hour in-person workshop had two goals. The first goal was for

participants to co-create their team research targets for the next 1.5 years (i.e. until the end of 2023). The second goal was for the team to identify factors that block, hinder, and accelerate their research capacity. We used the Sailboat technique (Tan, 2021) to structure the brainstorming session, which we describe below. We collected data in the form of 1) the written workshop outcomes documented in multiple photographs, and 2) observational data documented in notes from the two action researchers that facilitated the workshop with the team. The facilitators documented these observations during the workshop and in an activity reflection a few days after it was conducted. We conducted this workshop in June 2022. In this section, we first explain how the workshop was conducted and, then, how this process relates to the research questions defined.

To achieve workshop goal #1, we first asked participants to list down on their individual whiteboard their research targets for the next 1.5 years. Secondly, we asked the participants to share with each other their individual targets. This sharing was an important step prior to co-creating a team research target because, drawing on Situational Learning theory, participants need to first become aware of one another's goals to ensure the development of the team research target attempts to build on one another's research target. To achieve workshop goal #2, we used the Sailboat technique to extract factors that block, hinder, and accelerate their research capacity. The Sailboat technique is a retrospective exercise that prompts teams to share the external and internal factors that negatively and positively impact their team performance. Blockers are external factors that the team is unable to remove without external intervention. Hinderers are internal factors that the team can overcome without external intervention. Accelerators are both internal and external factors that the team considers to be able to boost their research performance.

We set these two workshop goals to directly answer both our research questions. Through workshop goal #1, we observed how the participants negotiated with one another and transposed their individual research targets into part of their team's research targets. Additionally, we observed the challenges the participants faced when attempting to address misunderstandings with one another during the process. Through workshop goal #2, we sought to reveal the factors that diminished (i.e. blockers and hinderers) and enhanced (i.e. accelerators) the participants' research capacities.

Data analysis
We analysed the workshop and observational data thematically (Boyatzis, 1998; Braun & Clarke, 2006). Observational notes taken by the action researchers were inductively analysed using affinity diagramming. Observations focused on the process of target setting and integrating individual and team goals, and not the component of the workshop exploring blockers, hinderers and enablers.

We explained the differences between blockers, hinderers, and accelerators at the start of the activity and instructed the participants to annotate each of their factors accordingly. Preclassifying the information in such a way, enabled us to conduct the first level of thematic grouping directly from the data. This data set consisted of 30 factors written down by the participants (all factors listed in tables 2-4), with the division into blockers, hinderers and accelerators reflecting the workshop participants' situated assessment of the factors rather than a coding choice of the authors. Next, we inductively grouped the factors based on the same or similar keywords which the participants wrote per

Research Targets	P1	P2	P3	P4	P5	P6	Team
Journal article	1x	3x	2x	2x	✓		10x
Conference paper				1x			
Book publication						1x	
NTRO – Industry report	1x		1x			1x	1x
NTRO – Creative work			1x				
NTRO – Unspecified		1x				1x	
Research income			✓		✓		
Research grant	1x	1x					2x
Research awards			1x		✓		4x
Impact outcomes				✓	✓	✓	5x – 10x
Business model						1x	
L&T programme			1x		1x		

Table 1. Individual (P1 to P6) and team-based research targets.
NTRO stands for Non-Traditional Research Outputs. L&T stands for Learning & Teaching.
√ indicates that the participants identified their target to achieve that form of research output but did not set a fixed quantity.

factor (refer to Figure 1). Finally, we supplemented the analysis with thick description (Geertz, 1973; Ryle, 2009). We used thick description to add situational details to give deeper and contextual meaning to the generated groups.
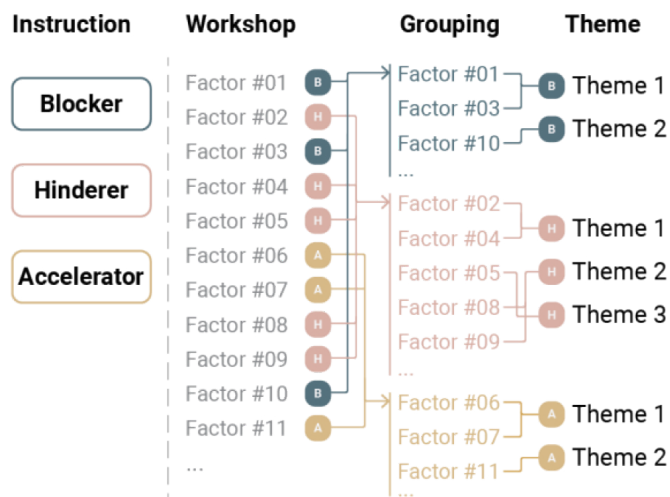

Fig.1. Data analysis process.

RESULTS

During the workshop, six participants listed and shared their individual research targets with the team before working together to create a list of team-based research targets for 2023 (refer to Table 1). The types of research targets were based on how the innovation hub performance is measured by its university in terms of research outcomes.

Integrating individual research targets into a team research target

We first describe the overall changes from individual to team research targets, then the tensions we observed during the workshop when the participants were negotiating the list of team targets.

Transforming individual targets to team targets

Instead of simply adding up everyone's target to create a list of team targets, the team created their joint targets from scratch. Immediately after writing down their individual lists, participants were instructed to negotiate with one another to identify a set of team targets. The differences in their individual targets served as prompts for the team to identify whether targets were relevant to their needs and whether the quantity per target was achievable based on their collective experience. Overall, targets were discarded, reduced, accumulated, multiplied, and made measurable.

Disregarded targets: When it came to research publications (journal articles, conference papers and book publications), conference papers and book publications were disregarded from the team target. A possible reason for this omission is that these outcomes were unattractive for most participants. For example, only P4 listed one conference paper and only P6 listed one book publication, whereas P1 to P5 listed a total sum of at least nine journal articles. Something different occurred with the Non- Traditional Research Outputs (NTROs), where creative work and unspecified NTROs were disregarded from the team target. A possible explanation for why these targets were discarded could be that most of the team was unfamiliar with the NTRO application process. Thus, perhaps NTROs were considered more achievable research outputs at the start of the exercise. However, during the workshop, another team member who had recently submitted an NTRO shared that the process was rigorous and time-consuming, which may have helped reassessing the team expectations.

Reduced targets: The participants originally identified six NTRO research targets, but eventually only set one NTRO target. Through their discussions, they realised that, while the team was ambitious to produce NTROs, they were also unfamiliar with the process. Hence rather than attempt to produce various NTROs, they instead sought to learn and produce only one NTRO (industry report).

Accumulated targets: Some targets appear to have been accumulated. For example, P1 and P2 each listed one research grant as their targets and the team listed two research grants as their targets. While the team did not explicitly mention what these grant targets were, the awareness of two individuals pursing research grants might have led the team to integrate their individual targets into the team's overall target.

Multiplied targets: Only P3 and P5 listed awards as their research targets. Yet, during the negotiation of awards, the final target doubled

to four.

Targets made measurable: P4, P5, and P6 listed impact outcomes as their personal targets without setting a quantity. One participant even wrote a question mark next to their 'impact outcomes', as if to note that it was important to achieve but had no idea how to do so. Yet, through the discussions, the team was able to not only set a range of five to ten impact outcomes to aim for but started writing down future events that were suitable to capture as one of these impact outcomes.

Tensions between individual and team targets

While the innovation hub was not given explicit research targets by their university, future projects needed to sustain and grow the innovation hub existing targets. For example, during the workshop, one of the directors shared a vision of the hub expanding to also become an innovation training centre. But to reach that stage, the hub's existing members must begin to amass a specific body of research to demonstrate credibility when starting the training centre. This meant that the team members needed to pursue specific research targets to contribute to the innovation hub's future credibility.

Research capacity factors: blockers, hinderers, accelerators

The sections below report workshop activity #2 outcomes, which are the factors that block, hinder, and accelerate research capacity in the innovation hub. Blockers are external factors that the team cannot resolve by themselves. Hinderers are internal factors that the team have agency to make changes and alleviate the issue. Accelerators are support mechanisms the team identified that will improve their capacity to conduct and produce research.

Research capacity blockers

The participants identified six factors that block them from doing research (refer to Table 2). On top of research activities, the university expected the innovation hub and its members to perform other roles, such as educators and workshop facilitators (#3 to #5). While these various roles deepen the participants understanding of their expertise, it also robs them of their research time. Additionally, when participants are assigned across multiple projects (#1), they are unable to develop the research for specific projects. While spreading the work to different people might alleviate the problem, the participants also reported the lack of people (#2) to impede their research capacity.

#	Blockers
	Resource allocation
1	Too many projects running simultaneously
2	Lack of people to do research
	Individual expectations
3	Workload models
4	Key performance indicators
5	Teaching activities compete with research activities
	Hub expectations
6	University expectations of the innovation hub

Table 2. Research process and production blockers.

Research capacity hinderers

The participants identified ten factors that hinders their research capacity (refer to Table 3). Unsurprisingly, the lack of time is the

most reported hinderer (#1 to #4), followed by the lack of research prioritisation (#5 to #7). While it might appear that these are hinderers the team can address (by managing their time and prioritising research), these hinderers might realistically be symptoms of resource allocation and individual expectations, which the participants identified as blockers in the section above. Since such internal issues are meant to be addressable by the team, but may in fact be a symptom of an external issue, this might have led some participants to develop negative feelings about research (#8 and #9), which would deter them from doing research.

#	Hinderers
	Poor time management
1	Time allocation
2	Time to plan and define all phases
3	Limited writing time (reporting research)
4	Lack of time to do research (conducting research)
	Lack of research prioritisation
5	Lack of project prioritisation
6	Prioritisation of deadlines [over research work]
7	Prioritisation of project needs [over research needs]
	Negative emotions
8	Sense of guilt with not contributing to hub's research
9	Tired and burnt out – lack of energy and motivation to think deeply and critically [about research]
	Limiting research processes
10	Lack of data collection rigor

Table 3. Research process and production hinderers.

Research capacity accelerators

The participants identified 14 factors that enhances their research capacity (refer to Table 4). The participants identified two forms of accountability: to an individual (#1 and #2) and to the team (#3 and #4). Participants found that setting boundaries, whether for tasks (#5) or time spent on task (#6), could help them progress their research more regularly. Being able to visualise what the research outcome will be like (#7), whether it has a significant impact on the team's target (#7 and #8) and map out the milestones for the project (#9), were thought to help the team decide strategically which research projects or tasks to work on first. The participants felt that assigning the right researcher to the right project (#10) and to have a clear research leader (#11) would accelerate the research process. One participant even identified that prioritising tech development and commercialisation (#12), which is the participant's area of expertise would progress the research quicker. Finally, the participants also thought that having external support such as a dedicated research programme (#13 and #14), may help them temporarily put non-research work on hold to focus on their research projects.

#	Accelerators
	Having accountability
1	Buddying up
2	Accountability partner
3	Periodic research review meeting
4	Culture and critical mass to support each other
	Setting boundaries
5	Well defined task
6	Setting deadlines
	Strategic planning
7	Determine output type and priority
8	Setting priorities [to research project]
9	Pro-active planning
	Aligning expertise to research
10	Determine how we value add to [research] projects
11	Tailcoat lead researcher/team
12	Prioritise tech development and commercialisation
	Having external support
13	Writing retreats
14	One day [as] research day

Table 4. Research process and production accelerators.

DISCUSSION AND CONCLUSIONS

This study – the first study in the ongoing *Team Research Strategy Project* – focused on documenting and analysing how an innovation hub developed their team research targets based on their team experience and expertise. In the sections below, we describe the main findings, describe the subsequent research opportunities that follows from this study and give recommendations for innovation hubs on developing team research targets.

RQ1 How can researchers integrate their individual research needs into a team's research targets?

Researchers need to first learn their team members' research needs before attempting to develop team research targets. When researchers are aware of what their team members are aiming to achieve may help the researcher gauge the practicality of their own targets. Through the development process, certain targets may be discarded, (e.g. conference papers and books) for they may not have a significant impact compared to other targets (such as journal articles). Researchers may also need to reduce their targets after learning from one another the magnitude and unfamiliarity of work needed to achieve the target (e.g. NTROs). In convenient cases, researcher's individual targets are simply added to the team's research target (e.g. research grants). In productive cases, researchers may be inspired to take on new targets after learning from another the simplicity and ease to achieve the target (e.g. awards). Finally, through the discussion process, researchers can triangulate unclear targets to understand collectively how such targets are defined and can be made more measurable as a target (e.g. impact outcomes). When researchers unintentionally withheld research targets, especially targets needed to grow the innovation hub, it created some tension during the development of the team research targets. This is because such innovation hub targets require every team member to contribute, and when these expectations are not transparent, it places a hidden expectation on the team members to perform.

RQ2 What factors enhance or diminish a teams' research capacity to achieve their research target?

Overall, there is a consensus that the expectations of the researcher to work across different projects and perform multiple roles, such as an educator and a workshop facilitator, stops them from conducting research. This is in line with previous findings where people working in academia face conflicting goals between teaching and research, which often hindered their research performance (Locke et al., 1994). Different time- horizons seem to play a role, and act in favour of short-sighted activities (Levinthal & March, 1993). While this expectation is a serious blocker of research activities, the severity is compounded by the poor resource allocation; assigning researchers to too many projects and the lack of human capital to manage the project workloads.

While researchers may identify factors they think they can rectify to improve their research capacity, such factors may reveal itself to be symptoms of the external blockages. In this case, the lack of time management and prioritisation (research hinderers), may not be addressable by the researcher because they are in facts the symptoms of project overload and lack of human capital (research blockers).

Finally, researchers identified having accountability and external supports can motivate them to do more research. Additionally, being strategic in choosing projects and gaining clarity on the research tasks needed to be completed by a certain date motivates them to do their research as well. There are varied reports on the impact of goal setting on research performance. In innovation context, Stetler and Magnusson (2015) found a curvi-linear relationship between project goals and innovation performance. High clarity on goals provide direction and focus (Zhou & Shalley, 2003) which in turn may lead to research performance in a particular direction. Having ambiguous goals could generate research ideas and outcomes in an entirely new area.

Furthermore, in innovation context, having a general goal to be innovative seem to generate positive innovation performance (Stetler & Magnusson, 2015). In the context of this study, participants may benefit from an explicit mandate by the hub directors to be more research-driven; something that was not mentioned in the results.

Theoretical implications

This study demonstrated how peoples' ideas and actions (specifically the participants' research goals and targets) adapted to their environment, which evidences Lave and Wenger's (1991) SLT. This study also demonstrated the importance of people interaction within the situation (Greeno, 1998) and that individuals may not have learnt anything new without this interaction (Brown et al., 1989). Specifically, the target-setting workshop (i.e. the situation) that facilitated participants to compare their goals and resolve their differences (i.e. the interaction) so as to create a set of team-based research targets (i.e. the new individual learning). Finally, the design and development of the workshop, specifically the question prompts used to get participants to describe, compare, then form a set of team research goals, evidence how the DDR framework was used to generate new knowledge and validate existing practices (Richey & Klein, 2007). In particular, how the workshop brought out the tension between individual and team targets (i.e. the new knowledge) and examined existing practices (i.e. the blockers, hinderers and accelerators of research).

Limitations and recommendations for future research

A study limitation is that participants were unable to gauge whether they set realistic research targets, be it independently or as a team. Providing a time frame of 1.5 years alone is not enough, as there was a large disparity in the number of research targets set by the participants. Being specific about aspirational, vs minimum viable targets, and understanding future workload allocations and available resources for conducting research may help assist target setting. We also recommend future researchers to use their past research outcomes, benchmark targets based on similar researchers past research outcomes, or use organisational guides if available to define achieveable research targets. Another study limitation is the lack of emphasis in defining what research targets are. As the participants are more than just researchers in the innovation hub, it is inevitable that they are involved in projects through different capacity. As such, we recommend future researchers to give their participants guidelines on what constitutes a research target.

Due to workshop time constraints, the team focused on negotiating the quantity of each target based on their collective experience in achieving those targets. While they brainstormed what potential projects would help the team achieve their targets, they were neither able to reach a consensus on which existing projects would be geared towards which target, nor were they able to identify all the projects needed to hit every target. Hence, subsequent workshops of this Team Research Strategy Project will be engaged to focus on unpacking each target. Similarly, subsequent workshops will facilitate participants to unpack their blockers, hinderers, and accelerators further, to identify strategies to remove research capacity blockers and hinderers, and develop strategies to implement and/or maintain their research capacity accelerators.

Implications for teams working in innovation hubs

A two hour co-design workshop was effective for teams to create shared understanding of indivudal and innovation hub research goals. Individuals had drafted prior to the workshop their research goals and interest, with individuals provisionally revising goals during the workshop according to the team research targets that were collectively set. Researchers in innovation hubs should incorporate some flexibility into their research targets so that they can adapt to organisational research demands and research opportunities that arise, leverage the expertise, interests and experience of others to set and/or achieve more research targets, or share with others the responsibility of learning an unfamiliar research process while attempting to achieve its outcome. When it comes to the factors that diminishes research capacity, innovation hub directors need to consistently work with relevant organisational parties to reduce the blockers as much as possible so that their research team can focus on absolving the hinderers. In order to make short co-design workshops more effective, hub directors could provide more strategic instructions, by sharing organisation or innovation hub targets in advance to accelerate the balancing and negotiating of individual and team research targets. However the presentation of such information in advance should be carefully considered so not to be counter-productive to the co-design methods where individuals have agency to collectively influence the outcome (in this case, the research hub strategy). It is important that the workshop and sets the tone for a supportive culture that motivates one another to perform research.

In terms of methods, a limitation on the study is the potential bias of action research observations, with notes and reflection as data sources for analysis. Recordings of conversation and/or reflection from all participants could be alternative ways to address this, however given time constraints to run a quick pilot, dual researcher viewpoints and triangulation with written workshop outcomes was selected.

Conclusion

This study contributes to the innovation literature by describing how a multidisciplinary team within an innovation hub developed their research targets and overall research capacity. To the best of our knowledge, how such research teams establish their research targets and build a research strategy has yet to be studied and reported. Hence, we case studied the process by which a research team at an Australian university's innovation hub establish their research targets. The findings reveal that a two hour co-design workshop enabled researchers to adapt their own targets to leverage research abilities of others in their team in developing innovation hub research strategies, and was useful to create shared understanding of future hub level goals. A range of hinderers, barriers and enablers were identified and spanned many themes including; resources, expectations, planning and management, accountability, emotions, boundaries and alignment from both individual and organisation levels. These findings are useful to inform the development of practical actions that aim to both leverage research enablers, and address hinderers and blockers in forming strategies for collective research targets.

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EXTENDED ABSTRACT:
Design thinking applied
to remote teams:
Systematic   review
and study opportunities

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ABSTRACT

PURPOSE

Immersed in a highly competitive environment, characterized by business internationalization and increasing user demand, companies seek new strategies to differentiate their product from the competition and maintain innovation (Jolak et al., 2021). A growing trend is the decentralization of development teams to have access to the best-prepared professionals, reduce costs and allow a deeper understanding of different markets in different regions (Eppinger & Chitkara, 2009). In parallel, the digital communication solution offering has increased together with higher degrees of customization for different demands and work methods (Marion & Fixson, 2021), allowing groups to work even asynchronously in various locations (Duranti & De Almeida, 2012).

Innovation is facilitated by design processes that seek to understand the latent demands of users, even when users cannot clearly share their needs (Liedtka, 2015). Design Thinking is one of the approaches used in the development of new solutions for raising awareness of user demands and, possibly, proposing innovations through well-established processes and techniques. It begins in the exploratory search for the problem in question and leads to a product or service proposal that solves such a problem within the project specifications (Dorst, 2011). Based on the user-centered design perspective, the team has a diversified expertise profile to provide a broad repertoire of knowledge for the selection and validation of solutions. Design Thinking is easily scalable by proposing a cyclical process composed of clear phases and feasible execution activities for non-specialists (Brown, 2008).

Challenged by the growing pressure to virtualize activities related to the product development cycle, companies adapt processes designed for face-to-face co-creation, to be mediated by digital communication tools (Jolak et al., 2021). Such adaptation is typically carried out empirically and iteratively without adequate consideration of the potential implications of Design Thinking assumptions, design individuals, and groups. As it is an emerging phenomenon, few in-depth studies understand the impact of the presence of such tools on the precepts of the design process. However, some recurring phenomena in the virtual configuration have already been observed, such as acceleration and shortening of specific phases of Design Thinking, challenges in the engagement and trust of the participants, and reduction of the sense of social presence in the meetings of the design team.

Given this context, the research question is defined as "How do remote collaboration tools mediate the Design Thinking process?". The main objective is to identify how collaboration tools mediate Design Thinking practices, identifying patterns in the processes that have been modified, adapted, and maintained to retain attributes that characterize Design Thinking. The study's focus on software application development is justified by the common set of tools that professionals and work teams share in design processes. There is the same pattern of communication tools and final products with similar characteristics, regardless of the company's sector of activity (Jolak et al., 2021). The study hypothesis is that the remote collaborative tools induce changes in how Design Thinking practitioners behave and design activities are structured and organized throughout the development cycle.

METHODOLOGY

To identify and analyze existing studies on remote design processes, the research method chosen was a systematic literature method called PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). It structures a set of standardized sequential practices organized by a checklist to ensure the reduction of bias and greater methodological rigor (Page et al., 2021). The authors gathered 202 articles from searches run through Web of Science, ScienceDirect, and Scopus scientific databases. The selected articles were tabulated and screened. After abstract and full-paper investigation, 17 articles were selected for the systematic review. The selected documents were coded and analyzed.

IMPLICATIONS

The results indicated that although creativity at first is not affected by decentralization, the literature exposes possible restrictions of the dynamics of remote work. The Design Thinking process is impacted by the changes that the tools induce in the communication and collaboration of the design team members. The reduction of time spent in the initial phases of the process, such as awareness-raising, and a greater focus on task coordination activities, stands out. In line with this, collaboration has become more challenging and dependent on the figure of an instructor or mediator, since remote work can change the engagement of members and prefer individual tasks over those carried out in a group.

Additionally, the growing supply of virtual communication tools has lowered the barriers to adoption in design teams, in addition to facilitating the communication of geographically dispersed people. Resources such as whiteboards, virtual voting, and videoconferencing gathered in a single interface helped to reduce the limitations of communication mediated by computers. The lack of a sense of presence is still seen as a limiting factor for the success of remote design dynamics. Virtual reality is seen as an opportunity to create immersive environments that reproduce the feeling of collaboration in the same space, incorporating components of non-verbal communication, such as gestures and facial expressions. However, prior training of the design team members to handle this software will be equally important.

This study is relevant for researchers and practitioners seeking to understand the current research maturity that investigates virtuality's effects on design processes. The present research is justified by the growing process of digitization of collaborative design practices in mobile applications development. Allied to this, companies seek opportunities to reduce the costs in the decentralization of their workgroups by hiring professionals from other countries, which consequently confers a multicultural and diverse profile to the workgroup (Eppinger & Chitkara, 2009).

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Looking Beyond Your Own Speciality: Student and Faculty Perceptions of Collaboration Opportunities

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ABSTRACT

This study examines engineering faculty and students' views of collaboration beyond their own field, based on 12 engineering faculty interviews and a survey with 101 graduate-level mechanical engineering students. Our analysis shows that faculty members' views on collaboration exhibit more diversity in terms of crossing disciplinary, functional, organisational, and geographic boundaries, and they view this collaboration as more integrated into engineering work, professional practices, and problem-solving. Students, in turn, report a narrower scope of collaboration, primarily focusing on multidisciplinary collaboration to utilise engineering output. Our study helps inform engineering educators to integrate diverse collaboration more effectively with course design.

KEY WORDS:

collaboration, engineering education, multidisciplinary collaboration

INTRODUCTION

Collaboration across diverse knowledge domains is an important driver of innovation (Borrego & Newswander, 2008; Akkerman & Bakker, 2009). As a result, collaboration, especially multidisciplinary collaboration, is emphasised as a criterion for engineering curricula across the globe (ABET, 2022; Engineering Council, 2020; Engineers Australia, 2010). The inclusion of multidisciplinary teamwork in the engineering education curriculum not only helps students to learn collaboration skills but also problem-solving skills by synthesising multiple perspectives (Lattuca et al., 2017).

To foster a collaborative learning environment and for students to learn different skills, it is important for both educators and students themselves to understand the concept of collaboration, different kinds of collaborations and potential collaborators related to engineering work. However, while many sources agree on the importance of collaboration, exactly how engineering faculty members and students themselves perceive collaboration still remains unclear.

To provide a conceptual basis for understanding collaboration and develop higher education engineering curricula for effective collaboration, in the current study we investigate how engineering faculty members and students perceive opportunities for collaboration beyond their own speciality.

THEORETICAL BACKGROUND

In the current study, we examine collaboration from a process perspective (Kolfschoten et al., 2010), focusing on the different collaboration forms that faculty members and students consider important in the context of engineering education.

Broadly, we can distinguish between two types of collaboration that take place in engineering education. Firstly, collaboration occurs across disciplines, both between students of different disciplines and between engineering educators from diverse disciplinary backgrounds (Costa et al., 2019; Dringenberg & Purzer, 2018; Borrego & Newswander, 2008). The range of disciplines participating in engineering education is continuously broadening. For example, Borrego and Newswander (2008) and Sochacka et al. (2016) found that social sciences and art educators increasingly engage in engineering education and joint research efforts. Secondly, collaboration occurs between different organisations, such as schools, universities and engineering firms, to support students' learning and the development of key professional competencies (Gillen et al., 2021). These various forms of collaboration manifest in increasingly diverse and complex engineering practices. Therefore, an important task for engineering educators is to design and facilitate opportunities for students to cultivate a range of collaborative capabilities needed in the field.

Indeed, opportunities to collaborate beyond one's own discipline during studies have been connected to several positive outcomes. For example, studies by McNair et al. (2011), Oehlberg et al. (2012), and Sochacka et al. (2016) on cross-disciplinary student and teacher collaboration have shown that students who collaborate across disciplines develop communication skills and gain the ability to value disciplinary diversity for teamwork, innovation and creativity. Cross-organisational collaborations between universities, industry partners, local communities, or other groups of stakeholders, in turn, have led students to report higher self-efficacy (Dunlap, 2005) and develop various competencies, such as project management, leadership, and time management (Borrego et al., 2013).

While these studies offered interesting insights into the benefits of collaboration for students' learning, many studies do also report

students experiencing challenges associated with collaboration. For example, engineering students can struggle to recognize and value the contributions of non-technical fields, which lowers students' performance in collaborative work (Richter & Paretti, 2009). Students can also find connecting to an interdisciplinary topic or problem challenging (Macleod & Van der Veen, 2020). These studies offer valuable insights into the benefits and challenges of collaboration. However, they did not examine collaboration from students' points of view. Since students' views of collaboration are closely related to how they collaborate, more research is needed to understand students' perspectives on collaboration and provide guidance for effective collaboration.

However, given that research has demonstrated systematic differences between novices and experts in a range of fields (Ericsson et al., 2006), student perceptions and outcomes of collaboration can also be assumed to differ from those of professional engineers. Indeed, research has shown that while more experienced engineers and designers take an integrated approach to problem-solving, novice and graduate students tend to struggle with problem definition and additional iterations (Ahmed et al., 2003; Cross, 2004; Eteläpelto, 2000; Björklund, 2013). Although studies comparing novice and expert engineers are relatively rare, research on engineering education does suggest collaboration to be valued as both a teaching practice and a key competency by academic experts (Borrego et al., 2010). In particular, engineering educators use interdisciplinary capstone projects and service-learning projects, where students work in teams, facilitated by scaffolding structures, such as milestones on the team's work plan, ideation, and prototype, to support students' team progress (Borrego et al. 2010; Van den Beemt et al., 2020). Further, Alves et al. (2016) found that the reasoning for engineering teachers' use of collaborative project-based learning is to foster students' teamwork and communication skills, in addition to problem-solving skills.

Other extant studies have illuminated collaborative processes through case studies, examining for example teacher collaboration and student collaboration in project-based learning (Sochacka et al., 2016; Dringenberg & Purzer, 2018), as well as collaboration between universities and industry partners (Gillen et al., 2021; Rojas, 2001). While these studies show the importance of collaboration that teachers put on engineering education and provide detailed descriptions of specific kinds of collaborative efforts, less is known about faculty perspective on different collaboration opportunities and respective reasonings.

As motivation to pursue collaboration - or any activity - hinges on the perceived value and expectancy of such efforts bearing fruit (Eccles & Wigfield 2002), a better understanding of both faculty and student perceptions of collaboration can help to predict what types of collaboration they are likely to pursue. This, in turn, can inform what kind of educational support might be needed to develop such practice further. As such, in this paper, we examine both faculty members' and students' perspectives on collaboration opportunities beyond their own speciality.

METHODS AND DATA

The study was conducted in a mechanical engineering degree programme at a Nordic university. Data was collected through semi-structured interviews (Merriam & Tisdell, 2015) with faculty members

and an online questionnaire for students (Creswell, 2002), both initiatives originating from teaching development efforts. The data collection was designed and conducted by the second author together with the teaching team of the degree program.

Faculty data collection

First, 12 engineering faculty members from the degree program were interviewed. Interview requests were sent to the faculty representatives of the seven different advanced study topics included within the degree programme, seeking two interviewees from each advanced study topic. Seven professors, three postdoctoral researchers and two doctoral researchers volunteered, representing all seven advanced study topics, such as product development and marine technology. The interviewees' work experience in engineering ranged from a few years to more than 20 years.

Semi-structured interviews were then conducted with the 12 faculty members on the required capabilities in the field of the interviewee. The interviewees were prompted to reflect freely on the core skills, knowledge, and attitudes important from the perspective of the advanced study topic they represented, the role of collaboration and sustainability for engineers within their field. Moreover, they were asked about the collaborators that engineers need in their field. As the intention was to create teaching videos, the interviews were video recorded by a colleague and transcribed verbatim.

Student data collection

The student data from the study comes from a teaching effort aiming to increase student awareness of collaboration opportunities that utilised one of the teaching videos created based on the 12 faculty interviews. Data was collected from a course that was compulsory for all master's level (graduate) degree students of the mechanical engineering program. Most students were in their first year of the two-year degree program. First, all students were shown a 17-minute video on collaboration, consisting of interview snippets (separately approved by the interviewees for sharing) from the 12 faculty interviews that had been sorted into short sections on the usefulness of collaboration spanning functional, disciplinary, geographic, and organisational boundaries. It is important to note that the video may have influenced student responses in the direction of aligning them with the faculty interviewees - a limitation of the current study.

After students watched the video, they were given a short online survey, designed by the teaching team for the course. The current study uses the last question in the survey, an open-ended reflection question "Who do you think would be useful to collaborate with outside of the mechanical engineering program? Explain why." 101 students filled out this question in the survey, with responses typically being a few sentences of text.

Data analysis

We then analysed the faculty interview data and student survey data. First, we inductively analysed the transcripts of faculty members with open coding (Charmaz, 2006) to remain open to all possible insights. Then the codes were categorised thematically (Braun & Clarke, 2006) based on the types of collaborations and their reasoning for different collaborations. Similarly, student data was coded through thematic analysis, first creating separate categories for this data. Then, the categories and the data within the categories in the faculty and student responses were compared with one another in terms of their content and frequency, examining differences and similarities in the type of

collaborations reported and the reasoning shared for these.

RESULTS

This section presents different types of collaboration mentioned in the data set: (1) cross-disciplinary and functional collaboration, (2) cross-organisational, and (3) cross-geographical collaboration. Further, we provide insights into the reasoning for each type of collaboration, to understand the different potential impacts these types of collaboration may have on students' learning. Table 1 presents a summary of the most salient categories and themes.

Cross-disciplinary and cross-functional collaboration

Crossing disciplinary boundaries in collaboration was the most common form of collaboration brought up by faculty and students alike, but they emphasised different collaboration purposes. Eight out of 12 faculty members brought up collaboration with others from different disciplines. They focused on how multidisciplinary collaboration facilitates students' learning of problem-solving through an integrated process. For example, a product development professor described the value of art and design disciplines to engineering students for identifying and defining problems which complement and facilitate effective and creative problem-solving:

Universities are very good at teaching engineers to become problem-solvers. But what I have learnt from art and design education is that design students learn much more about identifying the problems that are not visible often. So, combining these two approaches is really good and fruitful for successful development.

Besides integrating disciplinary knowledge and insights for problem-solving, faculty members also discussed how crossing disciplinary boundaries can discover new ways of doing and developing breakthroughs, rather than reinventing the wheel. In particular, two faculty members talked about the need to collaborate between engineering, computer science, arts, business, and material science to develop new technologies and ways of doing and impact the field and society.

Faculty members also discussed how multidisciplinary collaboration improves engineering practices. They mentioned a wide range of disciplines that engineers can work with, including those both within and outside the engineering realm. For example, mechanical engineers can work with collaborators from electrical engineering, computer science, medical science, material, business, art, and design. This type of multidisciplinary collaboration highlights the combined efforts of each disciplinary contribution to engineering practices. As one mechatronics post-doctoral researcher stated:

Collaboration is at the heart of mechatronics. [Although] we're taught at the mechanical engineering department with mechanical engineering skills, we need to collaborate as much as possible with autonomous systems and control engineers, electrical engineers, computer scientists, and product development because it's at the heart of making anything tangible.

Overall, faculty members' perspectives emphasise the impact of multidisciplinary collaboration on problem-solving, developing breakthroughs, as well as improvising existing practices.

Closely tied to multidisciplinary collaboration, half of the faculty members (6 out of 12) emphasised collaboration towards crossing functional boundaries in engineering practice, working with people from other functional units, such as manufacturing, assembling, shipping, supply, sales, accounting, and marketing. For example, another product development professor shared that:

When you develop products for people, you need to work with those people, [including] users and people who assemble and manufacture. Also, if you work within an organisation, you also need to work with the sales or marketing team, and those from other departments, depending on your product and your company.

Similar to faculty responses, students (95 in 101) also emphasised multidisciplinary collaboration and cross-functional collaboration for engineers, although students' perceptions of collaboration opportunities were narrower. Business, management, and economics (42 in 101), electrical engineering (39 in 101), art and design (34 in 101), and computer science (29 in 101) were the four most frequently referenced groups of disciplines for multidisciplinary collaboration, but a range of disciplines, functions and professions were brought up. An additional nine students mentioned opportunities to have collaborators from all disciplines, with limited specifications on how these could then contribute.

Overall, students did not tend to differentiate cross-disciplinary from cross-functional collaboration. They focused more on the need to collaborate with other disciplines from a cross-functional perspective to improve the market performance of produced solutions. Students often talked about disciplines along with functions. For example, one student noted:

Mechanical engineers cannot solve any problems by themselves [...] For example, in my workplace, we work daily with designers, electrical engineers, software developers, physicists, usability designers, and sales persons... The list is endless.

Students' responses showed clear interest in collaboration, particularly with various business and design functions or fields. The reasoning for such collaboration typically referred to needing disciplinary expertise from different disciplines. Their responses focus on collaboration as working in parallel with different functions, rather than viewing collaboration as an integrated process to co-construct novel solutions together. For example, students' examples separated commercialising products by marketing as an additional element separate from the technical engineering solutions, such as:

The most important one we need to collaborate with is someone who can connect the products and markets so that a company [has] the ability to sell what we design and make our production meaningful. By that standard, one can be someone who studies in the realm of industrial management and investment management.

However, the level and depth of student reasoning did vary, with some students representing collaboration as an integrated activity for producing better solutions:

City bikes contain a lot of mechanical features but there is also a need for software elements and sensors [...]. The effectiveness of city bikes can be monitored by the data of bike-riding and the number of users who are using it, which is more related to data science [...] If the bikes are battery-powered, creating charging technology and [including]

batteries in a user-friendly way is part of user-centric design. So, we can see that a simple bike involves a lot of fields and disciplines nowadays.

Cross-organisational collaboration

In addition to crossing disciplinary and functional boundaries, collaboration across organisations was brought up. Five of the faculty members emphasised collaboration with the industry. The importance for students to work with real-world problems and challenges by the industry partners were highlighted to help students learn to define problems, develop possible solutions, and prototype and test for innovation. Besides collaborating with the industry, faculty members also mentioned collaboration with academia, governmental organisations and professional societies to contribute to policy-making and societal and industrial impact, such as academic researchers working with ship classification bodies in the shipping industry. As an arctic technology doctoral researcher said:

Universities, companies, and classification societies all have their own agenda, but I think it [...] helps to use this kind of [collaboration] as an asset to [make a bigger impact].

In contrast, only six out of 101 students referenced opportunities to collaborate with industry partners to help develop professional competencies and build relationships for future employment as well as align with governmental interests. For example, one student said:

It is important, career-wise, to collaborate with the industry and see what skills are needed and make connections.

Besides collaborating with partners, a few other students also mentioned working with governmental bodies for civic responsibility, with different stakeholders to understand different needs for product development, and with other universities and schools to explore more learning opportunities.

Type of collaboration	Faculty interviews		Student survey	
	Salience	**Purpose (when mentioned)**	**Salience**	**Purpose (when mentioned)**
Cross-disciplinary	8/12 mentioned this form of collaboration, (between different engineering disciplines and art, design, computer science, business, material science, medical science, etc.)	Engage in problem-solving in an integrated process with other disciplines; develop new ways of doing and breakthroughs; improve the engineering practices	95/101 (Electrical engineering, business, economics, design, computer science, data science, medical sciences, chemistry, architecture, environmental engineering, etc.)	Improve the market performance of produced solutions with add-on elements from other disciplines/functions
Cross-functional	6/12 mentioned this form of collaboration, (with other functional units, such as manufacturing, assembling, shipping, supply, sales, accounting, marketing, etc.)	Improve engineering practices and their outcomes		
Cross-organisational	5/12 mentioned this form of collaboration, (between academia and industry partners, governmental organisations, professional societies, etc.)	Tackle real-world problems or challenges; create a bigger impact across organisations	6/101 mentioned this form of collaboration (with industry, and governmental bodies)	Develop professional competencies for employment; align with governmental interests.
Cross-geographical	4/12 mentioned this form of collaboration, (with different countries in general)	Exchange knowledge and skills; facilitate international work for certain fields	1/101 mentioned this form of collaboration (through exchange studies).	Have other learning opportunities

Table 1. Types and purposes of collaboration brought up by engineering faculty and students

Cross-geographical collaboration

Finally, while four faculty members discussed the importance of collaboration crossing geographic boundaries, the only reference made to international collaboration by students was one instance of exchange studies:

[...] mechanical engineering should be combined more with [computer science in mechatronics]. For example, more exchange opportunities can be created for [the university's] students to go to other countries such as TUM (Technical University of München).

Four faculty members, in turn, emphasised the importance of working in an international environment, particularly for specific subfields. For example, a marine technology professor shared that:

International collaboration can be very important in the maritime field and has different facets [of international collaboration]. For example, if somebody works for a shipping company, international collaboration is on a daily basis. [They] have to discuss with the international crew.

The faculty also highlighted the benefits of international student collaboration and research collaboration as ways to exchange knowledge and ideas to tackle problems and develop novel solutions for example, with different perspectives and approaches to sustainability and engineering materials.

DISCUSSION AND CONCLUSIONS

Our study examined the collaboration perceptions of engineering faculty members and graduate students, discovering clear gaps between faculty and student perceptions concerning the diversity and nature of collaboration. Faculty perceptions covered a wider range of collaboration partners and purposes integrated into engineering practice, with most students focused mainly on cross-disciplinary and cross-functional collaboration to commercialise engineering solutions. It is noteworthy that these differences were observed despite students having been exposed to a video sharing the faculty's perceptions immediately prior to sharing their own views on collaboration. As studies have shown that compared to novices, experts tend to possess a more elaborate understanding, knowledge, and experiences of their fields (Cross, 2004; Ericsson et al., 2006; Eteläpelto, 2000), the differences in scope of collaboration views can also be expected. In particular, more experienced engineering and education scholars have been shown to appreciate the interactions and connections between different disciplines and adopt a reciprocal approach to collaboration (Borrego & Newswander, 2008). The current study adds to this by demonstrating how such views can differ between students and experts, with implications for educators on how to scaffold building more expert-like understanding to students.

First, most students seemed to conceptualise cross- disciplinary collaboration as an additional element to add on top of engineering solutions, rather than as an integrated process for problem-solving and developing novel solutions in engineering work. Such a narrow view of collaboration may limit students' ability to recognize and value the contributions of other fields (Richter & Paretti, 2009). Moreover, adopting a segmented way of working, with engineering students being responsible for technical solutions and business and design students being responsible for commercialising and aestheticizing a product, is suboptimal, as non-technical students may not feel valued for their contributions to problem-solving (Macleod & Van der Veen,

2020). The observed lack of integration may stem from a limited understanding of the benefits of interdisciplinary collaboration - for example, Dringenberg and Purzer (2018) found that not all students were aware of the contributions of different viewpoints in the context of first-year engineering students solving ill-structured problems with peers from different engineering fields. These students were unable to tolerate a higher level of ambiguity or appreciate multiple perspectives from their team members. If educators wish to support students in conceptualising collaboration as an integral and integrated part of engineering, the current study suggests that additional efforts are needed to showcase how and why such collaborators might contribute to engineering problem- solving. Indeed, Lattuca et al. (2017) found that when engineering faculty emphasised applying knowledge MER from non-engineering fields and understanding how GEFO cultural, environmental, and economic contexts RMA contribute to integrated engineering problem-solving, T3 students reported higher levels of interdisciplinary competence.

Second, the current study suggests that cross-disciplinary and functional collaboration are more salient opportunities for students than cross-organisational or cross-geographical collaboration, despite all three being featured in the video shown prior to the survey. When cross-organisational collaboration was brought up by students, it was typically from the perspective of developing professional competencies in the context of university-industry collaboration. Indeed, engineering programs and higher education in general increasingly involve industrial partners in capstone projects (Marvri et al., 2021). Such collaboration with industrial partners encourages an increase in students' professional confidence (Dunlap, 2005). In comparison with university-industry collaboration, other organisational collaborators, such as governmental organisations and professional societies, were less mentioned by students than by faculty members. Yet, studies have shown that these can yield similar benefits to industrial collaboration in professional skills and preparation for work (Huff et al., 2016; May & Chubin, 2003). With the added benefits of increasing students' skills for social change (Huff et al., 2016; Litchfield et al., 2016; Cilio et al., 2011), educators could seek more diverse organisational collaborators in project-based learning and utilise service learning (Jacoby, 2003). Similarly, more opportunities for cross-geographical collaboration within one's studies, for example through international project sponsors or student collaborators in project-based courses (e.g., Mikkonen et al., 2018) could be called for, particularly as integrated collaboration in a transnational context remains challenging even for professionals (Subramaniam, 2006; Okhuysen & Eisenhardt, 2002).

Given the current results on student perceptions, we suggest that in order to pave the way for understanding and seeking more integrated and varied purposes for collaboration, engineering teachers need to 1) explicate the benefits of looking beyond one's own speciality to cross disciplinary, geographic, functional, and organisational boundaries, and 2) provide engineering students opportunities to engage in such diverse collaboration activities to build first-hand experiences in how such collaboration can be integrated within engineering work itself. Similar to separate ethics training risking presenting ethics as a discrete or peripheral issue rather than an integrated and central consideration in engineering work (Lönngren, 2021), the current study highlights the need to broaden student perceptions of the connection between engineering and diverse collaborators. Illuminating new collaboration avenues and more integrated opportunities can pave the way for developing more effective boundary-spanning collaboration

capabilities to tackle complex problems through systemic innovation. As we studied a limited number of engineering faculty members and students from a single institution, the results may not be generalizable. Additionally, we employed different formats of prompts and data collection for faculty members and students. Our questions focused on "who" and "collaborators", which may have directed student and faculty attention to persons rather than organisations or fields. Moreover, the faculty interview video and related survey questions may have prompted students to align their responses with the views voiced by the faculty members. As such, more research is needed to validate the salience of the types and purposes of collaboration identified in the current study, and how they interact. Further studies could also link the reasoning of these categories to learning and behavioural outcomes, such as the likelihood of selecting courses from different disciplines, as well as potential antecedents, such as type and amount of experience in the field. With the differences in scope and integration in collaboration perceptions observed in the current study, engineering educators can design collaborative learning activities to explicate the benefits of diverse collaboration and offer opportunities to gain first-hand experience of integrated collaboration with different disciplines, organisations and cultures.

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Theme 3:

Courses & Workshops

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Other studies zoom into specific courses and types of activities. For example, the effect of a certain type of co-creation workshop (Dieing et al). In one case, this involves a project involving more than 6000 students (Riveros et al). The developments towards remote education, where students were taught from home, were examined in the paper by Taveter et al which examined the difference between physical and virtual co-design workshops. Research that also stems from working and learning at a distance is the paper in which Sarasvathi's Effectuation Theory is applied to an online cooking exercise to practice design-driven entrepreneurship (Iandoli & James).

EXTENDED ABSTRACT:

A Comparative Study of Two Co-Design Methodologies

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ABSTRACT

PURPOSE

Involving end users and other stakeholders in creating new products and services is one of the cornerstones of design thinking. Different co-design methodologies can be used for this purpose. This said, there is a paucity of studies comparing different co-design methodologies for designing digital products and services. We compared co-design projects of software-intensive products from the perspective of requirements engineering, with an aim to increase the understanding of the benefits of different co-design methodologies for eliciting and representing early requirements. We performed the comparison based on four design projects, all pertaining to new digital services. All four projects were carried out at the Sandbox of the University of Tartu. The cases concerned represent the designing of (a) an app for ordering and using an autonomous vehicle; (b) a search engine for onboarding; (c) a banking service app; and (d) a physical-exercise app for adult users (Mooses, 2022). In this paper, we study the four co-design projects individually as well as comparatively.

METHODOLOGY

In two of the four co-design projects, we used the do/be/feel co-design methodology (Lorca, et al, 2018; Taffe, et al, 2022; Sterling & Taveter, 2009; Miller, et al., 2014; Miller, et al., 2015). This methodology involves facilitated co-design workshops that run in three diachronic phases: a) focusing on the functional requirements; b) focusing on the quality requirements; and c) focusing on the emotional requirements. In each workshop conducted for these two projects (cases "(a)" and "(d)"), the three kinds of requirements were represented as the respective functional, quality, and emotional goals to be achieved along with the roles required for achieving them. After each workshop, the goals themselves and the roles required for achieving them were constructively criticized and, on an iterative basis, rearranged into a hierarchical goal tree of functional goals, in which the relevant quality goals and emotional goals, as well as the relevant roles, were attached to the appropriate functional goals whose attainment they support. In the other two co-design projects (cases "(b)" and "(c)"), we used a practice-based design methodology, evolved locally at the University of Tartu Sandbox. The cornerstones of this "Sandbox methodology" are the following three co-design phases: (1) "human needs and feelings"; (2) "existing solutions"; and (3) "technologies". The human needs and feelings in the Sandbox methodology correspond roughly to the functional and emotional goals elicited by the do/be/feel methodology. The do/be/feel and Sandbox methodologies differ in that in the do/be/feel methodology, there are no direct counterparts to the existing solutions and technologies of the Sandbox methodology because, unlike the Sandbox methodology, the do/be/feel methodology is technology-agnostic. From these starting points, we set out to find commonalities and differences in the benefits of the two methodological approaches by using the findings from the four case studies that were conducted.

FINDINGS

Based on our analysis of the four cases, the abstraction levels of the two co-creation methodologies are different: while both methodologies start from eliciting functional and emotional requirements, the do/be/feel methodology appears in the end to not directly delve into technologies needed for satisfying the requirements, while the Sandbox methodology does. On the other hand, the Sandbox methodology appears not to directly deal with eliciting quality requirements. Our case analysis further demonstrates that the do/be/feel methodology appears to work well for identifying functional, quality, emotional goals, and stakeholder roles required for achieving those goals. The outcomes of the do/be/feel workshops can be readily transformed into hierarchically structured goal models that are easily understood by any stakeholder. The stakeholders can then use these models as boundary objects for their discussions to facilitate the further elaboration of the goals.

In co-creating the digital app supporting physical exercises, the do/be/feel workshops served well to discover and unpack common needs and preferences that the intended users appeared to have. In partial contrast, the do/be/feel workshop for the app to be used for ordering and using an autonomous vehicle resulted in rather generic sets of functional, quality, and emotional goals, and in rather generic roles. Discovering new ideas was more vague and less structured in the Sandbox methodology than in the do/be/feel methodology, according to our analysis. On the other hand, a clear benefit of the Sandbox methodology was that the expectations were from the beginning raised above the existing solutions, contributing to devising technological solutions with no predecessor on the market. This could be observed especially well when designing the onboarding app, which involved a high degree of uncertainty because of the not-so-well-explored problem domain.

IMPLICATIONS

Across our within- and across-case case analysis of the four projects, we can conclude that information and communication technologies have a lot of potential to support radical and genuinely meaningful product and service design. The do/be/feel co-design methodology fits better for designing fully immaterial solutions, such as the digital physical exercise app, the banking service, and the onboarding service. It fits less well for designing the app for ordering and using an autonomous vehicle, which involves a physical dimension. The do/be/feel co-design workshop appears to work less well in a not-so-well explored problem domain, such as designing the app for ordering and using an autonomous vehicle or the app for onboarding, and much better in a well-mapped problem domain such as designing the physical exercise app or the banking service app.

Our most important finding is the proposition that the do/be/feel methodology, on one hand, and the Sandbox methodology, on the other hand, complement each other, even in the same co-creation project. More specifically, on the basis of our analysis, it appears that the most efficient way to start the design process seems to be applying the do/be/feel methodology for eliciting and elaborating requirements in a technology-agnostic way. We also believe that the ideal methodology should consider already from the start of its application the existing solutions and how these meet functional goals. This can be achieved by the Sandbox methodology. We acknowledge that this kind of combination of two co-design methodologies can lead to the repetition of already existing ideas, products, and services. As another contribution of our paper, we propose our distinction between purely immaterial and partially material offerings as a valuable input for co-designers and other developers who are willing to improve their existing digital solution or develop a completely new one. We call for further research on all the findings stated above.

Note: All four co-design case studies benefited from the above-average digital literacy of the participants, who were mainly MSc and BSc students, and their ready access to digital tools.

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ABSTRACT

This paper provides a structured comparison of two global, interdisciplinary courses on design innovation that were introduced at inno.space. Both were inspired by the established ME310 course originating in Stanford and aim to provide a less intense learning experience that is more suitable for Bachelor students. Besides the rationales for the course design, the paper points out the influencing factors that reduce the complexity of the courses; as such, there is the ambiguity of the design challenge and a reduction of disturbing factors of teamwork. The presented work serves as a starting point for more rigorous research as well as inspiration for further course designs.

KEY WORDS:
curriculum design, interdisciplinary courses, user-centric innovation

INTRODUCTION

Inspired by the established ME310 curricula (Carleton & Leifer, 2009; Carleton, 2019; Wiesche et al., 2018) inno.space introduced two further user-centric innovation courses based on design thinking principles. After several years of experience running the ME310 course in cooperation with Stanford, Aalto and d.school Paris from 2015 on, and becoming a member of the DFGN in 2017, the demand at the university was increasing to offer a similar learning experience to students on a larger scale. We felt a particular need to provide more students with a chance to acquire 21st-century skills (OECD, 2019). This made us think about a more "lightweight" variation responding to two constraints: having to be less time- consuming (fewer ECTS) and suited for undergraduates. As ME310 is a very intense program in terms of credits/time and an expensive program for the cooperation partners, we were looking for ways to downsize the ME310 set-up while keeping learning outcomes that we judged essential. This finally led us to create a curriculum for a new 5 ECTS course named GDIP (Global Digital Innovation Program) which we have run five times since September 2019 in partnership with Sandbox (Design Factory Tartu, Estonia) five times until today. In 2020 we established a third course, iPDP (International Product Development Project) that we defined together with Design Factory HAMK (Hämeenlinna, Finland). The required student involvement of iPDP fits in between GDIP and ME310 and covers 10 ECTS.

Throughout the work presented in this paper we created a list of course characteristics that supported us in describing the main "design decision" for the little siblings of ME310, the GDIP and iPDP courses in a structured way. That way, we can point out the main commonalities and differences. The set of characteristics includes the course set-up as well as properties that are defined by the external project sponsor collaboration and the collaboration with the partner university.

The contribution of this paper is two folded:
• We provide a structured comparison between the courses and justify the differences through rationalization of our design decision. This allows universities to get inspired when designing their curricula. That way, our work can serve as "best practice" advice for an increasing demand of courses that enable students to work in ambiguous environments by promoting innovation and developing an intrapreneurial mindsets.
• Second, the set of characteristics can serve as a valuable starting point for a more rigorous research effort on the dependencies between course characteristics and learning outcomes under given constraints. It can set the ground for comparing between various other international courses on challenge-based design innovation as organised within the DFGN.

The paper is structured as follows: The section Theoretical Background elaborates on ME310 and its essential course elements that inspired our smaller courses GDIP and iPDP. The Result section lists the course characteristics and compares the various courses.

Additionally, the design rationales for these course characteristics are given. Finally, the quality of our design decisions related to the achievements of our courses as perceived by students and external partners is underlined by a small qualitative analysis as part of the Result section.

THEORETICAL BACKGROUND

ME310 as Blueprint
Established in 1967 at Stanford, ME310 has a long tradition and evolved through various phases (Carleton, T., & Leifer, 2009). It is a project-based capstone course in engineering education to grow the next generation of product designers/changemakers. As Larry Leifer phrases it: students learn to "dance with ambiguity" (Steinert & Leifer, 2011). Teams of master's level students from various disciplines work on complex engineering projects sponsored by industry partners. Since 2004 the students have worked in global teams, which means each team of 3-4 students located at one university partners with a similar number of students from a global partner university. The course runs over one academic year. Industry partners challenge the students to

explore solutions for the future. The students turn the challenges into tangible solutions as one of the final outcomes of the project. The course is organized as a product development project in a challenged-based style. It is structured in three main phases, exploring the problem space, solution space and making it happen. (see Liu et al., 2020; fig. 1 for an overview). Within these phases, students get a defined series of weekly or biweekly lectures and assignments that guide them through the innovation project in a structured way. One of the very unique types of assignments for the ME310 course are specific prototypes. The curriculum contains a series of different prototyping techniques that originate from design or engineering disciplines and scaffold students' learning by fostering the ideate, prototype testing cycle (Bushnell et al., 2013; Domingo et al., 2020). These cycles of experimentation are one of the key drivers of the innovation process. The different prototyping techniques support the students' understanding of the problem from various perspectives. They are one vital driving force to support a larger variety of ideas and to develop a deeper understanding of a potential solution. At many universities of the SUGAR network the course serves as an integral part of an engineering master's track combining engineering skill development with so-called T-shaped competencies and 21st century skills.

21st Century Skills

The 21st century skills have gained increasing attention. As Andreas Schleicher, OECD Education Directorate, states it (OECD, 2022):

> "Today, because of rapid economic and social change, schools have to prepare students for jobs that have not yet been created, technologies that have not yet been invented and problems that we don't yet know will arise."

Being competitive today requires different understandings and skills than those focused on by 19th and 20th-century education systems (Suto, & Eccles, 2014). Our lives have become more international, multicultural, and interconnected. Thus, it is not surprising that there is growing reference to the so-called 21st-century skills, which reveal what and how students today should learn to become productive citizens. Ehlers (2020) defines these skills as:

> "competencies that enable individuals to solve complex problems in a self-organized manner and to act (successfully) in high-emergent contexts. They are based on cognitive, motivational, volitional and social resources, are value-based, and can be acquired in a learning process."

To teach these skills, design thinking (Koh et al., 2015; Luka, 2019), project-based learning (Rajendra & Patil, 2020; Ravitz et al., 2012; Shaw, 2018) and challenged-based learning (Papageorgiou et al. 2021) have proven to be valuable learning models. Also, the positive impact of those approaches on acquiring the skills is not debated anymore, a more detailed understanding is however missing. There is a lack in showing dedicated connection between specifics in course design and dedicated acquired skills from the 21st century skill set.

Constraints and Goals for the Course Design

Given our teaching experience from ME310 with a very complex and intense set-up, we carefully considered which elements of this course we need to keep, drop or modify while defining our new curricula. The two constraints for the "lighter" version were (C1) less time-consuming, which can be translated into ECTS and (C2) suited for undergraduates to reach a larger cohort. They appear as characteristic in Table 1 with the IDs 2 and 3. Important goals for the design process of the courses were (G1) the learning outcomes for the students, (G2) an achievable learning journey for the students while having fun and (G3) an attractive offer for external partners to provide real-world challenges. The evaluation of our effort will be based on these goals, which we reference in an anecdotical way in the *Result* section.

METHOD AND DATA

The work presented here does not follow the classical empirical research approach as conducted in science. It is the outcome of a design process for curriculum design that is not yet scientifically evaluated and therefore is presented as a work in progress.

When deriving the set of characteristics for courses as bases for the comparison, we started with characteristics provided by Wiesche et al. (2018). These authors derived them from analysing various ME310 courses offered at different global universities in the SUGAR network. We built on this initial set and extended it by analysing our module descriptions and course planning for the mentioned courses ME310, iPDP and GDIP. Based on these sources, we identified, named and clustered characteristics in several group sessions between the involved course instructors.

The data for the evaluation of the feedback of students regarding G1 and G2 was derived from a retrospective conducted at the end of the GDIP course in summer 2021. The evaluation of the sponsors' perspective G3 was derived by analysing quotes from sponsors after the presentation of the student's results at the end of the GDIP and iPDP course in 2021.

RESULTS

Rationalised Comparison of Courses

We compare between the three courses with 20 characteristics, as listed in table 1. The table is structured in four main sections: Characteristics 1-6 list the course set-up. It includes our goals and constraints in addition to three characteristics all our courses have in common (the evaluation techniques for the student's performance, the organisation of content input and contact time with the teaching team, as well as the teaching team set-up). The three other main sections describe the interface to the external partner (7-12), the interface to the global university (13-17) and the applied prototyping methodology (18-20). These three show remarkable variations in comparison to the ME310 courses, which we rationalise in the following elaboration.

The main changes were made to reduce the complexity of the students' learning experience while keeping the project-based core of developing a tangible solution for a real-world challenge following the structured approach of prototyping cycles because we judge this as relevant for the learning experience and outcome. Two main anchors helped us reduce the complexity: the sponsors' and global partner collaboration.

We achieved reduced complexity in the interface to external sponsors through the following modifications:
  • We decreased the complexity of the design challenge by reducing its openness (9) and the height of innovativeness (10) (e.g., by ensuring the target user group is identified at the beginning and the challenge targets the near future instead of expecting a future outlook). Hence, this allowed us to reduce the number of different

		ME310	iPDP	GDIP
Course Setup				
1	Course objectives/ learning goals (Goal G1) Objectives mainly in line with Wiesche et al. 2018	• Students can handle ambiguous problem statements and develop tangible solutions to them (LG 1.1) • Students can apply design thinking methodology during innovation activities (LG 1.2) • Students can plan, create, and develop human-centric innovations in a semi-structured way (LG 1.3) • Students can apply the prototyping methodology in a structured development process (LG 1.4) • Students can work in international and interdisciplinary teams during innovation activities (LG 1.5) • Students can communicate and present their development outcome (LG 1.6) • Students gain creative confidence, self-efficacy, resilience and critical thinking (LG 1.7)		
2	Effort/Timespan (Constrain C1 for iPDP and GDIP)	20 ECTS / 2 semester Amount of ECTS varies between partner university	10 ECTS / 1 semester Same credits at both universities	5 ECTS / 1 Semester Same credits at both universities
3	Eligible students (Constrain C2 for iPDP and GDIP)	Master students of various engineering disciplines and design	Bachelor and Master students various engineering disciplines and design	Bachelor students from computer sciences and communication design
4	Student evaluation techniques	Combination of outcome-driven evaluation (based on project outcomes) & process-driven evaluation (based on how they reach project outcomes); Combination of team grading and individual grading;		
5	Content input/contact time	Weekly lectures with method/content input and missions launches for the team		
6	Teaching team	Professors with various specialties, teaching assistants, dedicated external "coaches"		
Interface to external sponsor providing the design challenge				
7	Type of external project sponsor	Large Companies	Small/ Medium Companies	Small/ Medium Companies; Communities; NGOs
8	Financial contribution	ca. 60.000 - 100.000 Euro	3000-4000 Euro	0-500 Euro
9	Design challenge (openness and time scope)	High level of openness / Foresight innovation	Medium level of openness / solution for the presence	More narrow design prompt / solution for the presence
10	Design challenge (level of innovativeness)	• High	• Medium	• Low
11	Topic areas covered	• Service, Product or Digital Design	• Service, Product or Digital Design	• Digital Design
12	Project outcomes	• Proof-of-Concept Demonstrator • Large public event presentation (audience 100 +) • Exhibition booth • Comprehensive report (up to 100 pages) • Prototyping booklet • Video	• Proof-of-Concept Demonstrator • Small public event presentation (audience 20 +) • Small documentation report (about to 30 pages) • Poster • Short Video	• Clickable digital prototype • Small public event presentation (audience 20 +) • Small documentation report (about to 30 pages
Interface to international partner university				
13	Alignment between global teaching team partners for lectures and coaching session	Mostly independent lectures and mission launches for the local parts of the teams, alignment on an individual level; the entire SUGAR network follows a general timing, but no joint global coaching sessions are provided	Lectures are given jointly at an aligned time in the weekly schedule; Students receive one mission as a global team; coaching sessions are held jointly with the entire global team with teaching team member representatives from both partner universities	
14	Collaborative Tools for global student collaboration	Mostly self-directed by the students	Setup/provided by the teaching team	
15	Face-to-face collaboration/ travelling	Several international travels for global team reunion / face to face collaboration; Usually joined Kick-Off and final presentation	One mutual visit; means one travel to the partner university	Conducted fully Online
16	Facilitation of global team collaboration	Mediation sessions when problems in the teams occur (detected by the teaching team or requested by the students)	Joined hybrid bootcamp to support the building of a shared language and process understanding; small proactive content units and activities to foster international teamwork	
17	Grading of global team	No alignment between the teaching teams; individually reported back to the local teams/ students by the local teaching team	Alignment between the teaching team on perceived individual and team performance based on several defined outcomes	Pass/fail in Tartu; continuous assessment over the duration of the course and grading in Mannheim based on individual and team-based outcomes
Prototyping methodology set by assignments				
18	Types of prototypes as requested from students as part of their assignments	Critical exp. prototype critical function prototype, dark horse prototype, funky system prototype, functional system prototype, part x prototype, final prototype (compare Domingo et al, 2020)	Critical experience prototypes, critical functional prototype, low and mid fidelity system prototypes, final prototype	
19	Sequential vs. parallel prototyping	Parallel prototyping in local teams until the final demonstrator	Parallel prototyping on an individual level to support convergence	
20	Number of cycles of experimentation	10-30	<10	<10

Table 1. Comparison of course characteristics between the courses ME310, iPDP and GDIP

prototyping cycles because a lower level of innovation makes it more likely to achieve a valuable project outcome with fewer iterations/failures. A reduced number of prototyping cycles defined by the assignments that demand different types of prototypes allows us to shorten the total course length. This difference in the number of experimentation cycles is reflected in the characteristics (18)-(20).

• In addition, we reduced the amount of effort students have to spend to produce deliverables for the sponsor. E.g., the smaller courses expect less polished project pitches, do not provide an exhibition and less comprehensive course documentation (11).

• As a positive side effect, it turned out that we could reduce the costs for the smaller courses (8), which allowed us to target different kinds of sponsors (9) for the smaller courses. As universities of applied sciences have traditionally strong connections to local small and medium enterprises, the smaller courses could include their challenges, which lead to different type of cooperating partners. In contrast, ME310 mainly involves large companies with their own innovation departments.

Also, we decreased disturbance originating from remote, multidisciplinary and international learning barriers (Jensen et al., 2018) within the international team collaboration and communication. These changes decrease the chances of global team miscommunication, which slows down the project's progress. Our main instruments in that respect are:

• A better alignment between the global teaching team members strengthens by joined assignments, lectures and coaching sessions (13).

• A virtual collaboration environment consisting of predefined templates and shared folders and communication tools provided by the teaching team (14).

• A joint virtual design thinking bootcamp at the beginning of the course as well as small exercises to foster team dynamic built into the curriculum (16).

Qualitative Evaluation

To provide evidence that the new courses fulfilled the desired design goals (G1-G3), we present the results of our qualitative analysis of student retrospectives and sponsor feedback as collected during the sequence of the courses since their introduction. Tab. 2 lists quotes from sponsors as stated during the gala of the iPDP and GDIP courses. The voice of the sponsors consistently expresses their satisfaction with the course outcomes.

I am flashed how these mixed teams from different educational backgrounds and locations work via the internet and are able to come up with impressive ideas and concepts.
Your solution is definitely worth a try run - we could implement it.
It is amazing that this program exists, and I wish it would be implemented in more universities. More people need to learn these things because our problems are getting more and more complex, and we need more sophisticated methods to solve them.
Even though I'm at home in the field of Design Thinking, it was very impressive how everyone got up to speed with the topic.

Table 2. Quotes of sponsors stated after the final presentations of GDIP and iPDP in 2021.

Whereas the quotes from students as exemplified in tab. 3 give evidence for the achievement of the desired learning outcomes. We also referenced in table 3 our interpretations of the learning outcome

as shown in table 1 characteristic (1). It has to be noted that we are only providing an excerpt and not a comprehensive evaluation here, as this is a work in progress and a complete evaluation is not available yet.

I learned, how to put myself in user's shoe to develop the best idea. (LG1.3)
It's okay to "start all over" or change the direction completely (LG1.4).
I learned, not to be be scared to redo everything. (LG1.4; LG1.7).
Even I as a technical person can design something beautiful. (LG1.7)
I learned that challenging yourself and going out of your comfort zone, so that you can see things different and new perspectives is important to find good solutions for a problem. (LG 1.2)
Ideas are not there to sell, but to solve costumer problems.
I learned, in order to find the best solution, you sometimes need to start over again. (LG 1.3)

Table 3: Quotes of students stated during the retrospective of the GDIP course in summer 2021. Annotated with the respective learning goals from table 1.

DISCUSSION AND CONCLUSIONS

Further implications of our work will be a more rigorous definition of learning outcomes in different course set-ups and their evaluation at the end of the course. This will allow us further investigations of the dependencies between the presented characteristics and the achieved learning goals. Without any further differentiation of learning goals, one obvious critique arising from our presented work is why we need the intense ME310 course if it does not achieve any more sophisticated or different learning goals? As Tab.1 shows, the learning goals between our three courses are uniform. We hope to derive a more precise differentiation with our future work to point out the differences in learning achievements that exist according to our experience but currently lack a proper specification.

Also, we see a high potential for future research on two particular course characteristics: the design brief and the prototyping methodology. In respect to the design brief, one should further investigate how to define the openness or ambiguity of the design brief in order to control it and to make different design briefs better comparable but also be able to pick the right level of openness and ambiguity to fulfil the course needs. Today this heavily relays on the experience of the teaching team. A more instructional approach, not relying on gut feeling, would be desirable. The second interesting area for further investigation is the prototyping process the students follow as part of the course design, being defined by the type of prototypes as well as the number of iterations. The controlled environment of our courses will allow us to research dependencies like: How exactly do different types of prototypes influence the effectiveness of the innovation process as well as its duration and project outcomes? Moreover, a better understanding of these dependencies allows us not only to draw conclusions on course design but also on innovation processes in general. For example, how do the different challenges that target service, product and digital design depend on the prototyping activities requested by the course? As the work of Koppenhagen et al. (2021) postulates for projects that develop physical systems, the "funky system prototypes" might be of particular interest. Given the fact that we took this out for our small courses, serves as a promising starting point for a closer investigation of the prototyping methodology in the controlled comparison of our three courses.

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Innovation learning experience at Javeriana Cali: Semana Diagonal

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ABSTRACT

Innovation in education, means more than merely adopting new education technologies: it is about fostering equality of opportunities and impacting communities by opening the academic sphere to real-life problem solving. Skill-based education has proven to be an important part of that innovation process by allowing students to go beyond classroom lectures to question established concepts, putting them into practice in their own contexts. By giving a relevant space to experimentation, challenge-based experiences and interaction with other disciplines and sectors, innovative education aims to develop skills and competencies that are significant in the professional and personal future of the students. This document describes the results of "*Semana Diagonal*" ("Diagonal Week" in English) as a skill-developing experience in the format of an interdisciplinary, challenge-based hackathon to solve regional problems that were formulated with industry and community partners. A qualitative assessment was carried out both by students and facilitators to identify the level of development of 5 selected skills. The findings of this study can contribute to the introduction of new pedagogical practices or the transformation of traditional ones by inspiring faculty members to design academic experiences that promote skills development and university management to support the creation of an environment for these new practices to thrive in.

INTRODUCTION

A paradigm shift in higher education continues to be an imperative around the world (UNESCO WHEC 2022), in the last years especially, the Covid-19 pandemic not only made visible but helped increase the inequality gaps in higher education, the need for stronger quality assurance and the complexity of the relation between education and technology (GUNI, 2022). In an environment of increasingly complex societal challenges, skill-based education appears to be an effective way to align to the demands of both the labour market (WEF, 2020) and a new citizenship of the world (Dondi et al., 2021), with the promise of a better preparation for the future by making students capable of owning their learning process instead of being mere receptors of knowledge.

In this context, this particular University began a double-diamond co-creation process to re-design its Learning Ecosystem, with the motivation to have a bigger impact on its area of influence as a regional university, looking for relevant transformations in the pedagogical, curricular, and administrative dimensions of its value promise including the incorporation of skills development as a central part of a new academic structure.

Semana Diagonal – SD was created as a "stirring moment"[1] within the passion-based co-creation process, aiming to inspire faculty members, students, and management to take transformative action towards an education model that incorporated skills development through active methodologies by creating a safe environment for experimentation and a full attitude to disrupt business-as-usual.

[1]The process of passion-based co-creation has five essential components or steps: stirring, empowering, embracing, connecting, and acting. (Björklund et al.2017)

SD 2021 constituted a 4-days hackathon where student teams followed a design thinking process to solve 30 regional challenges provided by industry and community partners. This activity was compulsory for the entire undergraduate population, including students and faculty. 3550 students (77% of the expected population) were joined by 481 teachers in the role of facilitators and had the opportunity to attend keynotes related to the challenges by 13 sponsors that presented current, real-life data based on their experience. Other 140 teachers offered workshops with relevant tools to solve the challenge, such as digital prototyping, business model creation or poster design; and the division of Student Life offered wellness (cultural, health, sports, and spirituality) activities that complemented the mental effort students were exerting to create a truly holistic experience. Reduced capacity of the main campus due to the pandemic, forced a majoritarian distribution of teams working remotely via Zoom and participating students were granted additional grading in one course of their choosing.

This study aimed to observe student teams' performance on 5 prioritized skills and was focused on determining if there were any changes in the use of those skills as the SD experience unfolded under the conditions that were previously described. These skills were social interaction or working with others, imagination and creative thinking, strategic thinking, systems thinking and problem solving.

These five skills were prioritized for their relevance to the graduate profile, for the possibility of observing them in a short period of time and for the possibility to work on their development within a problem-based learning approach, strengthening the links between the university and some of its main stakeholders (communities, government, and industry) around regional challenges.

CONCEPT BACKGROUND

A basic definition of Skill-based Education is one where learning is centered in the student, who develops knowledge, skills and attitudes that should be made tangible, observed, and assessed following performance standards (Fuerte, 2017).

Skill-based education has gained importance in the last years, promoting a transformation of the methodologies used in education. Opinions regarding this approach vary from perceiving as too reductionist and over-pragmatic to finding a value in the practical and experiential approach. The development of skills has led to a transformation in the length and focus of programs as well as to a cultural and structural transformation of higher education. In the European Higher Education Area (EHEA) for example, it has evolved to a modern view of education that has more than ever opened room to adapt to societal changes (Romero, 2017).

The idea behind it seems to be clear in the age of the Fourth Industrial Revolution where the skills that make us more human like creativity, empathy, resilience, critical thinking, or collaboration gain substantial relevance (EduTrends, 2019), not only for it is what separates us from ever increasingly intelligent technologies, or because they are almost indisputably necessary for "future sustainability and creation of value" (Flores et al., 2020), but because social and emotional learning positively influence academic performance (Brackett & Katulak, 2007). It is also not a new need, since educators and employers have been reporting for years the deficiencies in skills like communication, project management, foreign languages, cultural awareness, or teamwork among graduates (Schulz, 2008).

As for the definition of a skill Güneş (2018) summarizes the abundant exploration of the concept as "the ability to transfer knowledge into practice to perform a task or duty". It means different and interconnected sources of knowledge previously acquired are put into action towards a practical goal. Consequently, since knowledge can increase through experience and education, skills can be developed and transferred from one context to another in progressively complex ways.

Key sets of skills or skill domains for todays' world have been identified and listed with variations. Trilling & Fadel, (2009) identify four domains of the 21st century skills: traditional core skills, learning and innovation skills, career and life skills and digital literacies and more recently McKinseys explored four Delta categories of Cognitive, Interpersonal, Self-Leadership and Digital skills (Dondi et al., 2021). The work within these frameworks has been understood as a new learning paradigm or pedagogical shift (Sulistyaningsih, 2019), which has also opened a safe space for teachers to create more horizontal relations with the students, evolving from being knowledge communicators to mentors and companions in the skills development process, with a more active role for both sides (Romero, 2017).

Skills development is however not without challenges. Not only curricula should evolve to develop key skills and competencies effectively and efficiently in students, but certifications and academic portfolios should become adaptable, open, verifiable, and transferrable to reflect the evolution in the performance of skills, just as much as cognitive or technical achievements (EduTrends, 2019). Which has the added complexity of identifying relevant evaluation methods. The usual method being the use of rubrics or checklists with standards to compare performance with. This forces educators to carefully plan for assessment establishing criteria to ensure validity and reliability of the evaluation. Some factors contributing to lower reliability being short evaluation periods or single evaluators, rubrics that are not clear about the criteria, misalignment with learning goals, very subjective examiners, or external and environmental factors (Smee, 2003).

METHODOLOGY

Qualitative data was collected every day to assess the prioritized skills. There were two sources of information: 1) the teams of students who conducted a final reflection each day and 2) the facilitators who were able to observe the behavior of the student teams.

For both sources, skills were detailed as follows:

Social interaction or working with others, was described in terms of team integration, empathy building, assertive communication, and teamwork towards reaching a common goal.

Imagination and creative thinking were analyzed in terms of the novelty of the ideas shared and the number of possible solutions explored for the challenge.

Strategic Thinking was described in terms of the game plan to advance towards the solution, and the tactics used to reach goals, particularly a good management of limited resources like time and materials.

Systems Thinking implied approaching the challenge by incorporating contributions from each participating discipline and the awareness of the consequences of decisions made by the team.

Problem solving regarded as the ability to create a novel, feasible solutions considering short-term and long-term impacts, as well as the identified user's needs.

Students were presented with a checklist format they used once for every skill. Facilitators on the other hand used a complete rubric, observing all the skills in day one and day 4 to identify possible differences in the performance.

Students were given affirmations that aimed to spark a team reflection to assess their own performance each day. They were asked to discuss and share the reasons they resonated with any of those affirmations when applicable, and to consider a broad view of teamwork including communication, decision making, work environment, etc.

They were also asked to select one or more options that represented their experience from the following lists:

Social interaction or working with others:
- We were integrated as a team
- We had assertive communication (we respected each other's ideas and turns to speak)
- We made an effort to work towards a common goal

Imagination and creative thinking:
- Our ideation process was useful to build a solution
- We valued each idea in terms of relevance to the challenge
- Our ideas were different and novel

Strategic and Systems Thinking:
- We identified progress and pending tasks in our process of building the solution

- We built our solution with an interdisciplinary approach
- We used relevant strategies to achieve results

Problem solving:
- Our co-created solution is innovative and disruptive
- Our solution is relevant to the context we analyzed
- Our solution is viable and feasible

Finally, students were openly inquired about their perception of the SD experience and what would they suggest to strengthen innovative education in the university.

RESULTS

From the total of participating students, we obtained the following number of assessments each day:
- Day 1: Social interaction or working with others: 1145
- Day 2. Imagination and creative thinking: 1234
- Day 3. Strategic and Systems Thinking: 983
- Day 4. Problem solving: 788

Overall, students perceived they had a high performance in every skill, systems thinking being the highest and social interaction being the lowest; however, a distinct difference was observed between on-campus and remote groups, the latter having a lower performance in every skill. A trend that mirrored the quality of the deliverables which were assessed by a committee of experts. (See Table 1)

		Social interaction	Creative thinking	Strategic Thinking	Systemic Thinking	Problem solving
High	On-Campus	75%	78%	87%	90%	85%
	Remote	66%	68%	77%	85%	75%
Medium	On-Campus	8%	7%	12%		5%
	Remote	14%	14%	20%		13%
Basic	On-Campus	17%	15%	2%	10%	10%
	Remote	20%	18%	3%	15%	12%

Table 1. Students assessment of 5 key skills. Comparison between on-campus vs remote experience in 3 performance levels.
Source: Balance Semana Diagonal (2021)

For the open question, there were both positive and negative comments as well as suggestions to improve SD and to strengthen innovative education in the university. Within these last group we could identify topics related to the further development of the 5 prioritized skills:

- Integrating these methodologies in classes /Innovation courses
- More spaces for interdisciplinarity along the academic year
- More spaces for disciplinary encounters along the academic year. Strengthen teamwork and cooperation
- More spaces for collective work, listening, debating and co-creating
- More contact with industry and communities. Earlier internships
- Do we need classes, students and teachers? Re-thinking roles
- Use new media to teach and communicate: podcasts, web series, EdX, etc.
- Flexibility (curricular structure, schedules, methodologies). Personalization.
- Re-think evaluation

On the other hand, 380 facilitators perceived the performance in all skills consistently increased between the first and the second time they were assessed identifying Social Interaction as the skill with a higher

increase while Systems Thinking not only was the lowest performing skill but also the one that varied the least between assessments. Additionally, they also detected a distinct difference between remote and on-campus teams and identified Social Interaction as the highest scoring skill. (See Table 2).

	Social interaction		Creative thinking		Strategic Thinking		Systemic Thinking		Problem solving
	IA	FA	IA	FA	IA	FA	IA	FA	FA
Advanced	27%	52%	34%	45%	29%	42%	32%	42%	45%
High	44%	32%	41%	39%	48%	43%	43%	38%	42%
Medium	24%	14%	21%	14%	20%	14%	20%	19%	9%
Basic	5%	2%	4%	3%	3%	2%	5%	2%	4%
Average difference	+14pts		+9pts		+8pts		+4pts		-

Table 2. Facilitators assessment of 5 key skills. Comparison between initial and final assessment in 4 performance levels.
Source: Balance Semana Diagonal. (2021)

DISCUSSION AND CONCLUSIONS

Results indicate the challenge-based learning approach used in SD, was relevant for the development of 5 selected skills in most student teams, this happened in a very short period of time and with little preparation for the experience for both students and faculty members. This unveils an opportunity to create long-term curricular strategies to promote skills development in students. Moreover, it represents an opportunity to intervene the faculty training program in order to reinforce a critical mass that would face these types of challenges as part of their innovation culture and not only as a highly disruptive stirring moment.

An analysis of the perception of the experience comparing on-campus vs remote participants indicates active methodologies can be highly effective in on-person contexts while having poorer results in digital environments. Even though this points to favouring on-person experiences every time, it also represents an opportunity to create a new typology of experiences that are specifically tailored for the remote interaction. Further research should explore a matrix between knowledge areas, methodologies, and tools to find the best combinations for higher education.

Regarding the perception on skills development, there is a significant difference between students and facilitators. If ranked from higher to lower development, the perception of both groups is practically inverted (students: systems thinking (1), strategic thinking (2), problem solving (3), creativity (4), social interaction (5) vs facilitators (social interaction (1), creativity and problem solving (2) and strategic and systems thinking (3)). This could be explained by a higher expertise of the facilitators compared to the students, but it could also mean there is a lack of understanding on their behalf about the meaning of each skill. This should motivate the university to strengthen their skill-based culture for a better dominion of the concepts.

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Effectuation and creativity: a cooking exercise to practice design-driven entrepreneurship

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ABSTRACT

This paper aims to contribute to the debate on the role of making in entrepreneurial problem-solving and proposes a workflow to represent how effectual thinking occurs via the combination of tools and constraints with aesthetic decision criteria based on entrepreneurs' perceptions, emotions, preferences, and technical abilities. We propose a pedagogic framework to model design-driven discovery in an effectuation setting and present an experiential learning exercise to (1) provide students with an effective analogy to practice effectuation via a design-driven making experience; (2) helping them to reflect on the importance of aesthetic criteria, emotional validation, and empathy in entrepreneurial endeavours. The proposed exercise is built on using cooking as a metaphor for design-driven innovation. The design of the exercise is grounded on effectuation theory, design-driven entrepreneurship, and pedagogic approaches relying on an intensive use of co-creation and prototyping. The exercise was demoed to academic instructors during a virtual international conference on design-driven innovation. The experts' feedback and reactions were collected through the video recording of the session and follow-up conversations. This paper will present the exercise in detail, lessons learned, and reflections extracted from the demo session. We finally discuss how the exercise can be used to conduct empirical research to assess the effectiveness of design-driven teaching tools in entrepreneurship education.

INTRODUCTION

A paradigm shift in higher education continues to be an imperative Entrepreneurship education has witnessed significant pedagogic innovations in the last decade through the emergence of popular teaching approaches based on Customer discovery (Blank & Dorf, 2020), Lean start-up (Ries, 2011), Business model generation (Osterwalder & Pigneur, 2010), and, more recently, Design Thinking (Brown & Katz, 2019). These new approaches differ substantially from the traditional business-plan-based methods from the conceptual and practical points of view.

On the conceptual side, the new pedagogic tools are compatible with the effectuation theory (Sarasvathy, 2001), according to which entrepreneurs attempt to create a reality they can control instead of predicting outcomes through causal models. The integration between effectuation theory and design thinking can help transform entrepreneurship into a science of the artificial (Dimov, 2016; Berglund et al., 2020; Simon, 1996) to augment the effectiveness of entrepreneurial action (Berglund & Verduijn, 2018) and support the accumulation of entrepreneurial expertise via deliberate practice (Dew et al, 2017).

Methodologies such as Lean Start-up, Customer Discovery, and Business Model Generation have, in fact, much in common with Design Thinking, namely the centrality of prototyping and knowledge visualization, the necessity to engage with users and stakeholders, and the adoption of agile and scalable project management approach to manage uncertainty and support hypotheses validation via repeated testing of prototypes characterized by increasing fidelity. Notwithstanding these similarities, the injection of design-driven pedagogic tools in entrepreneurship classes is characterized by the predominance of ideation over "making" exercises (Sarooghui et al., 2019). This unbalance is probably the result of several factors, including a shallow or incorrect understanding of the conceptual underpinning of design-driven entrepreneurship, the limited availability of spaces, instructors, and resources for makers, and the lack of makers' exercises that are deliberately designed to integrate theories of entrepreneurial practice with Design Thinking.

In this paper, we focus on the latter issue by contributing with an exercise format that combines effectuation theory with a making experience based on using cooking as a metaphor to develop empathy and hone design skills. There is, in fact, a relative scarcity of experiential learning exercises based on effectuation theory compared to much research on this topic. The applications of effectuation and design to teaching entrepreneurship in a virtual setting are even less common. In the next section, we provide the theoretical background behind the exercise and propose a model to represent the design workflow in an effectuation setting. Sections 3 and 4 will describe the exercise and its validation with a group of design and entrepreneurship instructors. We finally discuss how the exercise can be used to conduct experimental research to assess the impact of making exercises on students' skills for creative problem-solving.

MODELLING THE DESIGN WORKFLOW UNDER EFFECTUATION SETTINGS

The duality of entrepreneurial action: experimentation and transformation

The tendency to believe that human creation involves translating an abstract idea into an artifact is known as ilomorphism. In contrast with the ilomorphic approach, the creation of something novel is not the result of a "production" based on abstract blueprints, but a process of organic growth based on the transformation and manipulation of materials (Ingold, 2013).

The role of physical experience as the structuring element of our cognition finds correspondence in theories of embodied cognition (Damasio, 1999; Lakoff, 2012), in which feeling, acting, and knowing cannot be separated (Damasio, 2021).

Entrepreneurship education is a receptive field for adopting pedagogical practices focusing on making if we reframe entrepreneurship as a science of the artificial (Simon, 1996), helping entrepreneurs to design effective outputs and courses of action (Dimov, 2016).

To illustrate how conceptualizing entrepreneurs as makers and entrepreneurship as artifact-centered design can be translated into pedagogical practices, we refer to the model in Figure 1. Following Berglund et al. (2020), we represent entrepreneurial action as a duality between experimentation and transformation. Human activity occurs across the interface between an external system (reality) and individual consciousness. According to Simon (1996), this interface is given by a design artifact through which we can engage with both systems. Typical entrepreneurial artifacts include prototypes, business models, marketing campaign materials, the design of suitable workspaces, etc. The artifact can be designed to test its effectiveness (Figure 1, left side) or via the transformation of materials to embody ideas into a meaningful object (Figure 1, right side).

Artifacts are both the input and the output of entrepreneurial action in both cases. For instance, on the experimentation side, a prototype can be subject to experimental testing based on specific hypotheses. The artifact will have to be designed so that the selected hypotheses can be tested. For instance, if a certain color palette in the interface is expected to improve accessibility, the prototype must implement that feature. The result of these tests will provide input to modify the initial design, e.g., by confirming or denying that a specific combination does improve accessibility.

Similarly, on the transformation side, a low-fidelity prototype can help scaffold ideas and trigger attempts to improve or refine the design. The outcome will be, again, a modified artifact.

An artifact-centred design view of entrepreneurship frames action as a sense-making and learning process through which entrepreneurs aim at i) generating a distinctive value proposition and ii) maximizing its fit with existing resources and underserved market opportunities. The combination of experimentation and transformation practices can support entrepreneurs in identifying novel solutions and opportunities by combining rigorous validation of distinct prototypes with the generation of new ideas and their embodiment into mutable artifacts to support co-creation and interpretative flexibility.

More specifically, higher-fidelity, distinct artifacts can be used as experimental stimuli to ascertain whether a novel solution can effectively address an identified market imperfection (Dorf Blank and Dorf, 2020). Specific hypotheses associated with the prototype's features and functions can be formulated and subject to objective testing following the scientific method.

On the transformation side, artifacts are underspecified and mutable to support ideas' cognitive and emotional scaffolding (Bjorklund et al., 2017; Passera, 2017) and their embodiment through manipulating
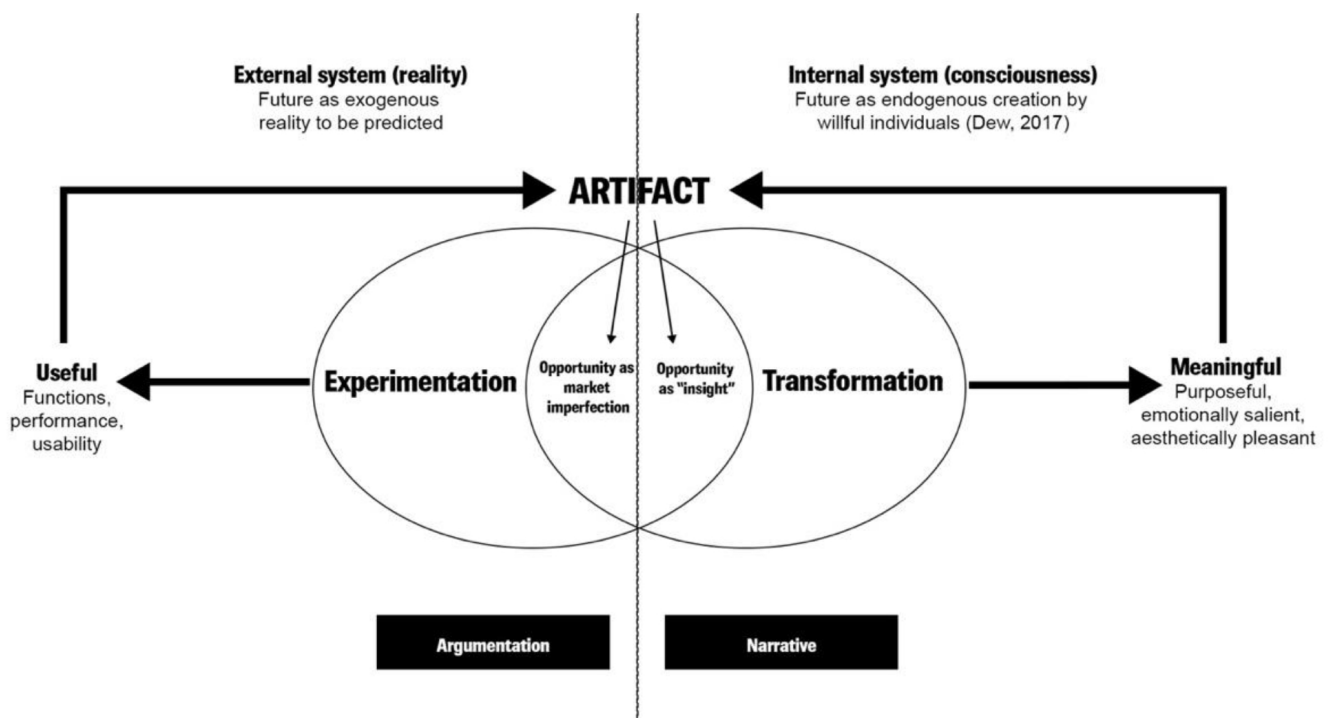
Fig.1. Entrepreneurial design as a duality between transformation and experimentation

technical, environmental, and mental constraints. In the transformation phase, artifacts allow us to think about possibilities and conceive the future as an endogenous creation by wilful individuals (Dew et al., 2017) instead of an objective reality that must be discovered.

Using underdeveloped and mutable artifacts creates room for interpretative flexibility, free-flowing user interaction, and a deeper understanding of technological limitations and user affordances. Transformational activities make creativity stem from the manipulation of materials and the more profound knowledge of technical possibilities and constraints (morphogenetic process) as opposed to abstract ideation. Students are continuously asked to question the take-for-granted and explore across boundaries. Finally, transformation allows them to hone aesthetic and emotional intelligence to better empathize with customers and anticipate hostile or welcoming emotional responses.

While more contemporary approaches to entrepreneurship education, such as Blank and Dorf's Customer discovery (2020), have had great merit in translating and applying the scientific method to testing the validity of market hypotheses, there is a severe shortage of pedagogic practices to train skills to support the transformational side of entrepreneurial action. The customer discovery process is based on a rigorous process of formulating testable hypotheses, developing metrics, and generating learning from failure. However, customer discovery does not directly and explicitly support generating hypotheses and insights. Entrepreneurs and students are asked to rely on their "talent" or "creativity." They are typically exposed to ideation exercises of dubious effectiveness. One reason behind this shortage is the already mentioned predominance of ilomorphism in education based on the notion that ideas and theories have a more privileged pedagogic status than artifacts and practice. Other factors include misconceptions about the nature and the practice of creativity, traditionally confused with the vague notion of ideation, or the lack of appropriate infrastructure to support makers (Sarooghi et al., 2019). Another reason is that transformation requires a different working logic, typically not taught nor deliberately practiced in business and technical schools.

Practicing transformation:
narrative thinking and effectuation

According to Bruner (1985), human thinking is the product of a duality between two different but complementary modes of thought:

argumentative and narrative. Argumentation and narrative differ primarily in their fundamental goals: the former aims to verify if a statement is true or false; the storyteller's objective is to convince readers that a particular chain of events sounds plausible and emotional. Another critical difference between valid argumentation and good storytelling is that the former cannot be underspecified. Conversely, the latter is deliberately left incomplete to solicit listeners' intervention in anticipating what might happen and playing with their expectations. As shown in Figure 1, argumentation is the logic for experimentation, while storytelling is the thinking mode of transformation. While storytelling is applied to text or speech, transformation can equally rely on the intense use of knowledge displays through visual aids, models, and other artifacts. More broadly, we identify the ability to reason aesthetically as the underlying thinking mode of transformation, based on the use and manipulation of materials and assessment criteria driven by emotional assessment and the pursuit of fitness and meaning.

Entrepreneurship research has focused on the role of storytelling in intention formation (Gartner, 2010), storytelling to support venture legitimacy (Becker-Blease et al., 2015; Fisher et al., 2017), as a teaching approach based on emphasizing stories of success VS failure (Steyaert, 2007), or as a mechanism to increase the effectiveness of marketing messages and branding. Limited attention has been dedicated to using artistic media to build a narrative to identify or revise entrepreneurial artifacts.

The use of storytelling is just one of the tools for applying a design-driven pedagogy to support the creation of transformational risk. A broader toolbox could include design heuristics and principles such as Maeda's laws of simplicity (Maeda, 2006), Gestalt laws (Wertheimer and Riezler 1944; Koffka 2013), emotional design (Norman, 2004), MAYA design principles (Hekkert, 2006), and art-driven approaches (Iandoli and Zollo, 2022).

A design-driven pedagogy is highly compatible with well-known theories of entrepreneurial action, namely Sarah Sarasvathy's ideas of effectuation (2001). Sarasvathy juxtaposes effectuation and causation as alternative thinking modes in entrepreneurial behavior. She defines causation as a cognitive "process that takes a particular effect as given and focus on selecting between means to create that effect" and "effectuation as a process that takes a set of means as given and focuses on selecting between possible effects that can be created with that set of means." (Sarasvathy, 2001, p. 245).

	Experimentation (Causation)	Transformation (Effectuation)
Givens	Effect is given	Some means are given
Decision making criteria	Optimize based on expected returns	Aesthetic, based on actor's competent perceptions, emotions, preferences, and technical abilities
Modus operandi	Planning	Co-creating
Unknowns	Anticipate predictable scenarios	Focus on controllable aspects of an unpredictable future
Outcome	Increase market share based on the recognition of market imperfections	Increase market share based on the generation of (intersubjective) insights

Table 1. A comparison of experimentation and transformation based on Effectuation theory (adapted from Sarasvathy, 2001)

Effectuation seems mostly at work in the transformation phase, while causation appears to be the underlying logic of experimentation (Table 1). Again, the duality reconciles different theoretical descriptions of entrepreneurial action. Additionally, an approach based on making can facilitate the translation of effectuation precepts into actionable teaching strategies.

Modelling the transformation workflow

Based on interviews with entrepreneurs operating in creative industries (DCMS, 2015) such as advertising, architecture, crafts, and visual arts, (Iandoli & Zollo, 2022) identify three salient moments of the workflow through which creative individuals practice transformation to identify novel solutions for a unique customer experience:

(i) Self-imposed constraints: demarcating a cognitive and emotional space in which discovery can unfold (Create the Box)

(ii) Self-guided discovery: play with rules and resources to identify good problems (Thinking within the box)

(iii) Resolution: recognizing tensions and resolving trade- offs ((Thinking outside of the box).

The first step shows that the search for novelty does not start in a vacuum or via freewheeling ideation, but it is based on a mix of expertise and emotional intelligence. For instance, in an interview that was part of the study with a famous chef founder of a 3-star Michelin restaurant, this space contains his vast technical knowledge of ingredients and cooking techniques combined with an emotional understanding and attachment to his own culinary culture and terroir.

Exploring this self-defined and well-articulated problem space in the self-guided discovery step helps identify available resources and constraints. In the chef example, those may include certain ingredients' physical and chemical properties, customers' expectations or technical limitations, pros, and cons of specific cooking techniques. In this step, an intense activity of manipulating materials and resources helps identify potentially good problems by generating hypotheses and serendipitous discoveries.

In the third step, some problems are solved by identifying relevant trade-offs and their closure through innovative combinations or additions. For instance, the salty-sweet continuum could be the base for determining a desired level of sapidity and may suggest the inclusion of a new ingredient, e.g., a variety of onions providing the additional sweetness moderated by some tanginess.

The proposed framework is consistent with an entrepreneurial effectuation logic since the workflow is oriented towards operating with available means and resources to create a controllable future. The workflow also aligns with the design thinking cycle based on the empathize-ideate-prototype process. The workflow is finally consistent with recent developments in cognitive science based on the theory of embodied cognition (Damasio, 2021). Embodied cognition argues that information processing is mediated by bodily interaction with the environment and that decision-making is driven by emotions as much as by "rational" assessment.

A cooking metaphor to practice transformation

As illustrated in the next section, we use the dual mindset model and the creative workflow framework to structure a design thinking exercise grounded on effectuation theory and identify checkpoints and materials for reflection and sense-making.

We decided to develop a cooking exercise inspired by Sara Sarasvathy's example to illustrate the difference between causation and effectuation (Sarasvathy, 2001). She compares two situations in which a meal must be prepared. The first refers to a restaurant chef preparing meals for the restaurant menu. The menu is designed based on known customer expectations and sourcing possibilities. The chef uses a causation logic to achieve given effects driven by these expectations and constraints and plans to acquire the necessary means to optimize the cost/benefit ratio. Contrast the professional chef with someone who has an unexpected guest and needs to improvise a solution. This impromptu chef will adopt an effectuation logic by reversing the relationship between means and effects. She will work with given means (the ingredients available in the house) and use aesthetic criteria based on perceptions, emotions, preferences, and technical abilities to achieve controllable and satisficing effects.

The second reason behind the choice of cooking is that preparing a meal is an intuitive metaphor for understanding user-centered design. When we cook for someone, we spontaneously empathize by developing assumptions about what our guests enjoy and need. We then experiment with ingredients and cooking techniques to realize a functional prototype. We combine technical and aesthetic criteria to judge whether the result is satisficing. Finally, we test our creation by collecting data, including verbal and non-verbal feedback from our guests.

Third, meal preparation is a task that requires participants to work with physical matter and be aware of the information gathered through their senses and assessed from emotional and aesthetic points of view.

Fourth, cooking is an everyday experience most people can relate to, and for which students may possess some experience and have access to cooking equipment in their private spaces. Finally, cooking provides a relevant real-world situation. Cooking and consuming food with other guests is very important in all cultures. It can be associated with family memories and social or religious rituals. It is prominent in many social situations where we must be mindful of others. Other creativity exercises, such as building a spaghetti marshmallow tower (Wujec, 2010), are not emotionally salient regarding users' feelings or for anticipating the consequences of bad design.

THE STRUCTURE AND IMPLEMENTATION OF THE EXERCISE

The proposed exercise combines effectuation theory and design thinking in an online teaching environment. The COVID-19 pandemic was an additional contingent factor. The impossibility of using labs and other makers' facilities triggered the idea of making spaces that could be available to students in their homes. Most people have access to at least some essential cooking tools and equipment in their houses or apartments, and the experience of cooking together would relieve them from the social isolation imposed by the pandemic lockdown. In this section, we provide instructions for independent replication of the exercise.

Setting and preparation

About one week before the exercise, each cook receives instructions to prepare for the event. We used a simple and underspecified problem statement: "In 45 mins, you must cook X", where X is a cooked/ prepared dish the students should be familiar with. In this version, the cooks are not presented with formal restrictions or expectations, and

the concept of the meal is left up to their interpretation. A variation of the exercise is to provide students with additional constraints to assess how their workflow is impacted; The cooks are expected to procure necessary ingredients independently and set up a webcam (phone, webcam, or laptop) in the kitchen or cooking area. Participants should also have access to a web-conferencing system such as Cisco Webex, Microsoft Teams, Zoom, etc.

Step-by-step implementation
The exercise starts with each student cook joining the zoom call from within their kitchens. A facilitator should be pre-selected to oversee the experiment as a timekeeper and by guiding reflections and discussion during and after the cooking phase.

We suggest the following timeline for the exercise:

(i) *Introduction and Welcome* (10 Minutes): The facilitator reminds the participants about the instructions and objectives of the exercise
(ii) *Cooking Phase* (45 Minutes): The participants cook the meal. While preparing the meal, the facilitator asks the participants questions to help them reflect on their cognitive and practical process of creating their meal.

Questions that could be asked during the cooking phase:
  • What was the source of your recipe? (Creating the box)
  • Can you figuratively open your brain and tell me what you are doing now? (Think within the box)
  • Are there any rules you follow when combining your ingredients? Or are you simply improvisingon the go? (Think within the box)
  • "How do you balance ingredients and flavors in this plate? (Think out of the box)
  • Did you violate any of the rules you usually use or introduce some new rules or variations (Think outside of the box)
  • (If the outcome is different than expected) How do you explain this? Was this an accident or the result of some experiment you were attempting? (Think outside of the box)

(iii) *Pitching the Final Product* (1-2 Minutes per participant): The participants will pitch/present their final cooked/prepared meal. A cooking contest can be included to make the exercise more engaging, or if an "audience" is present, they can vote on the best pitch.
(iv) *Reflection/Debrief Phase* (45 Minutes): The facilitator can ask follow-up questions to analyze the metaphor and extend it to other entrepreneurial activities. Possible topics that can be discussed during the reflection phase.
  • How this cooking experience maps to your entrepreneurial project? Any analogy?
  • Reflect on and describe the creative workflow you used to prepare the meal.
  • Did you have in mind a hypothetical guest? How important were the guest's expectations in the making of your plate?
  • How can this exercise be applied to other creative challenges?
  • Assuming students have been exposed to effectual theory: Did the experiment help you understand the difference between effectual and causal entrepreneurial action?

RESULTS

The simulation of the "What's cookin'" teaching exercise occurred through a demo session in which faculty and university administrators from three innovation centers (St. John's University Design Factory (New York), Design Factory Aveiro (Portugal), and Inno. Space Design Factory (Germany)) participated as testers. The participants were expert instructors and scholars with backgrounds in design, innovation, and entrepreneurship. The demo session was held during an online conference called International Design Factory Week. This one-week conference brings together worldwide innovation centers to discuss design and product development best practices. The data was collected from 1) a live Q&A debriefing session over Zoom 2) and an analysis of the session recordings.

The cooks were not presented with formal restrictions or expectations, and the concept of the "burger" was up to their interpretation. Some of the cooks purchased ingredients for the day of the experiment; others improvised with what they had at home. They were asked to set up a webcam (phone, webcam, or laptop) in the kitchen or cooking area and participate in the event connected via Zoom from various international locations. Some other participants attended the event as members of the audience.

During the cooking phase, the facilitator would ask cooks about their cooking process using questions like those reported in section 4. The questions allowed the cooks to think on their feet, allowing the audience to understand the thinking and the process the cooks were going through.

At the end of the 45 mins, each cook would pitch their creations to the group. Then, the facilitator moderated a group discussion on cooking as an analogy of effectual design and entrepreneurship.

After the session, the two investigators meet to review the Zoom recordings. The Zoom recordings were then automatically transcribed using Descript software. Approximately a ten thousand words document was generated in this way (about 20 pages). One of the authors examined the raw transcript for cleaning the text of transcription mistakes. Once the initial data review was concluded, the investigators met for 2 hours to define an inductive coding structure to annotate the session transcript based on the theoretical framework described in section 2 (Table 2).

The recordings and the subsequent transcript were then thematically independently annotated and analyzed through NVIVO to identify findings and observations based on the proposed coding scheme. One of this paper's authors participated in the annotation phase, while the second coder had not been involved with this research previously and was trained solely for the coding. The two coders met afterward to compare annotations and assess the level of agreement. Disagreements were then discussed and resolved. This approach is based on David Thomas' (2006) inductive approach to (1) condense and

summarize raw data, (2) establish links between research objectives and findings derived from the data, and (3) validate a framework to understand the underlying structure within the data (Thomas, 2006).
The transcript content was also analyzed to see what words or common concepts appeared most frequently within these themes. The frequency analysis is displayed in the word map of Figure 2. After conducting the thematic analysis, we discovered 22 instances of self-imposed

| Theme	Descriptions
Self-imposed constraints: demarcating a cognitive and emotional space in which the discovery process is free to unfold (Create the Box)	Discussions or comments that relate to crafting a menu or design for a product. How someone felt inspired by a personal experience that influences their product design or recipe.
Self-guided discovery: transform constraints into opportunities and resources (Think within the box)	Discussion or comments that relate to constraints, quality and quantity of the utilized resources, trade-offs, options and alternatives, trial and error, manipulation of the ingredients, observations and emotional reactions about the cooking process and intermediate results, concerns over missing ingredients or resources Discussion or comments that relate to constraints, concerns over missing ingredients or resources.
Resolution: identifying tensions and resolving trade-offs (Think outside of the box)	Discussions or comments about final results or products, resolving problems and identifying tradeoffs

Table 2. Coding scheme
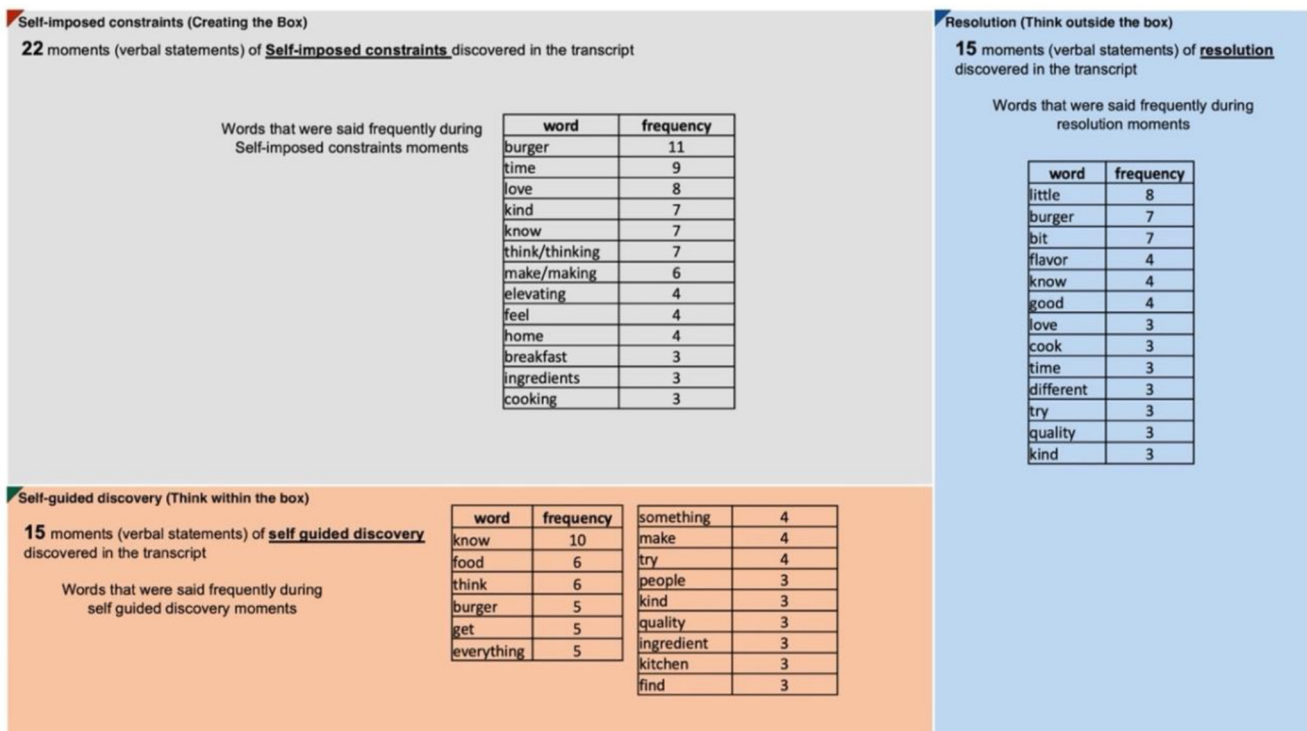
Fig.2. Treemap with frequent keywords. The size of each box is proportional to the number of moments coded for each theme. Words that were said frequently were then extrapolated from the data using databasic.io.

constraints (Creating the box), 15 instances of self-guided discovery (thinking within the box), and 15 instances of resolution (thinking outside the box). The analysis results are displayed in Figure 2, in which the size of the boxes is proportional to the number of instances for each theme. The most frequent and relevant keywords are reported in each box.

DISCUSSION

The word map in Figure 2 shows the prominence of keywords associated with inputs and resources (ingredients, flavor, kitchen, things) and with the making process (cooking, improvising, recipe, experience). The use of an effectual, making-oriented language provides evidence that participants resorted to an effectuation thinking mode driven by the manipulation of ingredients while creating the plate instead of rational planning and abstract thinking.

Observing the size of the boxes in Figure 2, it is possible to notice that the time and focus allocated to activating existing knowledge (creating the box) and manipulating available resources (thinking within the box)

constitute almost three-quarters of the process. This result provides evidence that the participants' creative workflow is firmly grounded on their toolbox of notions, rules, and resources and that they leveraged such toolbox to execute the task and produce results.

In some cases, these results were novel or unexpected. For instance, one of the participants who lacked some ingredients and wanted to make a vegetarian version of the plate resorted to replacing bread with tortillas and meat with a mix of ground beans and vegetables to address the challenge. These solutions were not planned or ideated initially but made up or identified by combining the challenge instructions with constraints, available resources, and pre-existing cultural preferences and knowledge.

Students can be invited to reflect on the importance of the richness and variety of such toolboxes in determining successful results. Students can also be reminded that playing with this toolbox and engaging with the making experience can offer alternative, viable, and potentially more effective pathways to problem- solving than abstract ideation and planning.

The exercise can also be leveraged to stimulate reflection on the importance of emotions in creative problem-solving. Cooking can awaken emotions and personal memories that can play different roles in each process step. During the "creating the box" phase, whereby initial processes, rules, and guidelines are often self-imposed, emotions can trigger positive memory and support inspiration. Emotional validation is used to assess options and outcomes or promote empathetic thinking in the other phases. These findings are consistent with the proposed 3-step workflow and theories on emotional design (Norman, 2004) and studies in cognitive sciences on the role of emotions in decision-making (Damasio, 1994, 1999).

For instance, during the experiment, when participants were asked, "What was the source of your recipe?" one participant went, "well, when I was younger, I would remember cooking burgers with my dad and how he did it; it was always a good memory.." and another participant mentioned that they want to "approach the burger with a certain taste" and wanted to center the experience of the burger around the friends and family who they normal would cook for. It was clear to us that, as a metaphor, cooking can reflect how powerful emotions can be in how individuals make practical decisions to develop a solution.

During the experiment, our cooks defined their rules when cooking their burgers based on their prior experiences and assumptions. The cooks disclosed some of their own "rules" when creating their burgers. One participant, for example, explained that they always toast their burger buns, as they believed the bun's crunch would counter any sogginess from the other ingredients on the burger. These rules can be determined by participants' mental models, emotional attachment, and culinary knowledge based on traditions or habits. However, the rules are not necessarily empirically valid or optimal. Students can also be reminded that leveraging internal, pre-existing knowledge can lead to the acritical activation of biases and stereotypes but that the making activity can help them put pre-existing beliefs to the test. Thus, one important output from this exercise could be to help participants critically reflect on their practices to question/improve them.

We also found evidence that the cooks discovered challenges and had to solve trade-offs.

Our cooks found out that sometimes they had to be creative with ingredients. Some cooks were missing "proper bread or eggs," so they had to maintain flexibility and quickly devise alternative plans to develop their final products. For example, when one cook couldn't find the eggs for their Brunch Burgers, they recombined some of the available ingredients to create a unique burger sauce and made Bacon Cheeseburgers instead. They abandoned their original plan to meet the time constraints.

In another example, one participant didn't have burger buns, so instead, they decided to use Pita Bread as their buns, using a repurposing strategy. In that way, they felt that the alternative approach made the product unique and different.

In several cases, the participants found that deviations from their plans often produced better results. Furthermore, when the participants faced a deficit, they were exposed to the emotions and process of overcoming that deficit. Such emotional pressure was a powerful motivator to devise alternative solutions quickly.

Our cooks were mindful of whom they were cooking/designing for.

The metaphor of the customer as a guest can also be fruitful for entrepreneurs. Most participants had in mind that they were cooking for a hypothetical guest and making assumptions about the guest's expectations of the meal. One of the participants had real guests and was cooking for them. We often adapt our recipes to their taste buds when we cook for others. In the same way, when we approach designing products for others, we are taking a human-centered design approach when we build a solution around them and their needs.

Students can be solicited to reflect on to which extent they incorporated these expectations in the making exercise or why they did not do so. They can also be invited to reflect on the exciting (or disastrous) emotional prospect of cooking something for a guest who likes (or dislikes) the plate. They can be invited to identify which factors can lead to successful or unsuccessful anticipation of customers' needs.

In one case, one participant had several guests for whom she was cooking. An issue of scalability emerged. Cooking for a large group of people versus one person reflects the same challenge an entrepreneur must face when scaling up production without losing quality. Cooking for a large group provided an unanticipated challenge. In this case, the cook resorted to a different workflow in which some items were pre-processed and combined in parallel so the guests could eat their plates together as a group.

CONCLUSIONS

The proposed exercise is a viable and engaging pedagogic expedient to teach effectuation and design-driven entrepreneurship in a physical or online environment. More broadly, the demo results provide fascinating insights into how novel experiential learning approaches to entrepreneurship can be devised by combining design thinking with effectuation theory and based on the centrality of the making experience in which "learning with things" prevails over "learning from things" (Ingold, 2013).

With this work, we also want to highlight the importance of creativity and aesthetics in identifying entrepreneurial opportunities and transforming ideas into viable products. We wish to draw scholars' attention toward understanding how aesthetic preferences and skills (the entrepreneurial right brain) interact with the rational entrepreneurial mindset driven by planning, organizing, and monetizing needs. Such research may support the design of a more balanced educational mix in which creative and aesthetic thinking receive adequate pedagogic attention and a more rigorous theoretical foundation for a pedagogy of making (Ingold, 2013) in entrepreneurial education.

This research could produce empirical validation for the dual mindset model presented in fig. 1, which would provide educators with solid practical support for developing more and better pedagogic tools to support transformation skills. While we have offered some evidence in this paper, the data have been obtained in a single session with participants that were engaged and seemingly aware of being part of a teaching exercise assessment.

For instance, it could be interesting to create a control group that simulates the cooking following an ideation-driven approach and then compare the two conditions in terms of learning indicators, quality of the solution, and structure of the problem-solving process.

We speculate that participants in the cooking group will outperform

subjects in the non-cooking condition on many indicators associated with awareness, student engagement, problem-solving skills, and quality of the solution.

Research experiments could also be designed to create conditions in which participants are asked to operate with a more or less balanced mix between experimentation and transformation. We speculate that the adoption of a balanced mix is associated to better results in terms of identifying more innovative solutions.

The structure of the exercise makes possible the introduction of many variants in its execution. These include the possibility of providing more or less constraining challenges briefs, the introduction of a surprise event, individual VS team-based execution, or more or less stringent limitations in the ingredients lists and other rules of the game. Implementing these variations can provide ways to achieve alternative pedagogic objectives and focuses. It can also provide a base for the rigorous design of research experiments and hypotheses testing. For instance, it could be interesting to create a control group that simulates the cooking following an ideation-driven approach and then compare the output and learning indicators results.

We speculate that participants in the cooking group will outperform subjects in the non-cooking condition on many indicators associated with awareness, student engagement, problem-solving skills, and quality of the solution.

By varying the level of prescriptiveness of the instructions, the exercise format could be used to investigate the impact of constraints on students' creativity. For instance, a control group could be created in which students are given less detailed instructions and their performance compared with participants in another group working on a more open and ambiguous problem definition. Another option could be to analyze the impact of a more structured problem-solving methodology. We speculate that better performances could be achieved with an intermediate level of structuration: some structures could make participants more creative instead of too little or too much.

Finally, the cooking exercise could be modified and leveraged to introduce entrepreneurship students to applying design heuristics, principles, and techniques. For instance, students could combine cooking with storytelling or explore the typical familiarity-novelty design trade-off in realizing a recipe.

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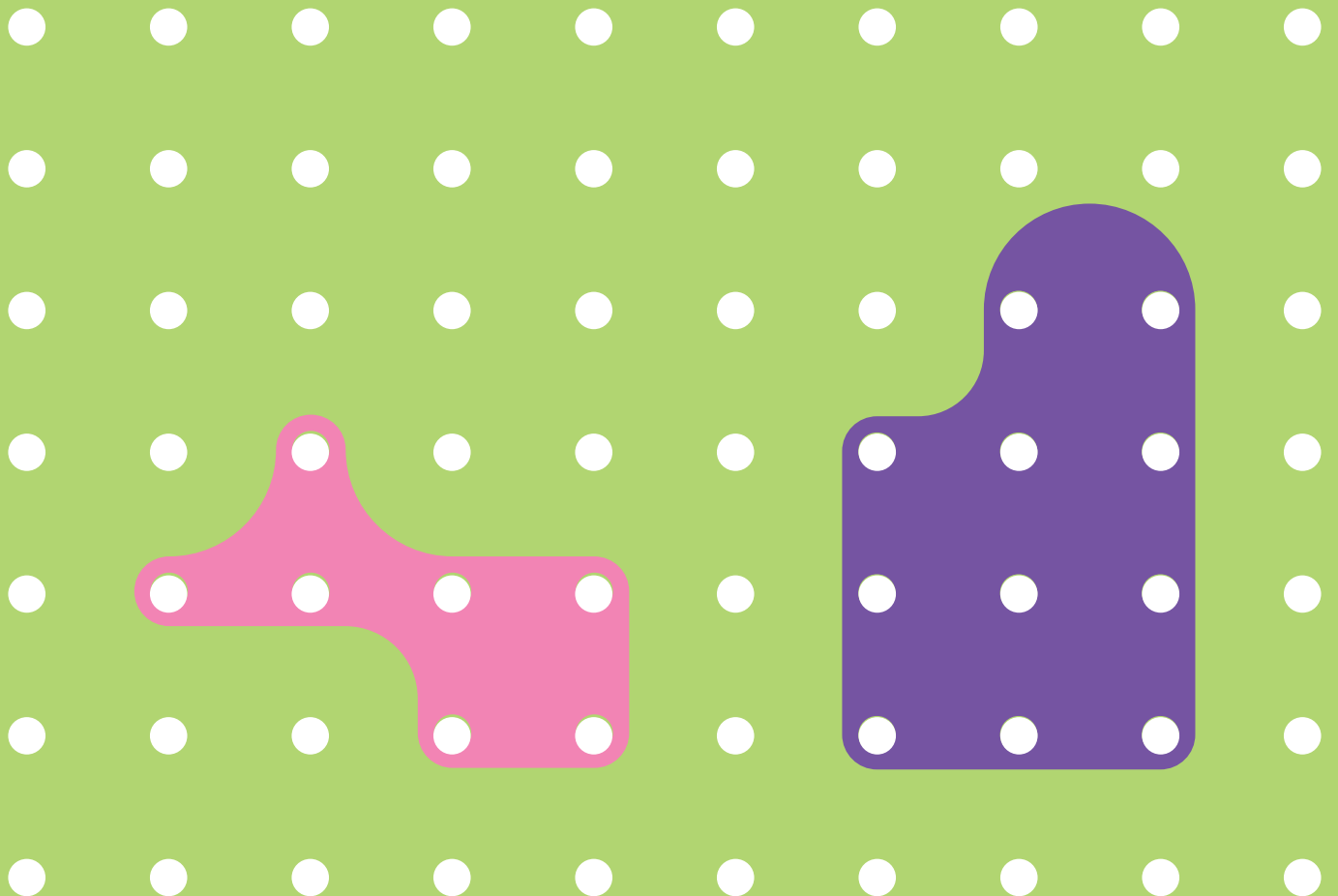
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Theme 4:

Sustainability

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Another emerging theme across the conference contributions is sustainability. For example, Lodewyckx et al. investigated the use of specific co-creation methods within the framework of the developing hydrogen economy, Ogink & Crul examine how designers can contribute to reducing the plastic soup in the ocean, and Kirjavainen and Kuukka take stock of the sustainability competences that are important for designers. Others have developed a very specific methodology for working on sustainability, such as the Japanese Kintsugi approach described by (Spiegeler, Castañeda & Ackermann).

FULL-PAPER:
From shock to re-creation: a Kintsugi approach to sustainability

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ABSTRACT

Climate change is one of the most pressing problems of our times. Coping with the associated causes and consequences requires both common policies on an interstate level as well as creative and sustainable technological solutions. Long-term successful political steering as well as new technologies in this context, however, critically depend on acceptance by the general population. Moreover, individual habits and behaviours collectively have a massive impact on our planet. A mindset-change in people can therefore be seen as a key element in these endeavours. This work aims at developing a pragmatic approach to fostering a sustainable mindset. Building on Kintsugi, we developed a workshop format that metaphorically guides participants through a journey that goes from shock to realization to re-creation. While handcrafting a Kintsugi-mug, students individually approach a topic in the context of sustainability and use the group innovation potential to collectively generate ideas and new perspectives for a sustainable lifestyle. We developed a mobile workshop station with an electric van and conducted the workshop with two school classes. This work discusses the developed method and its application. The associated templates and materials are made available, allowing other institutions to use and build on the presented workshop model.

KEY WORDS:

Research Campus ARENA2036, mindset, design thinking, Design Factory, kintsugi

INTRODUCTION

Currently, there are numerous endeavours that serve the global fight against climate change and that pursue a route towards a net positive impact of human beings on the planet. A variety of policies on a global, EU, and national level define the framework conditions within which innovation and development for more sustainable technologies happen[1,2]. However, neither policies nor technologies will be able to have a lastingly positive impact, unless (1) we find new and creative ways to address the problems we are dealing with and (2) instil an actual mindset-change in the people so as to foster new approaches to research and innovation and to create an actual acceptance of technological developments. To address these two issues, the Design Factory Stuttgart was founded as a hub that leverages the potentials of the Research Campus ARENA2036 and that focusses creative power on questions pertaining to sustainability. This work focusses on a paradigmatic Design Factory Stuttgart project – "GREENESTO – adVANce your Mindset" – that resulted from a close collaboration between the Green Office of the University of Stuttgart, the Institute for Entrepreneurship of the University of Stuttgart, the Research Campus ARENA2036, and the Design Factory Stuttgart. GREENESTO is funded through the "Stuttgart Climate Innovation Fund" and prevalently addresses questions regarding new perspectives on seemingly known problems as well as striving to foster an actual mindset change. The project develops a workshop model that enables trained coaches to travel to the relevant stakeholder groups to work with them on new perspectives on the topic of sustainability. The general focus of GREENESTO is on developing and implementing this workshop model that is based on the general concepts of Design Thinking (DT)[3-5] and Kintsugi[6] and to address critical population groups with it in order to foster an actual mindset change. With our contribution to the Design Factory Global Network

Conference, we would like to introduce the Design Factory Stuttgart to the community, present the project GREENESTO, and delineate and discuss the specific method used for the GREENESTO-workshops. It was not within the scope of this work to create measurable evidence for an actual mindset change after completion of the workshop, but rather to present the method and make the concept available to the public for further use.

The origin of the method uses various elements of the DT process but has a different goal. In contrast to marketable solution ideas for a specific group of people, this Kintsugi method is intended to be an aid to approach topics personally and to strengthen one's own ability to act. The group innovation power is to be used to recognize new ideas for oneself, to learn from each other, as well as to pursue the same goal together. The method metaphorically follows the Kintsugi philosophy from Japan. Kin means golden and tsugi can be translated as connect. Translated as a whole: golden connection. The following is reported about the origin of Kintsugi in Japan: Ashikaga Yoshimasa, a 15th century Shōgun had a special fondness for tea ceremonies. One day, when one of his beloved tea bowls was broken, he sent it to China in the hope that it could be repaired there. However, very disappointed by the result, he asked the best artisans of Japan to save his beloved tea bowl. And indeed, they were able to present him with a beautiful tea bowl made from the shards, but with a character and beauty all its own. The result was Kintsugi[6].

THE KINTSUGI WORKSHOP

The workshop was built on the metaphor of a Kintsugi mug – starting from the shock of destruction and ending with the re-created beauty of conscious imperfection (Figure 1). Workshops were held with a duration of three hours, which were divided into two blocks of 1.5

hours each. This matched the schedule of the primary target group of students. The following describes the individual steps in detail. Prior to the actual workshop content, an introduction phase and warm-up games were held with the group for a duration of 10 minutes each.

Fig.1. Schematic depiction of the Kintsugi metaphor used as a basis for this workshop.

The shock (35 minutes)

Unintended incidences often leave us with a moment of shock, which is a tangible experience for most people. A prominent example is a kid breaking a cup of milk, leaving it with a sense of guilt and helplessness. In the same way we understand our influence on the environment. In our globalized world the implications of our behaviour are obscured by the ramifications of ever complex mechanisms. Yet, humans net collective impact on our planet may leave us with this very same sensation of helplessness. The coach illustrated this to the scholars by breaking a mug, thus generating a moment of surprise. In continuation, the metaphor was explained by the coach and underpinned by personal experiences. The associated feelings of impotence and frustration were described together with the urging sense to collect the shards and to restore the initial state. While our experience may tell us that this is not possible, the described Kintsugi approach uses the positive energy of re-creation. A restored Kintsugi-mug was then presented to the scholars, illustrating that although the initial state couldn't be restored, we can create something even more precious. Nevertheless, the initial moment of shock still had to be endured. The scholars were now invited to break their own mug, with the shards being left aside for the moment. Prior to restoring the mug, the group was expected to define their own moment of shock in the context of climate change and sustainability. To foster creativity within this step, postal cards were laid out with images of landscapes or everyday objects. Scholars picked up their own card and described their personal shock to the group. It was within the responsibility of the coach to communicate that nothing had to be shared if not wanted. The reflexion sheets in the workbook were then filled out together. Scholars answered the questions 'What do I see/hear/say or do?', 'What do I think or feel?' and 'What frustrates me?'. The group then defined a common topic for a shock moment in the context of sustainability, which was written down in a place visible to everyone on the whiteboard.

Collect (40 minutes)

The second step consisted of collecting the shards. In our metaphor, each combination of shards was representative for a different element of the actual problem underlying the shock topic. The coach explained that it was important to understand these elements of the problem. Hence, scholars subsequently were instructed to collect information on the topic in an auto didactive manner. Depending on the age group, scholars used the internet or were guided by the coach with questions. The gathered information was noted in the workbook. Participants where then asked to choose the three most important pieces of information and to write them down on their shards. This information was then discussed in the group and documented by the coach with Post-It notes on a whiteboard. Before leading over to the recreation phase, the coach finalized this step with a short reflexion on the collected information. We recommend taking a short break of 10 minutes after this step.

Re-creation (30 minutes)

In the re-creation phase, scholars were instructed to play with the pieces, put them into order and to exchange pieces with other participants if necessary. Metaphorically speaking, each combination of ordered shards represented solutions or behavioural patterns everybody could incorporate in his daily life to mitigate the negative shock effects or to prevent them from happening again. In continuance, scholars were encouraged to write as many ideas in their workbook as possible. The coach guided this brainstorming with questions as 'What can we do to solve the problem?', 'What could you and I change?', 'What would person XY do?', 'How would nature / certain animals solve this problem?'. All ideas were then shared with the group and collected on the whiteboard. New ideas that arose based on others were included within the discussion.

Gluing (30 minutes)

In the gluing phase, the ordered shards were put back together with the help of a glue gun. The central message transported in this step was that everyone of us is part of the solution. We all are the glue holding together the pieces and our individual decisions and behaviour help to conglutinate the problem. The coach encouraged every participant to be part of the solution by taking a decision on the individual steps he/she could take. Everybody can positively impact the world according to his possibilities. Finally, scholars wrote their ideas in their workbooks and presented them to the whole group.

Gilding (25 minutes)

Finally, the conglutinated mugs were coloured with a golden pen. In Japan, these Kintsugi-mugs are of much higher value, as they are unique and embody the character and beauty of conscious imperfection. Scholars were instructed to imagine a story in which they as a protagonist turned their ideas into practice, which was noted in the workbooks and told to the group if wanted. Depending on the story, it was necessary to simplify or break the idea down into smaller pieces. Sharing stories with the whole group enabled participants to transfer elements of other stories to their own ideas and fostered a motivating sense of community.

Workshop materials

Each participant required a mug, a workbook, a Post-It block as well as a black and golden pen. Furthermore, a whiteboard, glue guns and creativity cards were employed. Creativity cards were common postal

cards showing landscapes or everyday objects. A pair of thin working gloves has proven useful when handling the shards and glue guns. We used modular furniture (Xbrick®, Stuttgart, Germany) for creating a flexible workshop environment. Within the GREENESTO project, an electric van was leased, building the base for our mobile workshop station.

RESULTS & DISCUSSION

The GREENESTO project was planned with the goal to foster an individual approach to the topic of sustainability and to use the collective innovation potential to carve out ideas for a mindset and behavioral change in everyday life. With this goal in mind, the Kintsugi method was developed, and two workshops were held in schools in Stuttgart, Germany. Students were between the age of 13 and 16. The workshop format was received positively from the targeted schools. Feedback from teachers included that they valued the learnings of their students, not only in the context of sustainability but also the elements covering soft skills as teamwork, brainstorming, presenting and storytelling. Students responded particularly well to the phase of research, where they independently searched for information in groups of two. The parallel processes of active participation and creative handicraft work were received as positive for maintaining concentration throughout the workshop. Partially, students had difficulties to grasp the meaning of the metaphor. A thorough preparation of coaches to tailor their explanation to the respective age group could help mitigate this issue. Also, the practical parts of the workshop often required more time than the mental tasks. Close mentoring was essential to guide especially younger participants successfully through these tasks. Furthermore, the destruction of the mug was not understood as a moment of shock by all participants. This step should be moderated carefully to bridge the gap between the metaphor and the practical example. From our experience, it is recommendable that students drop their mugs one after the other.

The presented Kintsugi method has many parallels to DT. Both approaches are divided into a problem and solution space and feature divergent and convergent thinking. However, the goal of our method was not to come up with an innovative product or service for a user but rather to encourage participants to reflect on their behaviour and impact on sustainability. We compare the moment of shock to the empathize stage of the DT process. While a team empathizes with certain users and their pain points in DT, Kintsugi draws the focus to the user of the method. We reflect on how we see our environment, our observations, what shocks us and the pain points of our behaviour and the people around us. This reflection is captured in a map comparable to an empathy map. Talking about painful personal topics and expressing emotions is not always easy. We employed creativity postal cards with simple images to support visual communication. Images are helpful when used as metaphors to explain and transfer a specific emotion. Additionally, our Kintsugi method guides the group to decide for a common pain point encountered in our daily life. Likewise, in DT the team identifies a relevant problem together. Before entering the solution space, the Kintsugi method includes a unique step of doing analytical research to make the problem tangible and to consider facts, causes and impacts. The re-creation step is highly comparable to the ideation step of DT. Employing various ideation tools, the teams collect ideas with a focus on quantity over quality. In continuance, the Kintsugi-mug is glued together, and every participant takes a personal decision, which has parallels to DT when selecting a specific idea. Finally, our method employed storytelling to communicate a "prototype"

of how participants plan to translate their idea into their daily life. Sustainability and personal topics are sensitive to communicate. Using the metaphor together with the practical handling of the mug allows for visual communication and lowers the barriers of self-reflection. Also, every thinking step is paralleled by the mug metaphor and the actions of the hands help to stimulate the thought process and to internalize the meaning of every step. In the practical implementation of our workshop, it was not needed to name the individual steps with words. Visual communication with the help of pictures is close to Japanese culture, where content is often expressed in images or stories[6]. Likewise, the Japanese language is built out of combined pictures. Our method furthermore incorporates various elements of the DT mindset. Creative confidence, radical collaboration and optimism are important for a successful Kintsugi workshop. The groups must stay optimistic and confident by understanding that the feeling of "I want to repair my broken cup" embodies the energy to come up with suitable ideas. Collaboration and being open to the ideas of others lead to inspiration and is an important pillar when generating new ideas. Here, empathising with other members of the team, their shocks, pain points and mindset is key[7]. A safe space for the teamwork allows participants to feel comfortable when reflecting and communicating. Finally, the DT mindset of bias towards action is a major aspect of this workshop. When participants opt for action, this format, which is based on visuals and experiences, can be an enabler for change on the personal level.

This work must be seen in the light of the following limitations. While we presented a ready-to-use workshop that has been tested in two schools, it was not in the scope of this work to provide scientific evidence for an actual mindset-change induced through the method. Future studies including pre- and post-testing with an increased number of workshops and participants are warranted. Follow-up studies could be analysed qualitatively with the help of interviews. Alternatively, quantitative self-assessment questionnaires with a 5-point Likert scale could be developed, similar to those suggested from Dosi et al. for assessing the DT mindset[8]. Also, having one workshop day per group might limit the learning effect for participants. We suppose that a format spread across multiple days would be beneficial for creating a long-term learning effect. This concept also might include follow-up sessions that could be run by professors independently with their students. However, our Kintsugi workshop was built to be a pragmatic approach toward fostering a sustainable mindset in its' participants. The method can be formed and developed to fit its respective context and desired outcome in future studies.

Using this metaphor as a method is nothing new. In the field of psychology and therapy it is used to change and work through life's difficulties. Princer employed a Kintsugi-influenced approach to foster self-forgiveness and resiliency in young adults with feelings of guilt[9]. Dobkin suggested to use Kintsugi in healthcare professionals with pandemic-related posttraumatic symptoms[10]. Relating Kintsugi to innovation and mindset change in the context of sustainability was originally proposed by Vicente Pinto Arenas in Chile. His vision is to use the metaphor as a common thread for developing holistic sustainable business models[11]. He calls his method: "circular mug". Our Kintsugi method is designed to enable individuals (regardless of age group; 13 years and older) to reflect on their own attitudes towards sustainability, to fully exploit the group innovation potential, and to conclude their own change process towards a conscious approach to the environment in small steps. Here, we draw on other Japanese approaches. In addition to Kintsugi, the understanding of the beauty of

imperfect things can also be found in Wabi-Sabi[6,12]. When it comes to sustainability, no one needs to be perfect, and no one needs to be the same. Taking imperfectly good steps is the gain we need. Also, both approaches start with accepting a painful fact. We want to apply that to the issue of sustainability as well. We want to be shocked by the consequences of human actions as well as acknowledge that just our presence currently has a very negative impact on our planet. From Zen we adopt simplicity6. It doesn't have to be an unprecedented idea. It can be something very normal that I change to contribute. It can also be something very simple but marks a real change for the individual. And finally, we take from Kaizen the opportunity of small things. We want to find small steps for people, where everyone can and want to do their best and thus courageously contribute and recognize its' imperfect golden value.

In conclusion, this work discusses the ramifications of an approach that goes from shock to realization to creation. The pivotal question is: to what extent does a shocking experience foster or inhibit creativity? Or, from a different perspective, is a shocking experience necessary in order to realize and make the sustainability issues that we are dealing with tangible. On a larger scale, these issues prompt the question whether it is possible to extrapolate the Kintsugi metaphor as an enabler for creative change. Here, we provide a methodological framework that can be taken as it is or adopted creatively and leaves room for abductive reasoning in future investigations. It is the small contributions of individuals that reflect the essence of Kintsugi and constitute a valuable part to a sustainable human footprint on a larger scale.

RESULTS & DISCUSSION

The fruitful discussions with Vicente Pinto Arenas on his vision for using Kintsugi as a method are gratefully acknowledged. His work formed the basis for developing this workshop.

DATA AVAILABILITY

All workshop related materials are made available on https://www.arena2036.de/de/DF-GREENESTO

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EXTENTED ABSTRACT:
Industry Perspectives on Sustainability Competencies for Design Creativity

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ABSTRACT

PURPOSE

In order to design creative solutions that allow for sustainable innovation and growth in the future, organizations need to integrate various perspectives into their development efforts. While sustainability related challenges are complex, systemic, and require comprehensive systematic change (Gaziulusoy & Erdoğan Öztekin, 2019), design as an area of expertise offers methods, tools, skills, and mindsets for understanding these holistic problems, identifying opportunities for development, and creating novel solution possibilities. Integrating design into organizations can assist with implementing this change. Design-driven organizations that embody a wide range of design capabilities are more likely to achieve sustainable innovation as opposed to companies that can not leverage an extensive range of design capabilities (Björklund et al., 2020).

The goal and role of design and designers have evolved as global challenges become more complex and in response the needed competencies are also changing. The requirement of design skills and knowledge such as material science, process knowledge, and knowledge of human behavior are becoming more prevalent (De los Rios & Charnley, 2017). According to a literature review by Wiek et al. (2011) there are five key competencies that are needed for sustainable development efforts. These are systems thinking competence, anticipatory competence, normative competence, strategic competence, and interpersonal competence (Wiek et al., 2011). All of these key competencies include more detailed requirements for needed skills, knowledge, and attitude areas. For example, methods for forecasting, envisioning futures, and creating scenarios are anticipatory competencies while interpersonal competencies include participatory and teamwork methods (Wiek et al., 2011). An empirical study building on the framework by Wiek et al. (2011) identified seven circular economy competencies for design (Sumter et al., 2020). These competencies are circular impact assessment, design for recovery, design for multiple use cycles, circular business models, circular user engagement, circular economy collaboration, and lastly circular economy communication.

As industries and economies face growing challenges and the need to integrate sustainability efforts in their functions increase, there is a need to identify future competencies. In this study, we set out to explore the industry perceptions of the required design competences or capabilities – knowledge, skills, and attitudes (KSA) – that designers use to tackle sustainability-related problems. We defined sustainability in our study and interviews through the holistic three-pillar sustainability framing, consisting of social, economic, and environmental aspects (e.g. Purvis et al., 2019).

DATA AND METHODOLOGY

The data used in this study was collected from 104 semi-structured thematic interviews with 101 organizations from across Finnish industries. The data was collected as part of a larger research project, and occurred during the Spring and Summer of 2021. The interviewees were in design positions as individual contributors (46%) and within managerial roles (54%). Organization types varied from private (70%) to publicly listed companies (24%) as well as public organizations (6%). Of these, 29% represented consulting companies and design agencies and 71% represented companies offering products and/or services. The interviewees were asked what they perceive as the skills, knowledge, and attitudes designers need for effective future-focussed sustainable design. Interviewees were also asked what skills, knowledge, and attitudes individuals within their organization needed to encourage sustainable design in the future. The interviewees were free to name any competencies without being introduced to the frameworks used in the study. After having the interviews transcribed verbatim, the answers to questions regarding capabilities were tagged and analyzed by categorizing the answers based on their thematic similarity (Braun & Clarke, 2006).

MAIN FINDINGS

Findings were aligned to the five previously identified key competences; systems thinking, anticipatory, normative, strategic, and interpersonal competence (originally framed by Wiek et al., 2011, expanded on by Sumter et al. 2020). Most of the KSA the interviewees identified were interpersonal competencies.

The identified interpersonal competencies included subcategories of *collaborating with others* and *selling issues to others*. When discussing the need to collaborate with others, the interviewees noted the ability to combine knowledge from different fields, understanding various disciplines and integrating diversity. The ability to sell issues to others included references to project management skills and behavioral knowledge, but also perseverance, resilience and courage to question and debate. Skills in facilitation and the facilitation of discussion, such as facilitating workshops, were also seen as a beneficial interpersonal competence.

The second largest emerging theme in the study was *anticipatory competence*, with mentions of KSA related to moving between imaginative and existing frames of thought. Some of these competencies were linked to creating new possibilities through diverging thinking processes, while others were matched to choosing between options (thus reflecting the need to apply convergent thinking and make decisions). Specific KSA noted by participants were adaptation and ideation skills, and a realistic attitude. The findings of this study are in line with the foundations of design thinking, which is a human-centered process (Liedtka, 2018).

The third largest category was *normative competence*, with subcategories of product-centricity and the ability to interpret data. The interviewees saw a need for strong design skills, passion for problem solving and hands on skills as needed normative, product-centric competencies for sustainable design. The ability to interpret information included references to critical thinking skills, understanding required metrics and the various aspects of sustainability. Being scientifically minded and relying on scientific knowledge when designing sustainable solutions was seen as beneficial. Systems thinking competencies were mentioned almost as frequently as product centricity. These competencies were linked to the ability to understand the product or problem at hand in a holistic way. The least identified category was *strategic competence*. Within this category the interviewees recognized a need for business-centricity, knowledge of different business models, strategic design skills, and understanding the market.

IMPLICATIONS

The results of this study reveal a variety of design competencies associated with sustainable design. However, findings may indicate that a gap exists within sustainable, industry required design competencies identified in previous research. The practical implications of this study include twofold educational implications. Firstly, that future designers should be educated with industry needs in mind and secondly, that practicing designers should pursue lifelong learning and develop their competencies during their career to meet the changing needs of a sustainable industry.

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EXTENTED ABSTRACT:
An inventory of initiatives to combat plastic soup from a designers point of view, and a review of 2 of these initiatives

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ABSTRACT

PURPOSE

In 2015, 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries, of which 4.8 to 12.7 million MT entered the ocean (Jambeck et al., 2015) and (Geyer, Jambeck & Law, 2017). Fulmar Litter Threshold Value Monitoring (Kühn et al., 2021) in the Netherlands shows an increasing amount of mostly plastic particles in the stomach of Fulmar. Plastic waste is a well-known problem on land, on river banks and finally in the ocean, what is generally referred to as *Plastic Soup* at sea and *plastic litter* at the coast. Marine debris has serious economic and ecological consequences. Economic impacts are most severe for coastal communities, tourism, shipping and fisheries. Marine wildlife suffers from entanglement and ingestion of debris (Kühn, Rebolledo & van Franeker, 2015), with micro-particles potentially affecting marine food chains up to the level of human consumers. The 10 most commonly found single-use plastics on beaches together make up 43% of marine litter (Rebolledo, De Gier & Dijkstra, 2022). The main sources of marine litter are shipping, fishing, beach recreation and the supply via rivers from land-based sources (Van Emmerik et al., 2020; Lozano & Mouat, 2009). The problem is related to our worldwide economic system, our fast consumption society oriented towards time efficiency and comfort. It is a complex, worldwide problem which asks for a system change and finding solutions on all levels of social and technical systems.

To avoid single use plastics, the design of new products, services and systems is necessary. Design methodologies specifically focused on this can help create support and cooperation across the projects that are being executed in The Netherlands. With its relatively long coastline The Netherlands, with its Wadden area (a UNESCO's World Heritage listed site, with 5 small inhabited, tourist islands), is a country where the plastic waste problem is quite visible. As a result plastic waste is receiving more and more attention.
Framework and methodology

FRAMEWORK AND METHODOLOGY

Most of the plastic pollution is from discarded products. This implies product designers can play an important role in solving the problem. The following design methodology framework is developed: "9R" Design methodologies ranging from Refuse and Reduce, to Recycle and Recover (Potting, Hekkert & Worrell, 2017)have been used and combined with the other mentioned methods. Since most of the waste is from fast moving consumer goods, strategies specific for 'products that flow" (Haffmans, Gelder & Hinte, 2018) are applied. Change of only the product context itself is not enough, higher system levels need to be adapted in parallel (Joore & Brezet, 2015), such as the Multilevel design Model (MDM) can be combined with the product level approaches to promote a value chain approach that includes all relevant stakeholders (Redante, et al., 2019). Lastly, different DfX approaches can be applied for product design in the various R Strategies (Moreno et al., 2016).

An inventory of activities is made and analysed according to the design methodology framework described above. Two specific projects, Single Use Plastic free hospitality on Wadden islands and 'Recycling of sea and beach plastic litter' are analysed in detail. Research questions for these two projects are *(1) what design methodologies have been deployed, and with what results, (2) what MDM systems thinking approaches can be combined with this and finally, (3) what DfX approaches have been applied for product design?*

INITIAL FINDINGS

Over 20 initiatives have been identified and described. The most relevant strategies identified are: (1) prevention (refuse/reduce), (2) clean up and recycling, and (3) transition towards natural and biodegradable materials. Next to these, awareness creation in local communities and beyond, is seen as highly relevant.

Two specific projects, Single Use Plastic free hospitality on Wadden islands and 'Recycling of sea and beach plastic litter' were selected for detailed analysis, since these jointly cover all three priority strategies, and are both well developed. Both projects show promising results and have included most of the relevant local stakeholders. Value chain development and involvement of other parties from these chains need to be further developed. Transition towards biodegradable products in both projects has only just started. Meanwhile reduction (hospitality) and recycling (litter) strategies for the existing waste amounts are under further development.

IMPLICATIONS

The analysis shows that the combination of product level and systems level design methodologies is necessary and relevant. Supportive policies on local and national level are necessary to bring the initiatives forward, since alternatives are technically available in most cases.

Intrinsic motivation from the companies and stakeholders involved appears to be an important driver. Also, specific consumer segments and their attitude towards sustainability determines the readiness to change and invest from the companies. Visibility of beach litter, for instance, is a strong motivator for specific consumer segments to demand changes in hospitality. Priority can get lower in case of various crisis situations (for example pandemics like Covid, employee shortage, economic situation). Solutions on the product level are tailor-made and have to be developed case by case. Biodegradable materials for products are still expensive and are still rarely used when there is no clear incentive. Further development of value chains for these new products is necessary, since a general strategy for the future can be formulated as: reduction of plastics where possible, replacement towards biodegradable where feasible, and compulsory recycling of remaining plastic.

KEY WORDS:
Plastic Soup, plastic pollution, design strategies, sustainable product development

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EXTENTED ABSTRACT:

Examining facilitation methods and practices for co-creation: a case of a workshop to co-create the nascent hydrogen economy

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ABSTRACT

PURPOSE

In complex undertakings, stakeholders seek to benefit from multidisciplinary thinking across various stakeholder groups towards common objectives (e.g. Hagy et al., 2017). While co-creation workshops are already intended to handle such considerations and provide a means to better address this challenge (e.g. Frow et al., 2015; Skarlatidou et al., 2019), there is more to the facilitated workshop than meets the eye. Overarching benefits of co-creation workshops are routinely published (e.g. Combrinck & Porter, 2021), as are analyses of the visual and physical artefacts used in such workshops (e.g. Heiss & Kokshagina, 2021). On the other hand, this study addresses the scarcity of research into the role of co-creation workshop facilitation in brokering cross-stakeholder interactions; specifically, design/facilitation factors and techniques that promote mutual co-creation in workshop environments (Graef et al., 2021). Co-creation workshops involve not just bringing diverse stakeholders together (Driessen & Hillebrand, 2012), but require early preparation and ad-hoc/on-the-go tactics to ensure conversations are evenly carried by all, and not biased towards the loudest voices or established hierarchies. Maintaining a workshop atmosphere that enables effective co-creation is a prevailing and significant challenge to facilitators (Mosely et al., 2018). However, the factors that go into preparing and facilitating a co-creation workshop approach are not thoroughly documented, and even less so published in the research community. We set three research questions to address this gap:

1. What factors must co-creation workshop designers consider ensuring the workshop activities are unbiased towards a particular stakeholder group and that every workshop participant has equal opportunities to contribute?
2. What techniques can co-creation workshop facilitators use to ensure participant discussions remain stakeholder-neutral?
3. Did such factors and techniques, geared to neutralise sector-specific discussions, impact individuals?

METHODOLOGY AND DATA

This study follows a case study approach (Yin, 2009) and investigates a co-creation workshop within the Australian energy sector, with several stakeholders with different interests. These interests situate across all areas of the energy value chain: generation, transport, storage, distribution, and use are key interests alongside products that can be manufactured for these areas. While these stages constitute immense value together, they are distinct from one another and constitute different disciplinary understandings and processes around boundary technologies. The study combines findings from existing literature with primary data gathered from: 1) the design of the co-creation workshop described below; 2) observations by facilitators during the workshop; 3) co-created workshop outcomes; and 4) workshop participant interviews. Data were analysed by three researchers who were present, and two researchers absent from the workshop. The data were first analysed by the researchers who were not involved in the design and delivery of the workshop to increase the data analysis objectivity. The study then discusses the key components and strategies needed to ensure co-creation remains neutral to any specific sectoral interest.

Three of the authors planned and facilitated a co-creation workshop for participants (N=15) representing different sectors comprising the nascent Fuel Cell Electric Vehicle (FCEV) ecosystem in Victoria, Australia. This is a sector that is experiencing high levels of interest on one hand, but rapid change and unclear strategic priorities on the other. Represented sectors included consulting firms, local government representatives, logistics companies, vehicle manufacturers, hydrogen producers, and government utilities. Participants first received a briefing about the workshop, before listening to two presentations from stakeholders constituting two separate parts of the FCEV ecosystem. Then working in small groups—which the workshop designers intentionally formed with a mix of sectoral representatives—participants were facilitated by subject matter experts to discuss and write down their perceived concerns, opportunities, challenges, and next steps for ensuring success for their industry. Facilitators ensured that, as far as practical, conversations remained sector-neutral to the extent that all participants could equally share their perspective. Small groups reported back to all participants after each working session.

FINDINGS

During preparation, workshop designers deliberately limited group sizes to five to ease facilitation and maximise chances for equal contributions from all participants. Physical 'canvases' were produced to guide discussion and help participants move together as the conversations proceeded. As written artefacts, the canvases constitute the result of discursive processes: what is co-created in them is a result of consideration, discussion, and negotiation within the group. Facilitator reflections emphasised the importance of supporting all stakeholders in their discussion around a topic that is of significance to them. In this environment, facilitators noted the need for stakeholders to 'hear' one another and their perspectives. Prompts were carefully crafted to be open yet directed for generating conversation. Keeping

conversation on track was an ongoing process, albeit assisted by the canvases.

The workshop engaged participants from different sectors to co-create a vignette containing a more calibrated understanding of challenges, opportunities, and strategic next steps relating to the FCEV ecosystem. Here, participants successfully synthesised content related to these considerations. The presence of diverse sectors greatly enhanced the utility of the co-creation workshop for all participants. By sharing insights between one another under facilitation, key points could be digested into neutral terms that were mutually intelligible for all participants. The workshop format provided a neutral forum upon which all participants could articulate and understand important points facing one another—and how these points could influence other actors in the ecosystem now and into the future. The nature of the FCEV ecosystem meant that this workshop enabled the types of co-creation discussion that are crucial for the early stages of nascent markets and emerging product categories. In this context, actions arising from working sessions related to understanding the breadth of regulatory issues to be surmounted and the need for different sectors to precisely coordinate their activities together.

IMPLICATIONS

This study contributes to the literature on co-creation by outlining co-creation workshop facilitation techniques to enable better cross stakeholder engagement and improve outcomes for large challenges and complex multidisciplinary landscapes. This study has practical implications for workshop designers and facilitators. For designers, considering the tacit co-creation process a key consideration of the planning process should be front and centre of workshop design. By doing so, effective co-creation is given the best opportunity to take place from the outset. This can also ease the work for facilitators as they encourage co-creation practices from participants. For workshop facilitators, fostering multidisciplinary—but non-exclusionary—discourse can help co-create new understandings and bring different participants closer together. This can lead to a better experience for participants, albeit requiring special attention from facilitators to ensure that this occurs.

We note the lack of research into facilitation for co-creation workshops specifically. We therefore highlight the need for practitioner materials for co-creation workshop facilitation to better inform best practice. Further research is needed to better understand how different techniques play out in various co-creation settings. This will give further insight into different variables such as stakeholders present, the workshop design and context.

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Theme 5:

Organisational Level
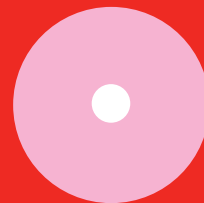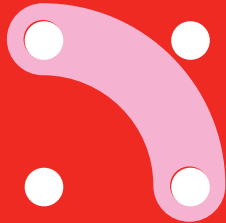
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Finally, there are several studies that look at the functioning of the organisation as a whole. This can concern the degree of inclusiveness in the workplace (Keipi et al) or how ambidextrous project management can help organisations respond quickly to social change (Derksen). One of the longest existing Design Factories can even look back on an existence of more than 10 years, and in their study its initiators try to surface the lessons learned in that time from the perspective of the Design Factory as a regional Community of Practice (Kocsis et al).

EXTENTED ABSTRACT:
A pop radiostation as example of ambidextrous strategic management

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ABSTRACT

PURPOSE

We should rethink the way we regard radio and look at its strategic capabilities, with a public broadcast pop music radio station as an example of ambidexterity. Ambidexterity refers to the ability to combine exploration and exploitation simultaneously, to both innovate and maintain the unique selling position of the radio station (O'Reilly & Tushman 2013).

The dilemmas that creative industry organisations (CIO) have dealt with for many decades are now common in many industries (Lampel et al., 2000) and CIO are studied to improve management of other organisations outside of creative industries. Older, so-called established media, such as radio and television, are overlooked in the discussion of flexible management. Radio has regularly been declared old or redundant by media, politics, and the public because of commercial competition since the nineteen nineties, algorithm-curated playlists online, the discussion on public broadcast radio. This discussion is fuelled by what governments should curate on public broadcast radio and what is up to market forces.

Meanwhile, public broadcasting pop music radio has always been adapting to competition, political changes, and technological challenges, whilst staying true to its own core concept. The contemporary concept of radio, even without its original technological parent platform of radio, is prevalent on multiple platforms. The case for this paper is Dutch radio station NPO 3FM, a Dutch pop music radio station within the National Public Broadcasting organisation (NPO) of the Netherlands. The station is one of five public radio stations. 3FM has existed since 1965, broadcasting under different names, but always strategically branded to serve a young audience. The content features new and famous pop music, news and discussions about themes that interest young people.

THEORETICAL BACKGROUND

Scholars have called for more interdisciplinary research perspectives in media studies, for more inclusion of economic and management perspectives (Albarran, 2008). Sociological and economic frameworks to study innovation phenomena offer promising approaches to examine the duality of media innovation in the light of their economic and societal implications (Dogruel, in Krumsvik & Storsul, 2013). Economic approaches to innovation as well as social-innovation and techno-sociological approaches are seen as enriching extensions.

Many management scholars (Wu&Wu, 2015 and Tushman & O'Reilly, 1996) have studied and assessed creative industry organisations (CIO) and have found them to be examples of flexible, resilient organisations in a turbulent environment. A creative industry, with content as its main product, enjoys only the success of its last broadcast; success is unforeseen and fleeting. As CIO organisations, media also adapt to their turbulent surroundings and innovate further at the same time; an example for all companies who want to keep innovating.

Jansen et al. (2013) followed creative organisations for an extended period to discover when exploration and exploitation were strategically implied; directing the right resources to the right strategy. Marijanen and Virta (2017) did some groundwork in studying a case of radio management, analysing the dynamic capabilities of the Finnish public radio station Yle, and highlighted the sensing and seizing moments of (incremental) innovation. This study builds on this framework and takes dynamic capabilities further, analysing the politics, market and digital turbulence around a radio station and analysing specific events that exhibit exploration and exploitation in relation to strategic management. Case study research, as a framework, is used to understand pop music radio stations' adaptability and innovation power, in relation to the strategic management of a public broadcasting radio station. This study references media studies, strategic management studies and communication and marketing studies. It contributes insights regarding multidisciplinarity to media studies as well as a longitudinal case study of CIO organisations to ambidexterity studies.

The roughly three-decade period, between 1992 and 2015, is the focus of the case study on 3FM. Public broadcasting is studied as opposed to commercial radio, being not as vastly predicted by income from advertising and market share. Public broadcasting also serves a public function and is funded through the national budget. On top of this, pop music radio is focussed on new content for young people in an ever-changing content environment, making change as a given factor, and strategic management more prone to experimentation.

METHODOLOGY

Methodology consists of a three-phased coding sequence of sources, in which media articles and organisation data sources were analysed. The analysis explored both public and sector specific media articles as well as interviews with key persons. These media sources are combined with generally available data on the radio station, like market share numbers, listener data and year reports of the broadcasting

organisation. Relevant themes come from the textual coding of sources, which are combined with general data and enriched through interviews with key figures in the radio stations' history. The resulting themes are then analysed and differentiated in exploration or exploitation motivated themes and explained in the context of strategic management.

EXPECTED FINDINGS

In the studied years, from 1992 to 2015, Radio 3 aimed to serve a young audience, with a (new) pop/rock music profile and discussions and news on themes that move young people. Market, politics, and technological developments caused a commotion in all three studied decades. 3FM had to deal with heavy commercial competition in the 1990's market, while it was busy developing itself into a unified youth pop music station with its own identity, while the first radio coordinator tried bringing all broadcasting organisations on Radio 3 together. At a high audience rating in the professionalised radio station market around the millennium, 3FM was politically and marketwise under constant scrutiny from government and commercial parties, discussing what public radio should be when popular music was so well served by commercial stations. These stations meanwhile lured star DJs away from public radio stations to their commercial stations with commercial salaries. The end of the nineties and especially the 2000's were marked by technological upheaval, 3FM experimenting with online and interactive social media and radio becoming visual through events. 3FM established radio as an audio-visual medium with the Glass House event, raising money for the Red Cross, and through their presence at other music events.

Staying at a steady high market share until well into the 2010's, when other DJ stars left the station and redivided themselves over both other public stations and commercial radio, shifts in programming of NPO 3FM became necessary. These shifts grew bigger as management changed more often, making listeners leave on their horses, leaving 3FM at another crossroad of minimised audience ratings in the history of the station. That is the general history of the radio station, but did 3FM exploit or explore? Which subjects were exploited or explored, in which moments in this history, and why was this possible or opportune in the strategy of the radio station? Results will shed a light on this. Preliminary results, as well as the executed methodology of this study, will be presented at the DFGN conference. The goal is to open minds further to alternative inspiration sources in general, and CIO and media organisations specifically, when searching for factors of resilience for organisations in a turbulent environment.

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EXTENTED ABSTRACT:
Designing inclusive work environments: Enablers and hindrances of workplace creativity

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ABSTRACT

PURPOSE

Creativity in organizations has long been a focal area of research in the organization sciences (e.g., Anderson et al., 2014; George, 2007; Montag et al., 2012). Designing an environment that can support employees' creative performance is a crucial task for service providers' management teams. However, designing a conducive environment for employee creativity is no trivial task, as contemporary organizations often reproduce management practices that reflect the dominant views of powerful decision-makers. The systemic overrepresentation of dominant actors and voices imprints on contemporary management practice, which may lead to the marginalization of other groups of employees, potentially undervaluing alternative contributions. This is problematic, as employee creativity benefits from the effective collaboration of diverse stakeholders (Rock et al., 2016) who are motivated to engage in collective endeavors. Recently, Zhu et al., (2018:2098) lamented that "knowing which team factors affect the creativity motivation of employees would be useful for managers responsible for enhancing the creativity of their subordinates. Indeed, there is still much to learn about team context effects on individual creativity (Anderson et al., 2014; George, 2007)." In this research, we contribute to closing this gap by exploring employee creativity in the context of a large design agency. Particularly, we ask how the design agency's work environment may enable or hinder its employees to flourish creatively.

DATA AND METHODOLOGY

We draw on a dataset of interviews with 67 employees in a large design agency. For the purpose of this research, we have zoomed in on interviews with designers in two office locations, resulting in a sample of 20 designers (14 men, and 6 women). While the importance of employee creativity may vary across industries, design agencies resemble a particularly revelatory, illustrative case, as design agencies can be characterized as organizations relying on employee creativity as a key capability. The interviews followed a semi-structured interview guide (Miles and Huberman, 1994) and featured questions about the culture of the company. We analyzed the data in four steps. Firstly, we inductively coded all responses mentioning elements of the organizational environment that influenced informants' creative ability either positively or negatively. In total, we arrived at 102 coded segments, 57 from the 13 men, and 45 from the 6 women. Secondly, we adopted Amabile's (1996) framework as a basis for semantic coding of various supporting and hindering elements. To ensure intercoder reliability, two of the authors coded the data individually, to then discuss any differences in coding until an agreement was reached. Thirdly, we reinvestigated each category to form subcategories and ensure semantic-level thematic similarity (Braun and Clarke, 2006). Lastly, we compared the coded segments across gender, both in terms of frequency and content.

MAIN FINDINGS

Our findings suggest that while there were clear patterns and common themes that were shared across genders, our data analysis also revealed subtle differences between genders that may easily go unnoticed. Based on Amabile (1996), we differentiated between three categories that collectively enable employees' creative performance: motivation, creative thinking, and expertise.

Motivation

Firstly, designers' motivation was supported by hiring practices considering cultural fit, an office policy that ensured direct personal access, and projects that were closely aligned with personal interests. These motivators were conducive to collaborative, meaningful, and autonomous work. Additionally, designers enjoyed an appreciative and caring attitude, as well as having passionate and motivated colleagues. On the other hand, designers' motivation was hindered when there was an apparent disconnect between managers and employees, and when commercial pressure was exerted by the sales department, essentially undermining desirable work attributes. Additionally, designers lamented a lack of transparency and internal understanding of their creative work. Interestingly, while male designers more often felt increased task motivation as a result of collaborative cultures and feeling challenged, female designers enjoyed an inclusive work environment, close interactions with one another, and doing work with a positive social impact. On the other side of the coin, male designers were more likely to mention a disconnect with sales, hindering their motivation, whereas female designers mentioned a lack of mentoring as a hindrance.

Creative thinking

Secondly, designers' creative thinking was enabled by the freedom to explore, while cultivating an open style of communication and a supportive task environment empowered employees to perform creative work with 'peace of mind'. On the other hand, designers' creative thinking was hindered by managerial overregulation, risk-averse behavior, or a lack of resource sharing. While male designers lamented

overregulation, they enjoyed a friendly and supportive work environment. In contrast, female designers enjoyed a frank and informal communication style, but lamented a disconnect with their designer peers, and focused on self-preservation, which hindered their creative thinking.

Expertise

Thirdly, designers' expertise was supported by being actively involved in projects from the beginning, feeling trusted by colleagues and managers, perceiving the management team as being future-oriented, and being embedded in a culture that values diversity and is open to reflection. On the other hand, designers' expertise was hindered by a lack of trust, a lack of clarity of team roles, and poor project scoping. While male designers enjoyed being perceived as a professional, and being able to show off abilities, which supported their perceived levels of expertise, female designers celebrated the ability to ask questions, challenge the project brief, and constantly learn and grow. Similarly, male designers lamented not being treated as a professional, while female designers frequently mentioned insufficient opportunities for growth as a hindrance.

IMPLICATIONS

Our study highlights the similarities and differences in perceptions of the same work environment by male and female designers. This builds on findings of earlier studies, for example, Beddoes (2021) showed how in early career socialization experiences gender impacted career outcomes, such as satisfaction. Taken together, the findings of our study highlight opportunities to better harness the full creative potential of a gender-inclusive working environment. The implications of our study are fourfold. First, design researchers may benefit from investigating how individual and team creativity can be supported through a work environment that takes into account gendered experiences. Second, design professionals may see our findings as a useful starting point to increase awareness of and support for the diverse experiences of their peers. Third, managers may take our findings as a stepping-stone for fostering creativity by taking into consideration the diverse perceptions, and varying enablers and hindrances of their employees. Last, based on our research, design educators may develop more tailored design education to equip design students with the appropriate knowledge and tools to navigate the reality of diversity in a contemporary work environment. Furthermore, our study opens up new avenues for future research. For example, our study should be extended to include more designers in more locations to see if the patterns hold true. Finally, the analysis should be extended to reveal differences not just across gender, but also across age, roles, organizational tenure levels of seniority, or cultural background.

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Innovation Catalysts: learnings from ten years of Design Factory Melbourne's interdisciplinary practices

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ABSTRACT

PURPOSE

This paper examines how an ecosystem of innovation is fostered in universities through a Community of Practice framework and sheds light on key enablers and barriers to developing, sustaining and furthering Industry-University collaboration efforts within higher education. There are approximately 175 Innovation Precincts in Australia ranging from collaboration networks, university precincts and industry clusters (Australian Government, 2019). The actors and organisations within these precincts are commonly known as innovation catalysts (IC) and over the past ten years, their purpose is to support Australian researchers in delivering greater community impact. To do so, ICs have become strategic players in forming Industry-University collaborations, where they facilitate and apply the fundamental research discovered in universities into solving industry challenges. However, a common challenge that ICs face is the need to work in multidisciplinary teams. While team members bring their specialised knowledge to the team, what is less understood, yet critically needed, is the team's tacit collaboration practices, such as fostering culture, mindset and managing shared understanding. A potential way to overcome this challenge is for ICs to operate as a Community of Practice (CoP) to foster a supportive community, co-create knowledge from multidisciplinary areas, and translate the interdisciplinary insights into industry actions and solutions.

RESEARCH METHODOLOGY

This paper is a case study of Design Factory Melbourne (DFM), an open platform for interdisciplinary education, research and industrial collaboration located at Swinburne University of Technology in Victoria, Australia. DFM can be defined as a triage of nodes that intersect with university and with industry in a community of practice. The uniqueness of DFM lies in the process of continuous learning and re-learning by which DFM evolves to meet different university and industry needs. Using the CoP evaluation framework by Wenger, Trayner & De Laat (2011), we (DFM staff) conducted a co/autoethnography (Coia & Taylor, 2009) study to analyse our industry-focused student and research projects. In the first round of reflections (autoethnography), we individually uncover the different types of value created in the projects, as characterised by the CoP framework. In the second round (co/autoethnography), we exchanged and evaluated each other's reflections. Additionally, we focused on uncovering the social skills and factors of participating in a CoP. These factors include mindset, culture, and shared understanding, which foster the value creation process. This co-reflection is twofold. Firstly, the additional perspectives on the initial round of reflections provided a critical reading needed to reveal latent learnings that were articulated too briefly. Secondly, the analysis deepened our individual learnings and more importantly, made us aware of DFM's tacit knowledge and practices.

RESULTS

From our co/autoethnography, we identified and described the key barriers and enablers of operating as an innovation catalyst within an industry-focused university. We categorised these barriers and enablers according to the CoP evaluation framework; 1) Activities and interactions, 2) Knowledge capital, 3) Changes in practice, 4) Performance improvement, and 5) Reframing value. From these insights, we also reported on the barriers and enablers in mindset, culture and shared understanding, which are harder to measure and often diminished in comparison with tangible outcomes. Due to the priorities of universities, which often focus on measurable outputs, we first briefly discussed the tangible outcomes of IC as CoPs. We then built upon this discussion to uncover the intangible outcomes that are often diminished and challenging to evidence. The intention of explicating these intangible outcomes is to demonstrate the impact of these downplayed factors on collaboration success as well as to identify the need for studies to examine these tacit processes. Finally, we discussed the tacit knowledge that ICs need to create the social conditions for innovation as framed by CoPs, which are less documented with a focus predominantly on the outcomes. From our preliminary evidence, we recommend organisations investing in IC initiatives to also consider the social factors and dynamics required to build and sustain a CoP. Additionally, such organisations also need to recognise the impact of IC work to include both explicit and tacit knowledge and expertise, especially when spanned across diverse disciplines, expertise and industry partnerships. Finally, we provide strategies on how design skills, such as Design Thinking and prototyping, build the social and innovation skills necessary to foster an effective CoP, and ultimately, an IC for Industry-University collaborations.

IMPLICATION

The impact of this research is that universities should consider investing in both tacit and explicit processes, methodologies, and goals for IC to thrive as a sustainable CoP, as a way to operationalise an innovation ecosystem that generates value for its various stakeholders. Given the disruptive difficulties that businesses confront, this research assists prospective industry partners in reading the CoP landscape within universities and leverages their innovation capabilities, research, and culture. Finally, this research enables researchers that are part

of multidisciplinary CoPs to broaden their repertoire of practice to act as an innovation catalyst and, as a result, consider their contribution beyond the scope of their discipline, especially useful when applied to pressing global challenges.

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