Design and Technology Education: An International Journal

30.1

Design and Technology: An International Journal

Design and Technology Education: An International Journal is published three times a year

Contributions
All contributions and materials for review should be made through the Journal website at:
https://openjournals.ljmu.ac.uk/DesignTechnologyEducation

D&T Association membership
To join the D&T association, or request further details on membership please contact:
Jacqui Eborall, Membership Secretary
Tel: 01789 470007
email: membership@data.org.uk

Volume 30
Number 1
ISSN 2040-8633 (online)
April 2025

Design and Technology Education: An International Journal

30.1

Issue 30.1 April 2025

Table of contents

Editorial: Moving forward from challenges and test-driving a new approach for the Journal

Kay Stables, Goldsmiths, University of London, UK
Lyndon Buck, University of Southampton, UK

Recent months have been challenging for the Journal as we have experienced some technical issues with the OJS website. However, we are now pleased to be able to say that problems have been overcome and we are back to our normal ways of communicating with readers, authors and reviewers. The challenges have resulted in us publishing the first issue of 2025 later than usual, but despite the problems, we are happy to be sharing eight very interesting research articles.

In the last issue of 2024, we made the embarrassing mistake of mentioning that the journal, in its current format, would be celebrating its 30th anniversary this year. Whoops, we meant its 20th. However, we received no comments on this and assume that no-one noticed our mistake! And it is still exciting to acknowledge that this new issue does mark the milestone of 20 years since the journal shifted its focus both to becoming an international journal and one that focuses primarily on research in design and technology education. However, the journal had existed in previous formats as far back as 1968 and the vast majority of material published since that time is still held in an archive that contains fascinating history and some real gems of insights into the development of design and technology education. We plan to publish the archive in the near future, so watch this space.

This issue contains articles from across all ages and stages of design and technology education, from researchers in Denmark, Finland, Ireland, Sweden, Lapland, Mexico and USA, exploring, explaining and sharing insights across design learning, incorporating humour, holistic craft processes, creativity, teacher guides, cultural insights, participatory approaches, AI and learning, interior design, sustainability, textiles, industry and society, future challenges and bioengineering.

Rather than providing insights into each article through summaries in the editorial, in this issue we are trialling a different approach to introducing each article, by letting the authors speak for themselves. So, we are including a new section in the journal where the abstracts for each article can be seen. As far as we know this is the first time the journal has trialled this approach and we would welcome feedback to see if it is one that we should continue with. We hope that you find the current issue enjoyable and valuable and we look forward to hearing your views on this new approach.

Abstracts

In this new section we are presenting the abstracts for each article published in this issue of the journal. The abstracts are arranged in the same order as the full articles. We hope this is seen as a useful addition to the journal and welcome feedback on the approach.

Crafting Humorous Soft Toys: Incorporating Humour to a Holistic Craft Process in Early Years Education

Marja-Leena Rönkkö, University of Turku, Finland
Juli-Anna Aerila, University of Turku, Finland
Tuula Stenius, University of Helsinki, Finland

Abstract

This study explores humour's role in a holistic craft process when 7–8-year-olds design personalised soft toys. Humour enhances learning environments by fostering joy, belonging and a positive atmosphere, acting as a motivational tool in experiential and arts-based learning. The study aims to answer the following questions: (1) What are the humorous characteristics of the soft toys created by the pupils? (2) How does the crafting of humorous soft toys proceed? Employing an educational design research methodology, the project involved 36 first-grade pupils from an urban Finnish school over a 10-day intervention. The study examines how humour, when integrated into a holistic craft process, supports the making and designing of soft toys. In the study, the pupils created humorous soft toys, often anthropomorphised with exaggerated or contradictory traits. Challenges emerged in translating 2D drawings into 3D soft toys, particularly with sewing and fabric painting. Nevertheless, the final products were unique and evoked positive emotions. The findings suggest that incorporating familiar elements, such as humour and soft toys, into the holistic craft process in early years education can enhance motivation and learning outcomes, thus supporting the integration of humour into educational contexts to foster creativity and emotional expression.

***

Using performative objects to foster creativity in an education setting to tackle complex challenges

Cathrine Winther, Aalborg University, Denmark
Søsser Brodersen*, Aalborg University, Denmark

Abstract

Creativity is often seen as something that occurs primarily during the ideation phase of design processes. However, this article argues that there is significant potential in enhancing creativity in the early stages and that this can contribute to youth learning and tackling complex challenges. Using a Danish educational setting as a starting point, the article illustrates how using performative objects in teaching situations fosters creativity in the early stages of a design process. The article concludes that creativity is not merely an individual skill but a social practice and process, where using performative objects creates a conducive context for creativity.

The teacher's guide's way of communicating with the teacher – within the subject of technology

Pernilla Sundqvist, Mälardalen University, Sweden
Susanne Engström, KTH Royal Institute of Technology, Sweden
Charlotta Nordlöf, Linköping University, Sweden

Abstract

The materials and artefacts utilized by teachers and students play a crucial role in education. In a subject like technology, where many teachers feel they do not have sufficient competence, curriculum materials such as textbooks and teacher guides provide important support for teachers. Teacher guides, in particular, have the potential to support teachers in different ways. The guidance provided in a teacher's guide can be either directive and talk through the teacher, i.e. telling the teacher what to do, or educative and talk to the teacher, i.e. telling the teacher how to do it and why to do it this way, thereby providing the teacher with knowledge to better understand the teaching of the subject. In this study, we analyze a teacher's guide for grades 7-9 to find out what kind of support it provides the teacher. An adapted framework for the design principles of educative curriculum materials was used. The analysis shows that this particular teacher's guide mostly talks through the teacher, giving the teacher directives on how to teach but without explaining why or suggesting other possible ways. The few educative features found are short and not very detailed. The support an educative teacher's guide could provide would give the teacher agency over their teaching and a better possibility to adapt teaching to situations and students. However, we see little of that kind of guidance in the teacher's guide analyzed in this study and conclude by outlining the possible consequences for technology education.

***

Three levels in culturally oriented product design: a participatory approach to cultural inspiration in design education

Weishu Yang, University of Helsinki, Finland
Henna Lahti, University of Helsinki, Finland
Pirita Seitamaa-Hakkarainen, University of Helsinki, Finland

Abstract

Culturally oriented product design relies on inspiration from the local cultural heritage in the creation of unique products with specific local features. An authentic experience of cultural design inspiration can facilitate novel design outcomes. However, only a few studies have investigated the acquisition of cultural inspiration from a participatory perspective in the field. To narrow this gap, a design workshop was organized with local government in China. Design students were asked to combine local cultural characteristics in everyday products and to generate new concepts that reflect cultural diversity and support local tourism development. We collected students' visual representations, text notes and recorded verbal explanations of the concepts behind the created product designs. The entire data was analysed following the method of holistic coding to identify the types of cultural inspiration and cultural levels. Data-driven analysis included two rounds of categorising. Using the product metaphorical mapping tool, we specified three cultural levels and the cultural elements related to them. The analytical method helped reveal students' design intentions in applying both tangible and intangible cultural elements The results demonstrated that design educators can support young designers to apply the participatory approach in bringing ethical cultural transformations regarding visual, behavioural and philosophical design features.

***

Artificial Intelligence as a Tool for Individual and Collaborative Creativity in Design Education

Miroslava Petrova, University of Monterrey, Mexico
Claas Kuhnen, Wayne State University, USA

Abstract

Integration of Artificial Intelligence (AI) in the design process is a growing area of research interest. Three years after its public launch in 2022, AI has already established itself as the most disruptive tool revolutionizing how designers conceptualize, iterate and innovate. As AI technologies continue to evolve, it is pertinent that design students are acquainted with the potential of the technology and how it can be integrated in their professional practice. The objective of this paper is to explore the role of AI as a conceptualization and research tool in interior design. We aim to examine its effectiveness in enhancing the ideation process and facilitating collaboration and knowledge sharing in intercultural design teams. The case study presented is a collaborative online international learning project (COIL) with the participation of interior design students from the University of Monterrey (Mexico) and Wayne State University (USA). Students were involved in experimentation with various AI tools and platforms in the early stage of designing children's spaces in commercial interiors. Through meticulous documentation and evaluation of all design variations generated were gained valuable insights on the impact of AI on the evolution of the ideas. To collect research data on how students' creativity, idea exchange and decision-making were affected, surveys and reflection writings were distributed. The findings confirmed that students developed a greater understanding of AI as an essential tool in the design process. They acquired skills in utilizing it to aid the decision-making during the conceptualization phase. Furthermore, AI fostered their self-confidence in communicating within culturally diverse teams. The conclusion discusses the challenges encountered and lessons learned from the integration of AI technologies into the learning process.

***

Looking, Experimenting, Creating, Telling – Testing a Pedagogical Model for Design Learning

Kathryn McSweeney, ATU St Angelas, Sligo, Ireland
Lorraine Portelli, University of Malta, Malta
Riikka Räisänen, University of Helsinki, Finland
Mari Kosunen, University of Helsinki, Finland
Zoi Arvanitidou, University of Malta, Malta
Päivi Fernström, University of Helsinki, Finland
Kaisa Hyrsky, University of Helsinki, Finland

Abstract

This article shares the outcomes of international workshops focused on traditional costume construction and surface embellishment techniques and designs. These workshops were inspired by the findings of the Creative Europe TRACtion (Traditional Costume Innovation) project. The latter motivated students and adult learners in the Republic of Ireland, Finland, and Malta to develop creative, sustainable, and innovative responses to traditional textile artefacts. The Finnish Association of Design Learning (SuoMu) Design Learning Model was applied to support the development of creative thinking in the workshops. Additionally, teaching strategies developed by textile educators and craftspeople in each context complemented the SuoMu Design Learning Model, facilitating interactions between workshop ideas, materials and participants. The workshops aimed to foster design, creative thinking, sustainability, innovation, and a deeper appreciation of textile heritage. Participant feedback was analysed through thematic data analysis, and the visual outcomes were examined for indicators of creative thinking, such as fluidity, flexibility, elaboration, and uniqueness. The SuoMu model played a key role in guiding the design process and developing creative thinking skills. Sketching and brainstorming techniques sparked a wealth of ideas, while group activities and practical and experiential learning supported the ideation process. The workshops led to numerous fluent and flexible responses and ideas, many of which evolved into unique and innovative designs. Participants developed visual literacy skills and textile cultural empathy while achieving sustainability in material usage.

***

Design students' views on future work at the stage of Industry 5.0 and Society 5.0: Dimensions and levels of resilience

Mari Silver, University of Lapland
Marian Silén, University of Lapland
Heli Ruokamo, University of Lapland

Abstract

This study investigates design students' perspectives on future work environments shaped by the evolving paradigms of Industry 5.0 and Society 5.0, with a focus on their views of work communities, technological advancements and systemic problem-solving. The concept of resilience is used as an analytical lens. The study explores the relevance of Industry 5.0 and Society 5.0 frameworks in the context of the design profession and examines how design students anticipate and interpret future changes in their professional landscape. The study addresses the following research question: What are the dimensions and levels of resilience according to design students' views of future work? Data were collected in 2023 from 92 design students at various stages of their studies. Using principal component analysis, three dimensions of resilience were identified: resilience in work community, in technological development and in systemic problem solving. The findings suggest that students are aware of major shifts in their field and express varying degrees of readiness and adaptability across the identified dimensions. These results offer insights into how design education might better support students in navigating the uncertainties of future work.

Roadmap to Early-Stage Medical Device Design through Experiential Learning and Role-Play

Steven C. Koenig, University of Louisville, United States
Gretel Monreal, University of Louisville, United States

Abstract

Purpose: Biomedical engineers that have the ability and skill sets to comprehend and retain basic anatomy and physiology (A&P) knowledge, apply fundamental engineering principles, use critical thinking, and communicate effectively across multiple disciplines to facilitate successful development and clinical translation of medical devices. The authors created an undergraduate medical device design course that follows a roadmap for developing novel devices and/or innovative technology from concept to clinical product with the course focusing on the early-stage of the development process.

Methods: A holistic approach is taught from the unique perspective of inventors, investors, and surgeons (IIS) by integrating interactive presentations, guest lectures, labs, field trips, and role-playing activities into a 15-week curriculum and meets ABET student learning objectives. Individual assignments require oral presentations and written reports that mimic project leaders on design teams, and group assignments are completed through IIS role-playing. These activities culminate with individual student design projects that help build self-confidence in their ability to successfully jump into and navigate the medical device development process. This is accomplished by identifying a clinical need, formulating an innovative concept, defining design criteria, fabricating a prototype to demonstrate proof-of-concept, bench testing to demonstrate feasibility, completing an invention disclosure, making an elevator pitch with constructive classroom critique, and writing an executive summary and detailed report emulating a NIH SBIR Phase I grant.

Results: Course effectiveness was demonstrated by: (1) 204% improvement in A&P knowledge, (2) positive role-playing evaluations (98.7% of students reporting that it was a useful educational experience, written feedback), and (3) favorable course evaluations.

Conclusions: A roadmap for early-stage development of medical devices using a holistic, experiential learning approach is presented to prepare undergraduate bioengineering students for future healthcare careers as engineers, scientists, clinicians, and/or entrepreneurs.

Design and Technology Education: An International Journal

30.1

Crafting Humorous Soft Toys: Incorporating Humour to a Holistic Craft Process in Early Years Education

Marja-Leena Rönkkö, University of Turku, Finland
Juli-Anna Aerila, University of Turku, Finland
Tuula Stenius, University of Helsinki, Finland

Abstract
This study explores humour's role in a holistic craft process when 7–8-year-olds design personalised soft toys. Humour enhances learning environments by fostering joy, belonging and a positive atmosphere, acting as a motivational tool in experiential and arts-based learning. The study aims to answer the following questions: (1) What are the humorous characteristics of the soft toys created by the pupils? (2) How does the crafting of humorous soft toys proceed? Employing an educational design research methodology, the project involved 36 first-grade pupils from an urban Finnish school over a 10-day intervention. The study examines how humour, when integrated into a holistic craft process, supports the making and designing of soft toys. In the study, the pupils created humorous soft toys, often anthropomorphised with exaggerated or contradictory traits. Challenges emerged in translating 2D drawings into 3D soft toys, particularly with sewing and fabric painting. Nevertheless, the final products were unique and evoked positive emotions. The findings suggest that incorporating familiar elements, such as humour and soft toys, into the holistic craft process in early years education can enhance motivation and learning outcomes, thus supporting the integration of humour into educational contexts to foster creativity and emotional expression.

Keywords
soft toy, holistic craft process, humour

Introduction
When craft design starts from personal life experiences, sensations and narratives, it transitions from a traditional technique and product-centred craft towards a more holistic craft process, where design and making progress alongside skill and expression (Laamanen & Seitamaa-Hakkarainen, 2009). The Finnish National Curriculum for Basic Education (FBNE, 2014) suggests that in first and second grade (6–9 years old pupils), familiarizing with the holistic craft processes should be supported through child-specific expressions and activities, e.g., imagination, stories, drama, play, games and the natural and built environments. However, the national curriculum for education (FNBE, 2014) does not mention humour, even though humour has many positive effects on learning in the early years and is vital to children's life experiences (Airenti, 2016).

In general, humour brings playfulness and joy to learning, develops feelings of belonging and generates a positive atmosphere (Anttila, 2008). According to Weisi and Mohammadi (2023), most teachers strive to develop a cheerful and friendly atmosphere in their classrooms through humour and feel that humour supports involvement in learning by relaxing and comforting learners. Even though humour is often seen mainly as a promoter of a positive learning atmosphere and overall well-being, it could have a more dominant role in learning as an object for learning (Aerila et al., 2017) or as motivation for experiential and arts-based learning projects (Aerila et al., 2023a, 2023b) like holistic craft. Previous studies (Aerila et al., 2023a, 2023b; Leung & Yeung, 2022; Rönkkö & Aerila, 2018) suggest that incorporating humour into experiential and arts-based processes often pupils to create more detailed artefacts, feel more enthusiastic about sharing their work with peers develop a stronger, more positive sense of attachment to their creations.

In the context of education, there may be several reasons for the low implementation of humour, both in Finland and internationally, but many of them may be related to teachers' lack of awareness of the pedagogical or welfare implications of humour and to teachers' prejudice against pupils' humour (Aerila et al., 2023a). In many cases, pupils' humour is viewed from teachers' perceptions of humour, only the humour produced by the teacher is acceptable and teachers determine when and what kind of humour pupils can use or what is humorous in pupils' actions (Aerila et al., 2021; Anttila, 2008). Teachers may, for example, take pupils' humour too seriously without understanding that, in many cases, their humour stems from boredom or a need for entertainment and dissipates quickly (Stenius et al., 2022). As humour is a very individual characteristic influenced by hereditary factors, the environment and the individual's temperament style (Martin, 2011), it is vital to investigate humour in versatile educational settings and develop research-based information about the benefits of exploiting pupils' own humour in learning.

This study incorporates pupils' humour into a holistic craft process. In this process, the pupils ideate, design, and create a soft toy, starting with designing a character to make others laugh. The aim is to investigate the types of soft toys the pupils create and how the process unfolds when they express their humour. The soft toy was chosen as the artefact due to its crucial role in early years development, supporting cognitive growth, language skills, imagination and pretend play, problem-solving, social skills, and physical activity (Goldstein, 2012). Further, soft toys serve as motivational aims for a holistic craft process as they are familiar to pupils and evoke positive feelings (Heljakka, 2021). Previous studies (Kokkinaki, 2023; Trawick-Smith et al., 2011, 2015) show that soft toys aid education by fostering empathy, self-reflection, emotional expression while enhancing social integration and creative play. In this study, the pupils participating in the holistic craft process are 7–8-year-old pupils. At this age, conceptual thinking influences humour creation (McGhee, 1984, 2002, 2019), allowing pupils to recognise that objects have different features, and by changing one specific feature, they can create humour. Additionally, they may find humour, for example, in opposing adults' prohibition, bringing up socially taboo topics (Paine et al., 2021) or prefer humour based on collisions, exaggeration and wordplay (Dowling, 2014).

In our previous studies, we have applied various themes alongside humour to investigate the pedagogy of craft. These themes have included local history (Aerila et al., 2016; Rönkkö et al., 2016), fiction and visual arts (Rönkkö & Aerila, 2022), as well as nature pedagogy, visual arts, digital learning and STEAM content (Aerila & Rönkkö, 2023). In these projects, the other art forms were used as a part of ideation and design and, on the other hand, as a part of self-assessment. In the previous study (Rönkkö & Aerila, 2018) concerning the implementation of humour to holistic craft processes, the context has been Finnish early childhood education and care. This study has indicated that humour not only helped the pupils to develop ideas for the craft product and refine its details but also encouraged them to work more persistently (Rönkkö & Aerila, 2018). As humour develops alongside other aspects of children's development (McGhee, 2019), it is important to explore the role of humour in the holistic craft process for school-age children, who are more linguistically, cognitively and emotionally developed (Vygotsky, 1978).

We pose the following research questions (RQs):

RQ1: What are the characteristics of the humorous characters created by the pupils?
RQ2: How does the crafting of humorous soft toys proceed?

Holistic craft process in early years education

The holistic craft process is a form of creative arts-based learning in which pupils realise artefacts from ideation to design, implementation and evaluation (Pöllänen, 2009). According to the Finnish National Curriculum for basic education (FNBE, 2014), this holistic craft process aims to give pupils experience with longitudinal processes that span multiple working sessions and enable the implementation of craft products. Typically, pupils in early years' craft classes create small items, such as pouches and bags, paintings, shelves, various decorative objects and jewellery, and they learn and apply techniques, such as nailing, sawing, sewing, crocheting and painting (Rönkkö & Aerila, 2024). The framing of these tasks can be arts-oriented or emphasise functionality and technology, but the most important aspect is to give children space to make their own decisions (Aerila et al., 2019) and to see possibilities, analyse alternatives, and experience both failures and successes (Rönkkö & Lepistö, 2016). The holistic craft processes in early years education are usually designed pedagogically to develop knowledge and skills required in expression, designing and making crafts and so that pupils' skills and knowledge is accumulated (Rönkkö & Aerila, 2024).

According to Rönkkö and Aerila (2024), playful or creative activities are traditionally employed at the beginning of the holistic craft process to inspire ideation. However, it is important to ensure that motivation is sustained throughout the process (e.g., Deterding, 2016). The artefact created is key to motivation, especially for younger pupils. When the artefact is meaningful and usable for the pupils, they will probably be more motivated to design and make it (Rönkkö & Aerila, 2015). Therefore, the craft product should be chosen from the world of the learners, and it should be of such a level of difficulty that the pupils are likely to succeed in making it (Rönkkö & Aerila, 2024).

In the holistic craft process, ideation is the first phase – like in many other creative problem-solving processes (e.g., Pöllänen, 2009). In early years' education, the pupils often require support in ideating and designing craft products (Yliverronen, 2014). Ideally, ideation aims to make learning more relevant and engaging (Omwawi, 2024). Inspiration for a craft product can arise from virtually any source, with even the smallest detail capable of sparking the creative process (Eckert & Stacey, 2000), and the ideation can be supported with the use of imagination, storytelling, drama, play, games and other modes of expression, and by exploring both natural and man-made environments (Hope, 2008; Yliverronen, 2014). Previous studies (Bellieni, 2022; Hoicka & Martin, 2016) show that humour positively affects creativity and ideation in creative learning processes. In Leung and Yuen's (2022) study, children created pop-up books from visual and literary art. In their literary art activities, humour was related to alliterative names, hyperbolic humour, multiple meanings, wordplay, personification, metaphors and incongruous storylines. Rönkkö and Aerila (2018) investigated humour in the ideation phase of a holistic craft process within early childhood education and care, finding that humour not only supported children in developing ideas for the craft product and working persistently on crafting but also fostered emotional attachment.

During the second phase of the holistic craft process, which is designing, the aim is to define the primary purpose, the properties and the maintenance of the craft product and gather the information necessary for making the artefact (Pöllänen, 2009). Usually, this phase involves acquiring knowledge about craft techniques, materials, and tools through experimenting, examining and defining the product's aesthetic and functional qualities (Rönkkö & Aerila, 2024). However, when it comes to younger pupils, as in this study, the teacher usually chooses the crafting techniques, and during the process, some specific crafting techniques are practised (Yliverronen, 2014). Further, it might be essential for the teacher to set design limitations, as this can help pupils refine their ideas into practical designs (Lahti et al., 2022). Pupils' learning sensitivity is utilised in craft education by guiding them from the beginning to design the craft products, carrying them out safely and technically correctly, and encouraging to use various design methods and understand the importance of planning as part of the crafting (Yliverronen & Seitamaa-Hakkarainen, 2016).

The making phase of a craft process means implementing and practising concrete skills such as cutting, gluing, and combining materials. In early years education, the making phase additionally enhances pupils' fine motor abilities (Yliverronen & Seitamaa-Hakkarainen, 2016) and their craft skills (know-how about the materials and techniques) to execute their plans created in the design phase (Rönkkö & Aerila, 2024). In making, especially the younger pupils often face challenges, and they must have patience and the ability to endure incompetence (Bodrova & Leong, 2012). Sometimes, teachers' and pupils' perspectives on a successful project can differ, and it seems that for especially younger pupils means having the artefact ready and the opportunity to realise creativity during the process (Aerila et al., 2024; Rönkkö & Aerila, 2024; Yliverronen, 2014). Thus, self-assessment is crucial for pupils in educational contexts as part of creative learning processes. It allows them to evaluate their learning and prepare for future projects by setting realistic goals and recognising the value of practising various sub-skills (Andrade & Valtcheva, 2009).

Method

Study context

The study was implemented through an intervention in two primary school groups in an urban area of western Finland, and crafting is part of a larger framework. The whole intervention (Aerila et al, 2023a) took place from late April to the end of May 2021, and it unfolded over approximately 10 days, with around two daily lessons. The intervention was designed collaboratively by the first two researchers, the primary group teachers and a project worker. Due to COVID-19 pandemic restrictions, the researchers and project worker could not participate in the implementation, except for the collaborative storytelling session.

The intervention concentrated on implementing a soft toy in a holistic craft process based on pupils' perception of humorous characters. The two primary groups of participants were in the first grade; there were 36 pupils aged seven or eight. The progress of the holistic craft process is presented in Table 1.

Table 1. Phases of designing and making a soft toy as a holistic craft process

	The phase of the holistic craft process	Activity	Aims and tasks for pupils' craft process
Day 1	Ideation	Watching a video clip of a humorous book Friendship book sheet	Motivation
	Designing	Drawing a humorous character	Getting ideas Using imagination, expressing ideas, presenting characters
Day 2	Technical planning	Making a stick puppet for the Kamishibai performance	Stick puppet as a prototype of a soft toy
Days 3–7	Making	Making the soft toy	Drawing outlines onto fabric Fabric painting for details Cutting fabric with seam allowance (researchers sewed the edges of the soft toy) Stuffing the soft toy with cotton wool and hand-sewing the opening (Decorating the soft toy)
Days 8–10	Evaluation	Assessment	Completing the self-evaluation sheet
	Reflection	Kamishibai performance	Taking soft toys to the performance and showing them to each other

The holistic craft process began as ideation with an extract from a humorous children's book *Dog Man* by Dav Pilkey (2018). Due to the restrictions of COVID-19 pandemic, the extract from the book was presented to the pupils as a video clip. After watching the video clip, pupils engaged in small group discussions about humour, which sparked ideas for creating characters that make others laugh. In the ideation phase, the characters were sketched by drawing and writing. The writing was implemented on a friendship book sheet (e.g., their character's name and hobbies), and the drawing was by using wax crayons and the frottage technique on an A4-size paper. Before the design phase started, the pupils were informed that the drawings would be converted into a stick puppet and later into a soft toy. In the holistic craft process, the stick puppets served as prototypes and cutting patterns for the soft toy. The making phase started by the pupils drawing the outlines of the stick puppet and making decorative patterns with wax crayons and fabric paint on a fabric (the pupils used their drawings as models for the decorations). This fabric was the material for the soft toys. After the fabric had dried, the pupils cut around the outlines of the soft toy while ensuring a seam allowance. The researchers then sewed the front and back pieces of the fabric together with a sewing machine, leaving space for turning the fabric inside out. The pupils then stuffed the soft toys with cotton wool and sewed up the opening by hand. At the end of the making phase, the pupils had the opportunity to decorate the ready-made soft toys with additional details. At the end of the craft process, the pupils presented the finished soft toys to each other. The stick puppets and the soft toys were later a part of a theatre performance that concluded the whole intervention (Aerila et al., 2023a) of which the holistic craft process was a part of. In the performance, stick puppets functioned as actors for a kamishibai theatre performance and the soft toys were following the performance with the pupils. Kamishibai is a traditional Japanese storytelling method that uses picture cards and small theatre stages to present stories. It can be utilised in education to teach languages, cultures, art education, and many other subjects, making learning both visual and interactive (Aerila et al., 2022). Finally, the pupils completed a self-assessment survey evaluating their entire learning process, including the holistic craft process, the implementation of the soft toy in general and its humorousness in particular (see Table 1).

Data and data analysis

The study employed educational design research as a methodological approach that focuses on developing and iteratively refining educational interventions—such as programs, teaching strategies, or learning materials—while simultaneously generating theoretical insights. This approach is characterized by its dual objectives: addressing practical educational challenges and contributing to scholarly understanding (McKenney & Reeves, 2018).

The primary data consisted of materials created by the pupils during different phases of the holistic craft process, such as the friendship book sheet, a drawing of the humorous character, a stick puppet, a soft toy and an evaluation sheet. All materials were photographed and saved in the university's cloud service. The secondary data comprised the teachers' memos written during or after the classes. The data were examined using thematic analysis, which is used to identify similarities and differences and summarise key features (Braun & Clarke, 2013).

In the analysis, the researchers first familiarised themselves with the data. To answer the first RQ, the analysis progressed from investigating the entities of the humorous characters to looking at the details. In the first stage, data-driven analysis was conducted to classify the soft toys based on their primary characteristics, resulting in themes such as human/animal, scatology, or references to popular culture. This phase also explored their individual and shared features, focusing on aspects like names, incongruences, visual appearance, and individuality. To address the second RQ, the data were analysed in relation to the themes of ideation, designing the soft toy, and the progression of the process as an individual endeavour. This focused on tracking each pupil's progression, noting challenges and successes in designing and making.

Findings

The humorous characteristics of pupils' soft toys

The analysis revealed that pupils followed their original idea of a humorous character consistently throughout the holistic craft process and seemed to focus on copying the details of the characters created in the ideation phase as carefully as possible. However, the soft toys of individual pupils were all different. The soft toys were represented according to the students' descriptions in their friendship book sheets; the first phase of the analysis classified the humorous characters as human or animal characters (n = 21), scatological characters (n = 10), and characters related to popular culture (n = 5). The human/animal characters were often named with typical human first names (e.g., Pekka, Silvia or Lilli) or with information about the animal that the humorous character represented (e.g., Super Lizardman Lion). In all the names of the scatological characters, there was a word related to excrement (e.g., Poop Family, Super Poo and Colourful Pee). The characters sourced by popular culture were often named to refer directly to a phenomenon (e.g., COVID-19) or copied the name of an inspiring character (e.g., Moominpappa and Minion). The naming of the characters encapsulated the character's key characteristics, personalised the character and helped them to remember the character during the process. It may be that, for the younger pupils, naming the character improved their engagement in the process and helped them to focus; it was easier to plan the realisation of the character in the next steps when the character was called by a name. The names of all the humorous characters and their classifications are presented in Table 2.

Table 2. Primary characteristics of soft toys

Classification	Soft toy's name
Human/animal	Silvia, Babna746, Pekka, Tipititi, Super Lizardman Lion, Siticky Bird, Odd, Blöö, Frans, Tube, Funny, Aunt Loose, Pete, Petri, Dog Perdi, Pertti the Buck, Lilli, Rocky, Aauu, Pekka, Mauro
Scatology	Little Fart, Pong, Poo, Poop Family, Fart Boy, Super Poo, Poopy, Poo Head, Ghost Poo, Colourful Pee
Popular culture	Moominpappa, Petetri, Patu, COVID-19, House Monster

All the humorous soft toys had common characteristics, regardless of the category in which they were placed in the first stage of the analysis. Almost all the soft toys had features related to anthropomorphism. The anthropomorphic features mainly focus on the head, facial expressions, and limbs. Even the poop soft toys were given human traits, such as smiling mouths. For example, the Poop Family is depicted as a cheerful family consisting of a mother, father and child (see Figure 1). Another example is House Monster, which has elements such as windows serving as cheeks and a chimney resembling a hat, as well as added elements like hands, eyes, legs and a mouth (potentially represented by the door), giving it a highly human-like appearance (see Figure 1). Adding human features to the characters might have been guided by the assignment in the ideation phase – the friendship book sheet – which asked for human-like qualities, such as diet, hobbies or superpowers.

Figure 1. Collage of soft toys: Poop Family and House Monster (soft toys with stick puppets)

The humour of the soft toys was primarily seen in the details that added contradictory features to the soft toys. This included names (e.g., Bird Sausage, Little Fart) or diets (e.g., Aunt Lause eats horse manure and Moominpapa eats pumpkin soup) and strange characters being involved in ordinary activities (e.g., Petri can fly and Aauu's hobby is climbing). The contradictions in the soft toys also involved exaggerating or multiplying features, such as the eyes and legs. Some soft toys had body parts that were out of proportion, like large stomachs, oversized heads with tiny legs or unusual teeth, which were often broken or missing. Many human characters had exaggerated navels. For some characters, the contradiction was manifested in the creative implementation of colours, such as multi-coloured or wavy lips. For example, a soft toy called Silvia (Figure 2) has exceptionally long feet (exaggeration of legs) and bright red hair (creative implementation of colour).

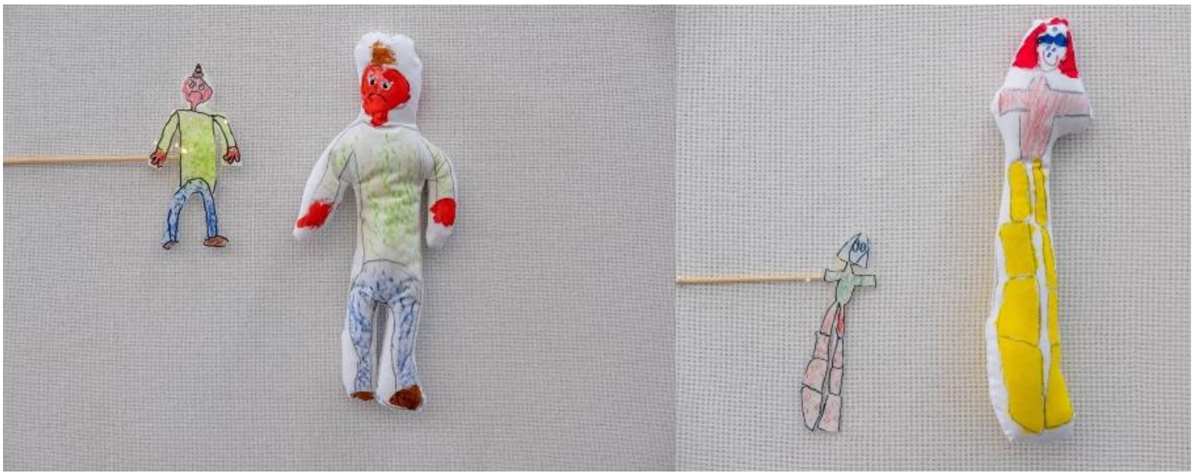


Figure 2. Collage of soft toys: Pete and Silvia as stick puppets and soft toys

As noted in the analysis, many of the soft toys depicted poop and pee characters (scatological humour). These soft toys represented perhaps the most stereotypical view of humour, as many of these characters resembled the emoji of the corresponding themes and were similar in colour to the subject. In other words, they were quite predictable: The poop soft toys were brown and appeared as separate piles or between the buttocks in pants. However, there were some soft toys expanding on this theme, as they incorporated elements like colourful stinky clouds or exaggerated features, such as flatulence. Scatological humour was also integrated into the characters of the other categories. For example, a human soft toy named Pete had poop on his head, as a bird had pooped on him (Figure 2), making him so angry that his face turned red. The addition of the poop element in some soft toys seemed a bit unplanned or illogical. Instead, the pupils added them primarily to make others laugh. One of the pupils confirmed this by stating that he created a poop character as it usually makes others laugh.

Most pupils had several humorous details in their soft toys. For example, the pupil who invented a soft toy called Little Fart followed his original idea of a multi-handed, multi-tasking character throughout the learning process. In the initial drawing, Little Fart was depicted with even more hands and featured additional elements, such as a crown, lack of hair, an open mouth and a distinctively green 'sausage' on its navel. The final soft toy had a brightly coloured body, a brown face and an exaggerated navel. Another soft toy, Stinky Bird Sausage, also exhibited contradictions in terms of both features and colour. Furthermore, it had an unusual name, multiple eyes, three mouths and fin-like hands and feet. Stinky Bird Sausage maintained its colourful appearance in all forms, whether as a drawing, stick puppet or soft toy (Figure 3).

Figure 3. Collage of soft toys: Little Fart and Stinky Bird Sausage as drawings, stick puppets and soft toys

It was surprising that, in the analysis, we could find hardly any humorous details suggesting aggression or violence. The low number of these was also unusual in the sense that the children's book used as a motivator contained many references to explosions, harm to people and other forms of violence. The lack of this kind of humour might have been influenced by the instruction, which emphasised the positive feeling of those who would see the character (draw a character that makes others laugh), or this might have been due to the static nature of the characters. Violence and aggressiveness in humour perhaps require a more dynamic and active approach. This was also evidenced in this study, as the only references to themes were found in the friendship book sheets that contained story-like parts.

The progress of pupils' crafting humorous soft toys

The humorous book was an inspiring source for ideation, chosen for its humour and appeal to the target age group. Humour in the book helped spark ideas, which the pupils brought to life by sketching and writing on a friendship book-like sheet that asked questions about their soft toy's favourite food, activities and possible superpowers. The pupils quickly decided on the shape and colours of their soft toys and drew their designs. In drawing, the pupils were asked to create a character that would make others laugh, and they did not know that the character would later be transformed into a soft toy during a holistic craft process.

In implementing designs, the stick puppets and soft toys were figure patterned with a technique called *frottage*. Although this was an unfamiliar technique for the pupils, it allowed them to add decoration to the surface. The method made it easy for the pupils to add details to their soft toys, resulting in a unique design reflecting their perspectives. However, while the frottage technique was quite easy on a paper surface, applying it to fabric was significantly more challenging.

While the stick puppets were A5 paper size, the soft toys were intended to be larger and cuddlier. The pupils were tasked with using a scanner with adult assistance to enlarge their designs. While most pupils understood the process of enlarging the stick puppets, transforming 2D images (the drawings and stick puppets) into 3D soft toys proved challenging, particularly when drawing limbs that were too narrow for sewing and stuffing, a problem that was often resolved by adding a fabric backing to facilitate the process. Learning to visualise in 3D helped pupils transform ideas into physical craft products. Spatial visualisation required imagining the integration of colours, shapes and sizes. In the process, conceptualising the soft toy in 3D, including the front and back views, was crucial for understanding the toy's structure. One pupil notably applied this concept to a toy with a COVID-19 theme; on the front piece, he depicted a face with a mask, while on the back piece, he illustrated the occiput. However, visualising characters from different angles presented difficulties, as some pupils struggled to envision the soft toy differently from behind (see Figure 4). For example, Super Lizardman Lion is drawn with similar front and back representations.

Figure 4. Collage of soft toys: COVID-19 and Super Lizardman Lion as drawings, stick puppets and soft toys (from front and back)

The crafting process involved a variety of skills and techniques. Sewing presented challenges like needle threading, which required concentration and fine motor control. Additionally, pupils had to paint their characters onto fabric using paints and brushes, which proved difficult for some and occasionally led to frustration. Painting on fabric was much harder than using coloured pencils or markers on paper, mainly because the pupils' motor skills were still developing, making it challenging to manage the fine details needed for painting. Furthermore, some pupils chose brushes that were too large or loaded with too much paint, making achieving the desired precision in their soft toy designs even more challenging.

Having a soft toy as the final product of a holistic craft process was a good choice, considering the process and the learning objectives practised within it. The soft toys in this study did not correspond to traditional soft toys but were more unconventional and even disgusting. However, it is noteworthy that despite seemingly repulsive features, all the soft toys evoked positive emotions, surprised viewers and left them in a good mood. These toys evoked feelings of ownership in pupils, enhancing their sense of responsibility and connection and encouraging social interactions, particularly through play.

In this study, we successfully selected a motivating product that met the learning goals, matched pupils' abilities and was almost completed within the set timeframe. At the end of the making phase, the pupils could add extra effects using materials such as pipe cleaners, sewing by hand, braiding yarn and so on to create features like horns, body parts, accessories, jewellery and combat tools. However, they had to forego these detailed additions due to time constraints. The study showed that more time should be allocated to finish the products. Adding more details to the soft toys during the drawing would have been beneficial, especially if they had been shown the materials during the process, helping them choose the appropriate ones.

Discussion

In this study, we investigated a holistic craft process in which the pupils in early years education implemented an individual soft toy and where the pupils' idea of a humorous character formed the basis for the individual characteristics of the soft toy. According to this study, humour created an engaging framework for pupils to undertake a long-term effort and create a personalized soft toy. It is worth noting that even though the soft toys or their humorous characteristics did not necessarily reveal all about pupils' perceptions of humour, the pupils found their soft toys humorous and were happy with the result. Further, it seems that humour allowed the pupils to create original characters and to be imaginative while gaining the learning aims of a holistic craft process.

The results of the humorous characteristics of the soft toys accord with the findings of Loizou and Kyriakoi (2016) regarding young pupils' humour. In their study, Loizou and Kyriakoi (2016) applied Torrance's test (2006) of creativity to humour and employed the concepts of fluency, flexibility and originality. In their application, fluency is manifested in the number of humorous events, situations and actions; flexibility means the themes and ideas are not within the rigid and expected perspective of humour, and originality contains unique ideas. Loizou and Kyriakou (2016) also created categories of colour and feature violation, as well as violence and humorous symbols, to illustrate the humour children prefer in their outcomes. In the study, pupils' humour had several characteristics of fluency, flexibility and originality. In this study, humour emerged especially as contradictions in names, attributes and appearance and in violating expectations of the soft toys' colours and features. According to Loizou and Kyriakou (2016) children's humour is sometimes less creative. This less creative and original humour means e.g., clowns, certain facial expressions and scatological elements. These less creative humorous characteristics were in the minority in this study as there were only a few soft toys with scatological characteristics.

The holistic craft project described in this study had many elements familiar to children: humour, a soft toy and drawing. These aspects allowed the children to focus on the steps of the crafting process and helped them both visualise the finished product and engage in the activity. The process involved many problem-solving situations: transferring the humorous character onto the fabric, cutting the fabric into the shape of a soft toy and transforming the character from 2D to 3D. In the future, it might be worth planning these problem-solving situations more carefully and from the versatility perspective. For example, it might be necessary to use a technique other than drawing to transfer the figure onto the fabric. Changing the technique could motivate those who find it difficult to draw while at the same time adding to the process, for example, the opportunity to practise one more craft technique. According to McLain and others (2017), in the design process, it is good to guide pupils to focus on imagination and design thinking rather than letting technical knowledge take the focus. The results of this study relate to this notion, as using imagination, one's own experiences and knowledge in the process transformed the holistic craft process into a more child-oriented process, enabling the pupils to concentrate on content that was familiar and important to them. Furthermore, by combining humour with crafting, pupils could practise empathic designing and making by considering the end users of their artefacts in both concrete and abstract ways throughout the process (see e.g., Bosch et al., 2022).

The significance of the soft toy lies in its familiarity, which provides both comfort and a solid foundation for the creative process, inspiring ideas for soft toys. According to the analysis, almost all pupils created soft toys that presented a contrast to traditional cute soft toys like teddy bears, as there were strange human figures, poo cuddles and imaginative animals. This is unsurprising, as similar soft toys are on the market, especially in the humorous soft-toy segment. These kinds of 'ugly' and contrasting soft toys create amusement and strong emotional responses through contradiction or surprise. Rajagopal (2019) notes that Angry Bird soft toys are one example of this kind of soft toy. This emotional connection to the soft toys became especially evident during the theatre performance, where each pupil in the audience hugged their soft toys several times, demonstrating the deep bond they had formed (see e.g., Heljakka, 2021).

Conclusion

Our results show that bringing elements of pupils' humour into the school context does not prevent the achievement of learning goals; indeed, it is possible to design learning processes and tasks to meet learning goals while allowing pupils to express themselves and benefit from what matters to them. Moreover, humour is a skill that should be practised, and its skilful use requires the ability to empathise with the recipient and interpret the situation (Heintz et al., 2017). It is therefore important to encourage teachers to use humour in various learning situations (also at a policy level) and to highlight how receiving and interpreting humour can be practised and is influenced by many factors.

According to Rutland (2009), there is a need to break down the boundaries of art and design education and enhance collaboration between the subjects of art and crafts to support and improve creativity in educational contexts. In this study, the collaboration was widened across several school subjects: mother tongue and literature (creative writing, drama, literature), visual arts and crafts. It might serve as an example of how effective creative learning processes – like a holistic craft process – might be when the different phases of the project are moulded into learning goals from different school subjects. In this way, crafts could act as an integrator of learning and support pupils' engagement in longer learning processes.

Limitations and ethical considerations

A notable limitation of this study is that the data were collected exclusively from two classrooms, with the learning process facilitated by two teachers who followed guidelines provided by the researchers. Moreover, specific restrictions related to the COVID-19 pandemic in Finland impacted the intervention period. While pupils had attended school since the beginning of the academic year in the fall of 2021, the researchers could not be physically present except during joint storytelling sessions conducted outdoors in the schoolyard. The seams of the soft toys were sewn by adults using sewing machines rather than by pupils. This decision was made to ensure safety and adherence to the project schedule.

Additionally, a methodological limitation of educational design research lies in its context- and data-specific nature, which can limit the generalisability of findings to other settings or populations. The study was conducted following the EU's General Data Protection Regulation and the ethical principles of research with human participants in the human sciences in Finland (Finnish National Board on Research Integrity TENK, 2019). The pupils were informed about the study in advance and consulted again during its duration. Additionally, they were allowed to withdraw from the study at any time.

References

Aerila, J.-A., Laes, T., & Laes, T. (2017). Clowns and explosions: Finnish preschoolers' perceptions of humour. *Journal of Early Childhood Education Research*, *6*(1), 108–135. https://journal.fi/jecer/article/view/114072/67271

Aerila, J.-A., Rönkkö, M.-L., & Stenius, T. (2023a). Humour-themed holistic learning processes in a Finnish primary school. *The European Journal of Humour Research, 11*(4), 75–92. http://dx.doi.org/10.7592/EJHR.2023.11.4.841

Aerila, J.-A., Rönkkö, M.-L., & Stenius, T. (2023b). Humor as a source for collaborative storytelling: Perspectives to dynamic and static stories. *HUMOR: International Journal of Humor Research*, *36*(4), 607–629. https://doi.org/10.1515/humor-2023-0047

Aerila, J.-A., Siipola, M., Kauppinen, M., & Lähteelä, J. (2022). Finnish children's perceptive to kamishibai: A multisensory storytelling method for arts-based literature and language education. *Journal of Creative Practices in Language Learning and Teaching, 10*(2), 11-26. https://doi.org/10.24191/cplt.v10i2.3196

Aerila, J.-A., Rönkkö, M.-L., & Grönman, S. (2016). Field trip to a historic house museum with preschoolers: Stories and crafts as tools for cultural heritage education. *Visitor Studies, 19*(2), 144–155. https://doi.org/10.1080/10645578.2016.1220187

Aerila, J.-A., & Rönkkö, M.-L. (2023). Learning STEAM content via arts-based hands-on activities. In W. Yang, S. Kewalramani, & J. Senthil (Eds.), *STEAM education in the early years: Achieving the Sustainable Development Goals* (pp. 91–107). Routledge. https://doi.org/10.4324/9781003353683

Aerila, J.-A., Stenius, T., Laes, T. & Laes, T. (2021). Opettajan ei tarvitse olla humoristi: pierusta ja sen vierestä. [The teacher does not have to be a humorist: Something about scatological humour]. *Journal of Early Childhood Education Research*, *10*(3), 269–281.

Airenti, G. (2016). Playing with expectations: A contextual view of humour development. *Frontiers in Psychology*, *7*, Article e1392. https://doi.org/10.3389/fpsyg.2016.01392

Anttila, T. (2008). *Lukiolaisten käsityksiä huumorista ja kokemuksia opettajista huumorin käyttäjinä* [High school students' perceptions of humour and experiences of teachers as users of humour] [Doctoral thesis, University of Joensuu]. Joensuu. https://erepo.uef.fi/handle/123456789/8742

Andrade, H., & Valtcheva, A. (2009). Promoting learning and achievement through self-assessment. *Theory Into Practice*, *48*(1), 12–19. https://doi.org/10.1080/00405840802577544

Bellieni, C. V. (2022). Laughter: A signal of ceased alarm toward a perceived incongruity between life and stiffness. *New Ideas in Psychology*, *68*, Article e100977. https://doi.org/10.1016/j.newideapsych.2022.100977

Bodrova, E., & Leong, D. J. (2012). Scaffolding self-regulated learning in young children: Lessons from tools of the mind. In R. C. Pianta (Ed.), *Handbook of early childhood education* (pp. 352–369). Guilford Press.

Bosch, N., Härkki, T., & Seitamaa-Hakkarainen, P. (2022). Design empathy in students' participatory design processes. *Design and Technology Education: An International Journal, 27*(1), 29–48. https://ojs.lboro.ac.uk/DATE/article/view/3046/3067

Braun, V., & Clarke, V. (2013). *Successful qualitative research: A practical guide for beginners*. Sage.Dunbar N. E., Banas J. A., Rodrigues D., Liu S-J., & Abra G. (2012). Humor use in power-differentiated interactions. *Humor, 25*(4), 469–489.

Deterding, S. (2016). Make-believe in gameful and playful design. In T. Turner & T. Harviainen (Eds.), *Digital make-believe* (pp. 101–124). Springer

Eckert, C., & Stacey, M. (2000). Sources of inspiration: A language of design. *Design Studies, 21*(5), 523–538. https://doi.org/10.1016/S0142-694X(00)00022-3

Finnish National Board of Education (FNBE). (2014). National core curriculum for basic education. Finnish National Board of Education.

Finnish National Board on Research Integrity TENK. (2019). *The Finnish code of conduct for research integrity and procedures for handling alleged violations of research integrity in Finland*. TENK. https://tenk.fi/sites/default/files/2023-11/RI_Guidelines_2023.pdf

Goldstein, J. (2012). *Play in children's development, health and well-being.* Toy Industries of Europe. https://tiestorage.b-cdn.net/resources/Play-in-childrens-development-health-and-well-being-final.pdf

Heintz, S., Ruch, W., Lau, C., Saklofske, D. H., & McGhee, P. (2022). Development and validation of the Short Version of the Sense of Humor Scale (SHS-S): Paving the way for assessment of humor skills training. *European Journal of Psychological Assessment: Official Organ of the European Association of Psychological Assessment*, *38*(4), 320–331. https://doi.org/10.1027/1015-5759/a000670

Heljakka, K. (2021). Liberated through teddy bears: Resistance, resourcefulness, and resilience in toy play during the COVID-19 pandemic. *International Journal of Play*, *10*(4), 387–404. https://doi.org/10.1080/21594937.2021.2005402

Hoicka, E., & Martin, C. (2016). Two-year-olds distinguish pretending and joking. *Child Development, 87*(3), 916–928. https://doi.org/10.1111/cdev.12526

Hope, G. (2008). *Thinking and learning through drawing in primary classrooms*. Sage.

McGhee, P. E. (1984). Development of the creative aspects of humour. In P. E. McGhee & A. J. Chapman (Eds.), *Children's humour* (pp. 119–130). John Wiley & Sons.

McGhee, P. E. (2002). *Understanding and promoting the development of young children's humour*. Kendall/Hunt.

McGhee, P. E. (2019). Humor in the ECEC classroom: A neglected form of play whose time has come. In E. Loizou & E. Recchia (Eds.), *Research on young children's humor: Theoretical and practical implications for early childhood education* (pp. 83–106). Springer.

McKenney, S., & Reeves, T. (2018). *Conducting educational design research* (2nd ed.). Routledge. https://doi.org/10.4324/9781315105642

McLain, M., McLain, M., Tsai, J., Martin, M., Bell, D., & Wooff, D. (2017). Traditional tales and imaginary contexts in primary design and technology: A case study. *Design and Technology Education: An International Journal*, *22*(2), 26–40. https://openjournals.ljmu.ac.uk/DATE/article/view/1552

Kokkinaki, K. (2023). The soft toys as a consolation play-object in school after the Covid period: The Teddy Bear Project in primary art classroom. *European Journal of Education Studies*, *10*(4), 282–295. http://dx.doi.org/10.46827/ejes.v10i4.4786

Laamanen, T.-K., & Seitamaa-Hakkarainen, P. (2009). Sources of inspiration and mental image in textile design process. Art, Design & Communication in Higher Education, 7(2), 105–119. https://doi.org/10.1386/adch.7.2.105_7

Lahti, H., Kangas, K., Härkki, T., & Seitamaa-Hakkarainen, P. (2022). Challenging creativity constraints: Three design studios in craft teacher education. *Techne Series: Research in Sloyd Education and Craft Science A, 29*(1), Article e4250. https://doi.org/10.7577/TechneA.4250

Leung, S. K. Y., & Yuen, M. (2023). Exploring talented children's humour through creating pop-up storybooks. *Education 3–13*, *51*(8), 1325–1341. https://doi.org/10.1080/03004279.2022.2071453

Loizou, E., & Kyriakou, M. (2016). Young children's appreciation and production of verbal and visual humour. *HUMOR: International Journal of Humor Research*, *29*(1), 99–124. https://doi.org/10.1515/humor-2015-0131

Martin, R. A. (2011). *The psychology of humour: An integrative approach*. Elsevier Academic Press.

Omwawi, A. (2024). *From inspiration to garment ideas: Elucidating the threads of inspiration in apparel design ideation* [Dissertation]. University of Helsinki.

Paine, A. L., Karajian, G., Hashmi, S., Persram, R. J., & Howe, N. (2021). "Where's your bum brain?" Humor, social understanding, and sibling relationship quality in early childhood. *Social Development (Oxford, England)*, *30*(2), 592–611. https://doi.org/10.1111/sode.12488

Pilkey, D. (2018). *Koiramies* [Dog man] (J. Kapari-Jatta Trans.). Tammi.

Pöllänen, S. (2009). Contextualising craft: Pedagogical models for craft education. *International Journal of Art & Design Education*, *28*(3), 249–260. https://doi.org/10.1111/j.1476-8070.2009.01619.x

Rajagopal. (2019). Branding in emerging markets. In *Competitive branding strategies: Managing performance in emerging markets* (pp. 193–224). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-24933-5_7

Rutland, M. (2009). Art and design and design and technology: Is there creativity in the designing? *Design and Technology Education: An International Journal, 14*(1), 56–67. https://openjournals.ljmu.ac.uk/DATE/article/view/2294

Rönkkö, M.-L., & Aerila, J.-A. (2024). A friend to Milli Mörriäinen: The storification method supporting pupils' crafting processes. *Techne Series: Research in Sloyd Education and Craft Science A*, Article e5488. https://doi.org/10.7577/TechneA.5488

Rönkkö, M.-L., & Aerila, J.-A. (2022). Kertomukset ja käsityö varhaiskasvatuksen eheyttävissä oppimisprosesseissa [Stories and craft as a source of holistic learning processes in early childhood education]. In I. Ruokonen (Ed.), *Ilmaisun ilo. Käsikirja 0–8-vuotiaiden taito- ja taidekasvatukseen* [Joy of creativity: Handbook for arts education of 0–8-year-old children] (pp. 149–164). PS-kustannus.

Rönkkö, M.-L., & Aerila, J.-A. (2018). Humour in a holistic learning process in a preschool setting: Unique soft toys and stories inspired and further developed by children's sense of humour. *FormAkademisk, 11*(2), Article e1858. https://doi.org/10.7577/formakademisk.1858

Rönkkö, M.-L. & Lepistö, J. (2016). The craft process developing student decision making. *Techne Series: Research in Sloyd Education and Craft Science A, 23*(1), 48–61. https://journals.oslomet.no/index.php/techneA/article/view/1457

Rönkkö, M.-L., & Aerila, J.-A. (2015). Children designing a soft toy: An LCE model as an application of the experiential learning during the holistic craft process. *Techne Series: Research in Sloyd Education and Craft Science A, 22*(1), 44–58. https://journals.oslomet.no/index.php/techneA/article/view/988

Rönkkö, M.-L., Aerila, J.-A., & Grönman, S. (2016). Creative inspiration for preschoolers from museums. *International Journal of Early Childhood, 48*(1), 17–32. https://doi.org/10.1007/s13158-016-0159-z

Stenius, T., Karlsson, L. & Sivenius, A. (2021). Huumori lasten kanssa – ovi yhteisöllisyyteen? [Humour with children? A door to community?]. *Journal of Early Childhood Education Research, 10*(2), 11–40.

Trawick-Smith, J., Russell, H., & Swaminathan, S. (2011). Measuring the effects of toys on the problem-solving, creative and social behaviours of preschool children. *Early Child Development and Care*, *181*(7), 909–927. https://doi.org/10.1080/03004430.2010.503892

Trawick-Smith, J., Wolff, J., Koschel, M., & Vallarelli, J. (2015). Effects of toys on the play quality of preschool children: Influence of gender, ethnicity, and socioeconomic status. *Early Childhood Education Journal*, *43*, 249–256. https://link.springer.com/article/10.1007/s10643-014-0644-7

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Weisi, H., & Mohammadi, V. (2023). Humour in the classroom: Forms and functions among Iranian EFL teachers. *The European Journal of Humour Research*, *11*(1), 168–183. https://doi.org/10.7592/EJHR.2023.11.1.739

Yliverronen, V. (2014). From story to product: Pre-schoolers' designing and making processes in a holistic craft context. *Design and Technology Education: An International Journal, 19*(2), 8–16. https://openjournals.ljmu.ac.uk/DATE/article/view/1635

Yliverronen, V. & Seitamaa-Hakkarainen, P. (2016). Learning craft skills: Exploring preschoolers' craft-making process. *Techne Series: Research in Sloyd Education and Craft Science A, 23*(2), 1–15. https://journals.oslomet.no/index.php/techneA/article/view/1505

Design and Technology Education: An International Journal

30.1

Using performative objects to foster creativity in an education setting to tackle complex challenges

Cathrine Winther, Aalborg University, Denmark
Søsser Brodersen*, Aalborg University, Denmark

Abstract

Creativity is often seen as something that occurs primarily during the ideation phase of design processes. However, this article argues that there is significant potential in enhancing creativity in the early stages and that this can contribute to youth learning and tackling complex challenges. Using a Danish educational setting as a starting point, the article illustrates how using performative objects in teaching situations fosters creativity in the early stages of a design process. The article concludes that creativity is not merely an individual skill but a social practice and process, where using performative objects creates a conducive context for creativity.

Keywords

creativity, performative objects, creative contexts, education, complex challenges

Introduction

> *'...the more time a subject spent in defining and understanding the problem and consequently using their own frame of reference in forming conceptual structures, the better able he/she was to achieve a creative result (Christiaans, 1992). Defining and framing the design problem is therefore a key aspect of creativity.' (Dorst & Cross, 2001, p. 431)*

Today's challenges, such as climate change, food shortages, and inequality, require new approaches and competencies that foster creativity and the ability to act (EVA, 2020). These challenges are complex and addressing them requires understanding "competing underlying values and paradoxes" (Carcasson, 2016). Several authors highlight that creativity is one of the most essential skills for success in the 21st century (Glaveanu et al., 2020; Gray, 2016; Rahimi et al., 2024). There is no single or straightforward solution to today's challenges. Lambert (2017) argues that complex political, social, and environmental issues require creative solutions and societies. However, there appears to be a gap in the literature regarding how creative methods can be explicitly designed to evoke and support mindsets that foster tackling complex problems (Pearson, 2022). This article will discuss, guided by the research question: How does facilitation and staging of objects support creativity and contribute to developing competencies to tackle complex problems among youth in an educational setting? The research question is investigated through performative objects and staging creative contexts, focusing on the early stages of a participatory design process. We define performative objects as non-human actors that support a creative context and facilitate negotiations and reflections within collective action.

Scholars recognize the value of citizens' contributions to the co-creation of knowledge in a process that is not only practical but also collaborative and empowering (Duea et al., 2022). In more traditional design processes, creativity occurs when the designer realizes and recognizes something significant, making creativity an outcome of the designer’s insight (Dorst & Cross, 2001). However, in participatory design, everyone affected by the situation can contribute creatively to the design process (Bratteteig & Wagner, 2012). Creativity within participatory design is considered one of its essential virtues, alongside collaboration, curiosity, empowerment, and reflexivity (Steen, 2012). Although Steen (2012) describes these as separate entities, they are highly interdependent.

While creativity is vital in design processes, more research is needed on the contextual and social significance of fostering creativity among participating actors. The early stages of a participatory design process are often quite ambiguous and challenging to navigate due to various potential obstacles and the differing needs of participants (Sanders & Stappers, 2012). Traditionally, in participatory design, this navigation relies on standard qualitative research methods (such as interviews and observations) rather than explicitly creative activities. We argue that creativity has the potential to support navigation in the early stages of design, facilitating a more open-ended and collective exploration of complex challenges.

Although many researchers argue that everyone is creative to some extent, and the CERI (OECD Centre for Educational Research and Innovation) highlights that many people engage in creativity daily (OECD, n.d.), Sanders and Stappers (2012) suggest that creativity primarily belongs to childhood and is not prioritised in adult life. This could be problematic, as addressing complex challenges requires creative solutions and a population that is confident and capable of engaging in creative activities. One way to foster creative confidence and mindsets is through the school system, where exercises and methods that promote creative contexts and negotiation skills can be taught. However, to advance this effort, it is essential to understand and discuss how to define and conceptualise creativity, how creativity is currently approached in school settings, and what aspects need strengthening or support.

Creativity as interactive and collaborative processes

Creativity is a fluffy concept to define (Lambert, 2017). Generally, creativity is understood as the ability to generate new and valuable outputs and open new perspectives (Cudowska, 2018). It brings imagination and valuable outcomes for both individuals and society. However, a crucial factor in fostering creativity is providing a necessary foundation of information and education (Suciu, 2014).

Since creativity is strongly connected to generating new ideas, it is often associated with the later stages of the design process. However, we believe that creativity is also valuable in the early stages, where understanding and defining a problem take place. Dorst and Cross (2001) argue that a deeper understanding of a problem through conceptual structure formation increases the likelihood of achieving a creative outcome. A brief literature review supports this argument, which will be elaborated on later. Figure 1 illustrates the findings of this review. Little attention has been given to using creativity in the discovery phase, where the focus is on exploring problems and challenges.

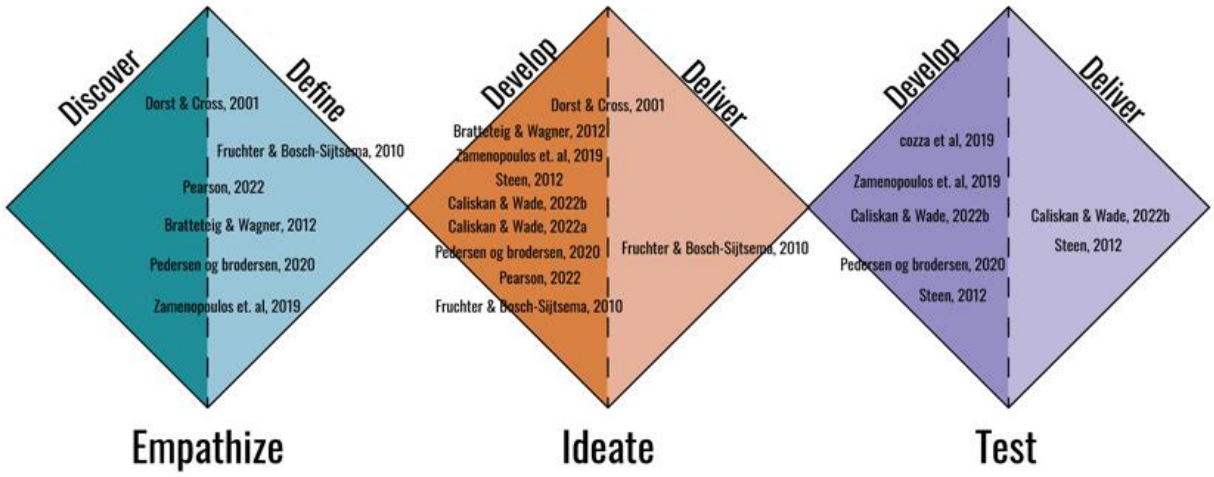


Figure 1. Findings from a brief literature review. The categorization does not depend on the level of participation or on who is participating; it is based solely on how creativity was actively incorporated into each phase. The model is inspired by the design phases in the Double Diamond framework (Design Council, n.d.)

Literature on creativity (Austin, 2003; Bratteteig & Wagner, 2012; Cummings & Blatherwick, 2017; EVA, 2020; Franklin, 2022; Jacucci & Wagner, 2007; Lambert, 2017; Suciu, 2014, Csikszentmihalyi, 1999; Sternberg, 2012) tends to interpret it through three distinct perspectives. Understanding creativity as an individual competence involves viewing it as something a person possesses or a skill that can be developed through practice (EVA, 2020). Suciu (2014) argues that a person's creativity can be stimulated by engaging in creative processes within a supportive environment, having a mentor, and participating in discussion-based games. Csikszentmihalyi (1999) and Sternberg (2012) define creativity as a process through which an individual produces something original. Supporting this, Jacucci & Wagner (2007) state that most literature on creativity has focused on the individual cognitive processes, neglecting the influence of objects and the collective processes of creativity. Austin (2003) proposes another definition, i.e. 'creativity is a long and complex series of interactions' between individuals and the setting in which something new is created. Thus, creativity is created between human and non-human actors. Understanding creativity as processes requires an introduction to the educational area since it is in this arena it is proposed. EVA (2020) concludes that creativity can be described as a co-creative process that enhances other goals, such as student learning. It involves not only thinking creatively but also being able to act creatively. Lambert (2017) emphasises that creativity is rooted in culture and is not merely a function of individual personality, competence, ability, or motivation. It is the intersection of attitude, process, and environment where an individual or group produces something valuable within a social context.

We define creativity as something that arises through a reflective process involving iterative interactions between humans and non-humans. Our observations suggest that creativity does not necessarily stand-alone but develops through collaboration among actors and as part of various actions. Creativity requires a context for imaginative thinking and openness, integrating playful elements and inspirational resources to engage participants and introduce surprise and discovery (Bratteteig & Wagner, 2012). It calls for an environment that encourages alternative thinking methods beyond traditional settings. Franklin (2022) highlights the need to promote tools and creative techniques that enable people to think and act differently, as fostering alternative understandings of why and how things are — and how they could be — is essential for transformative sustainability agendas. This underscores the importance of cultivating a context that encourages interactions between humans and non-humans.

Fostering creativity in education

This article argues that there is significant potential for integrating and experimenting with fostering creativity in teaching through a participatory design approach and that it needs to be supported using objects. In what follows, we will explore the role of objects when creating creative contexts within an educational setting.

The purpose of the educational system is to prepare future citizens to act in society, i.e., being able to tackle uncertainties and complexities. EVA (2020) argues that fostering creativity is one way to handle such complexities or wicked problems. In recent years, there has been a growing interest in developing students' creativity competencies and supporting creative processes in formal educational settings in Denmark and internationally (EVA, 2020). It is believed that creativity is essential for critical thinking (Abrami et al., 2008), problem-solving (Runco & Acar, 2024), can enhance people's ability to see new relations (Edl et al., 2014) and can contribute to personal well-being and personal development, which all support a democratic society and active citizenship (EVA, 2020). Relating the role of creativity to Bloom’s taxonomy, it is the highest level of learning (Rahimi et al., 2024).

Although scholars view creativity as a valuable component in education, there is still a need for broader social acceptance and recognition of its importance in schools (i.e. primary schools and high schools). Murgatroyd (2010) argues, 'Many teachers still teach subjects in a way that resembles how this was done 25 years ago or more’ (p. 259). He continues, ’The narrative about schools and change is that they are at the forefront of change. The reality, which can be attested, is that they are not — they look, feel and are almost exactly as they were 25 years ago’ (p. 260). One might argue that the school system should evolve to allow for more innovative and creative teaching methods. Cudowska (2018) suggests a need to develop a culture of creativity to enable students to reach their full potential. In Danish high schools, creativity must also be incorporated into the examination process. EVA (2020) concludes that fostering creativity can be challenging because it is a diffuse and ambiguous concept, making it difficult to evaluate and define creative competencies. To address this, this article demonstrates integrating creative contexts, as an active part of teaching and education, supports students' engagement and learning when working with complex challenges.

The role of objects in creative processes

In design processes, especially participatory design processes, it is common to involve various materialities to enhance tangibility and participation (Brandt et al., 2012). One may say that objects are just as important as participants when fostering participation and creativity (Pedersen & Brodersen, 2020a). One may say that objects are just as crucial as participants when fostering participation and creativity (Pedersen & Brodersen, 2020a). Pedersen & Brodersen (2020b, p. 73) argue, that the designer ‘conceptualize activities whereby objects are circulated between actors during design events such as ethnographic field studies or workshops as frontstage activities, because this is where design efforts become visible to non-designers and begin to perform in a collaborative way'. These materialities (physical or online 'things') are named and performed differently in literature, like devices, objects, prototypes, artefacts, probes, representations, tools, models and non-human actors. They can be staged and act in different ways in a design process: as boundary objects, intermediary objects, performative or even transformative (Brandt et al., 2012; Bratteteig & Wagner, 2012; Caliskan & Wade, 2022; Carlile, 2002; Pearson, 2022; Pedersen, 2020; Pedersen & Brodersen, 2020; Sanders & Stappers, 2012; Zamenopoulos et al., 2019). Often, objects in participatory design support empowerment processes and assist citizens in shaping their environment (Zamenopoulos et al., 2019). Therefore, the role of objects is also potentially contributing to transforming power. Following this, Pedersen & Brodersen (2020) argue that objects bring the opportunity to raise the voice of people who do not have one. This can be translated into educational settings, where teachers work with different distraction and ambition levels.

Caliskan & Wade (2022) claim that devices are the necessary link to bridge actors and networks, having a formative role in the assemblage of actions. When a designer creates things and puts them into action, it automatically takes a role in negotiating networks. Because objects have a strong agency in their presence, they can contribute to the making of action (Caliskan & Wade, 2022). The authors do not focus on creative devices but on devices that can create agency in negotiation processes. However, we believe it is essential to consider objects' role in fostering creativity in educational settings, highlighting the importance of clearly defining objectives when developing creative environments.

Sanders and Stappers (2012) advocate for developing "make-tools" because they allow for a deeper exploration of experiences, bringing tacit and latent knowledge to light. They argue that this depth cannot be achieved solely through "do-tools" (observation techniques) or "say-tools" (interview techniques). "Make-tools" are designed to enable and encourage participants to create tangible expressions of their feelings, engaging them in a creative act related to the subject being studied. For "make-tools" to be effective, they should vary in abstraction, content, openness, aesthetics, and form, allowing participants the freedom to express themselves. An example of a creative "make-tool" could be design games (Vaajakallio & Mattelmäki, 2014), which support creativity in all stages of the design process.

Facilitating an environment that enhances students' natural learning abilities is essential for fostering creativity (Cudowska, 2018). However, little research has been conducted on this topic, highlighting the need to explore the role of context in creative development and to determine how best to support teachers in adopting this role. EVA (2020) emphasizes that it is crucial for teachers to receive support in becoming sources of inspiration for creative work, thereby fostering a safe and curious classroom culture.

Reflection and understanding problems and solutions in new ways are essential to creativity. According to Carlile (2002), boundary objects can make knowledge understandable across different actor worlds; more importantly, they can transform knowledge into new forms. Moving beyond boundary objects, some objects can also act as intermediaries. Such objects can cross various knowledge worlds and mediate negotiations between actors by providing a shared or novel reference point. These objects are flexible and capable of representing concerns and translating meanings between actors to facilitate progress in the design process (Boujut & Blanco, 2003). Inspired by these insights, we argue that objects can perform independently, not only as intermediaries between actors, and that this performativity can help foster creativity.

Franklin (2022) argues that objects can only be regarded as creative or as fostering creativity when confronting people who respond to the object's role. This is essential for supporting the development of a creative space; that is, the object itself does not need to create creativity, but rather, the interaction between the object and people fosters creativity. This idea is supported by Cozza et al. (2020), who describe how shaping a design cannot be attributed solely to people but also requires conceptual tools that enable systemic thinking. It is necessary to establish connections between individuals, groups, and objects to enhance creativity, with the objects serving as the 'glue' in this process (Fruchter & Bosh-Sijetsema, 2010).

In summary, we conclude that objects can be performative and foster creativity, enabling youth to tackle complex problems. Objects can act, be negotiated, and be translated; most importantly, they do not need to foster creativity directly, but creativity can emerge through the interactions and negotiations between objects and people. Building on these conclusions, this article explores how fostering creativity through the use of performative objects can contribute to developing competencies among youth to tackle complex problems.

Methodology

A brief literature review of articles was conducted as part of writing this article. Articles with titles that included terms like "creativity", "participatory design" and "objects" were selected. These articles were analysed to identify how objects were used to foster creativity and where they were in the design process.

The empirical material used in this article is based on a course of study in a Danish high school in Copenhagen. The course of study is part of the EU-funded research project YouCount, which was conducted by one of the authors. The case involved 17 students who acted as co-researchers, having a role in exploring ways to create a more youth-friendly, sustainable local environment. As a part of the collaborations, the students were divided into five research teams, where they needed to discover, define and solve a local-based challenge.

The examples draw on a methodological framework that combines citizen social science (Albert et al., 2021) with participatory design to foster sustainability action competence (Winther & Søgaard Jørgensen, 2024).

The study is twofold; the researcher carried out a participatory design research project studying how to engage youth working with complex challenges while facilitating a participatory design process into which the youths were invited and where they were to carry out participatory design activities. The research carried out is part of the researcher's doctoral project. Thus, the researcher had a double role while teaching and facilitating the different exercises (elaborated in what follows), i.e. as a researcher and a teacher. This double role sometimes meant that the researcher intentionally focused more on the students and their learning than making in-depth notes and observations, maybe leaving some data uncovered.

During the study, several methods usually used within the participatory design field were taught and facilitated to the students (Figure 2).

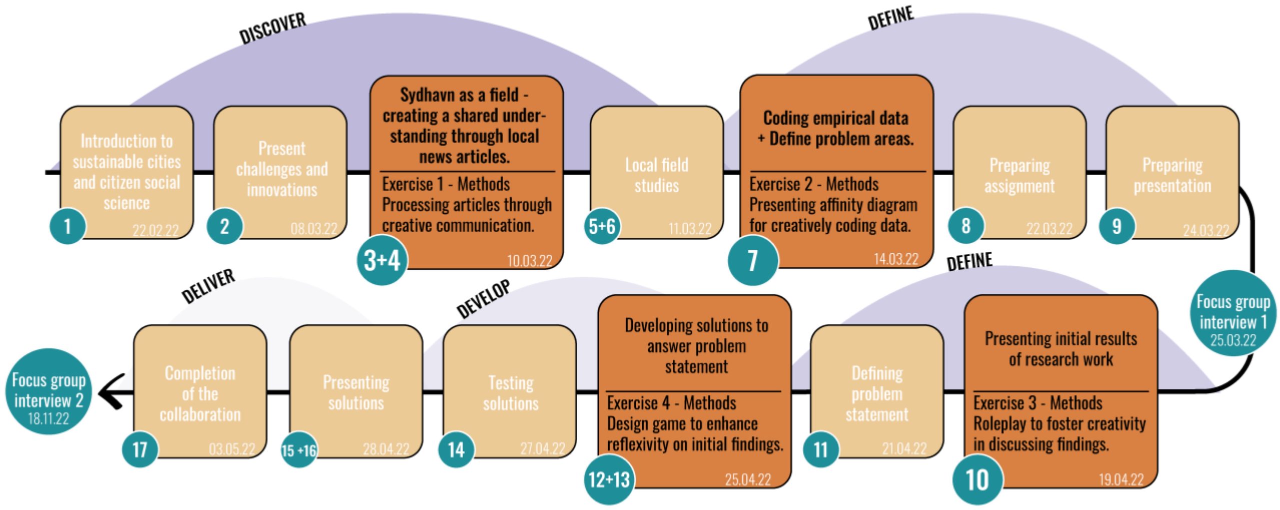


Figure 2. Overview of the high school collaboration. The orange boxes highlight the interactions used in the analysis, including the methods used to enhance creativity.

The figure illustrates the 17 modules facilitated by the researcher, including two focus group interviews. The four highlighted modules are used in this article's analysis.

The researcher facilitated two focus group interviews to evaluate the collaboration with the high school. One interview was conducted during the collaboration and one 6 months after the collaboration ended. At each focus group interview, 3-4 students participated.

Since this article focuses on how creativity can be fostered in the early stages of design processes, the analysis only reflects on this, although the collaboration explored the whole design process.

The examples presented in this article illustrate methods such as field trips and observations (Spradley, 1980), allowing the students to observe and understand the field through their own eyes and feelings. Finding quotes in articles and representing them visually was a method that enabled the students to read a text in depth. Also, the Design Games method (Vaajakallio & Mattelmäki, 2014) was introduced. Here, participants engage in dialogue through various game elements, such as rules and game pieces. Additionally, the students were introduced to the analytical coding tool, the affinity diagram (Beyer & Holtzblatt, 1997; Tomitsch et al., 2020), because it could help them organise their field notes into concrete themes. Lastly, enactment tools (Brandt et al., 2012; Tomitsch et al., 2020) were introduced to the students, i.e. roleplay, since this method encourages participants to embody either challenges or solutions.

The empirical data used as a basis in the examples that follow are based on the participatory observations(DeWalt & DeWalt, 2011) notes and pictures taken by the researchers during interactions with the students, supplemented with insights from the two mentioned focus group interviews with students after the course of study.

Enabling creative contexts in high school settings

In what follows, we outline how creativity is fostered through creative contexts and how the staged objects act performatively to generate discussions and reflections. Four exercises in a high school setting are analysed. In all the exercises, the researcher staged and introduced the methods to the students, but they engaged with the methods and objects, producing creativity.

Exercise 1: Creative processing of articles for mutual understanding

As a part of the second module in the course of study, each research team received an article related to the local area. The learning objective was for the research team to achieve a shared understanding of the area. It was the students' responsibility to communicate the content of their article to the rest of the class. The researcher did not impose any restrictions or guidelines on how they should present the article, but materials such as pencils, A3 paper, coloured cardboard, etc., were provided. Each team was given a physical copy of the article, allowing them to cut out quotations and pictures as part of their presentation.

By staging an open-ended exercise, a space was created for students to transform the article into a visual format that could be easily communicated and understood by their peers. During the exercise, students collectively engaged with the materials provided, and the open nature of the interaction fostered a context for discussion and interpretation.

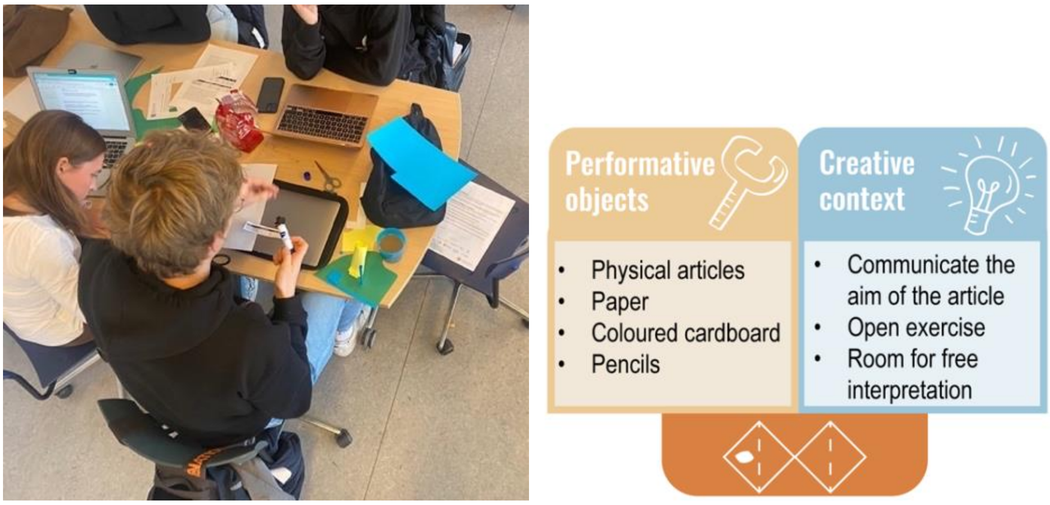


Figure 3. Students interact with objectives to communicate information from articles. And provide an overview of performative objects and creative context.

Fostering a creative context enables collective creation and reflection. Allowing students to develop ideas and act on them immediately increased their engagement with the exercise and the area's challenges.

> *'It was super nice that we had to create and present posters, making it more visual. The fact that we needed to develop it by ourselves made us come up with many cool ideas (Focus group interviews).*

This exercise created a motivating environment for the students: 'I liked that everything was not based on sitting individually in front of the computer. Instead, there was a space for discussion, allowing me to argue for our idea. Because you had already discussed it with your research team, it was easier to discuss it in front of the whole classroom' (Focus group interview).

During the exercise, the performative objects encouraged students to work creatively with written words and challenges in the early design process. This approach allowed them to negotiate, discuss, and engage with the challenges, fostering a shared understanding within and across the research teams. By this, the researcher also initiated a creative space different from what the students are used to. Introducing a creative environment within the school setting was a strategic choice to open the students' creative mindset for future interventions.

Exercise 2: Creativity in early converging phases

Before this exercise, the students went on a field trip to explore the local environment. Different from the first exercise, this exercise investigates how students creatively can work with the empirical data they gained from the field trip.

During the exercise, the students were asked to write down their observations and questions individually, developing several field notes (Spradley, 1980). They had been trained beforehand in coding data using the affinity diagram method (Beyer & Holtzblatt, 1997; Tomitsch, et. al., 2020). Each research team coded their data and experiences from the field trip to identify specific themes to focus on and develop innovative solutions. At the end of the exercise, they presented their defined challenges to the rest of the class. Post-its, blank sheets of paper, coloured pencils, and photos from the field trip were provided to support the students in the coding process.

The physical objects supported a creative context by acting as performative tools, enabling students to engage with and share their field material, make sense of it, and define the challenges they observed in the neighbourhood.

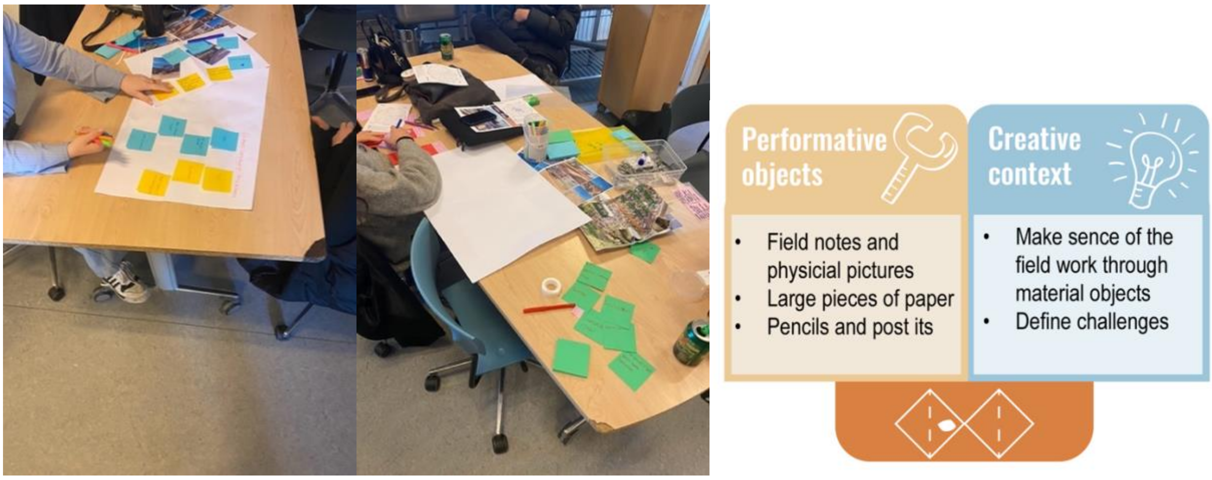


Figure 4. Students process data and interact in a creative context. Overview of performative objects and creative context.

Interestingly, the physical objects allowed students to move beyond traditional academic coding methods, instead using Post-its and pictures on posters. The coding exercise helped students share knowledge with the research team and interpret their empirical material.

This approach demonstrated a transformation in the use of objects as students engaged in discussions about their observations and experiences, creating new knowledge that informed their process of defining challenges.

> *'The fact that we were allowed to create something ourselves was nice, and it made me want to do more because it was both creative and fun. It enabled another kind of activation of the brain. Working creatively is different from writing five pages about something. We were allowed to paint, use colours and create posters. The creative elements motivated me in this project' (Focus-group interview).*

The performative objects that enhance the creative context are physical representations of the empirical material. The affinity diagram method is often used in the design process converging phases, assisting the designer/student in defining problems or refine solutions. Particularly in the early, more ambiguous stages, the affinity diagram supports designers/students in navigating the "fuzzy front end." This method gives a voice to the empirical material, where its physical representation and ongoing adjustments continually "speak" to the students. By working with the empirical data creatively, each photo or quote becomes a point of reflection.

Exercise 3: Roleplay for critical thinking

Opponent roleplays (Brandt et al., 2012; Tomitsch, et. al., 2020) were used to provide presentation feedback. Four role cards, each representing key interests for different actor groups, were developed by the researcher beforehand for the roleplay. The researcher anticipated that the roleplay would foster negotiation and create a fun, creative, and engaging environment in the classroom. The researcher designed the exercise to bring diverse perspectives from the field by incorporating varied values and viewpoints related to the defined challenges. This method allowed students to critically examine their defined problems and reflect on the diversity within the area.

The opponent cards and student presentations enabled a creative context in the project's definition phase, fostering a space for critical reflection and discussion.

Figure 5. Opponent cards for roleplay exercise. Overview of the performative objects and creative context.

The cards encouraged students to ask critical questions; some even performed an act representing their field trip findings. This creative dialogue brought a different energy to the classroom than traditional PowerPoint presentations. This exercise was also mentioned during the focus group interview half a year later than the exercise was performed, showing the potential of enacted creativity.

> *"At one point, we had an exercise where we were different people from Sydhavn, and then someone would present an idea, and we had to ask questions based on who we were—a kind of role-playing exercise shaped by our backgrounds and opinions. We learned a lot from that. It was fun to 'play' people you normally dislike; that was a great element, as I experienced a different kind of teaching. And all the discussions – that was great. I think that's also why we remember it so well now" (focus group interview)*

Interacting with objects and classmates in this way establishes a more relatable framework, which is essential for complex discussions. Moreover, it demonstrates that creativity enhances critical thinking and fosters an ability to view relationships from new perspectives, as argued by EVA (2020).

The opponent cards, as performative objects combined with the roleplay instructions, created a creative context in which students could act differently, broadening their perspectives and enhancing their critical thinking skills.

Exercise 4: Creative gaming for reflection

As a part of the development phases of the students' work, the researcher developed a design game (Vaajakallio & Mattelmäki, 2014) supporting innovation work. The design game consisted of 9 tasks in the four design phases: Discover, Define, Develop, and Deliver. The researcher provided a worksheet for the students to follow to support each task. In this exercise, we focus on the discovery and definition phases, which are understood as the early design phases.

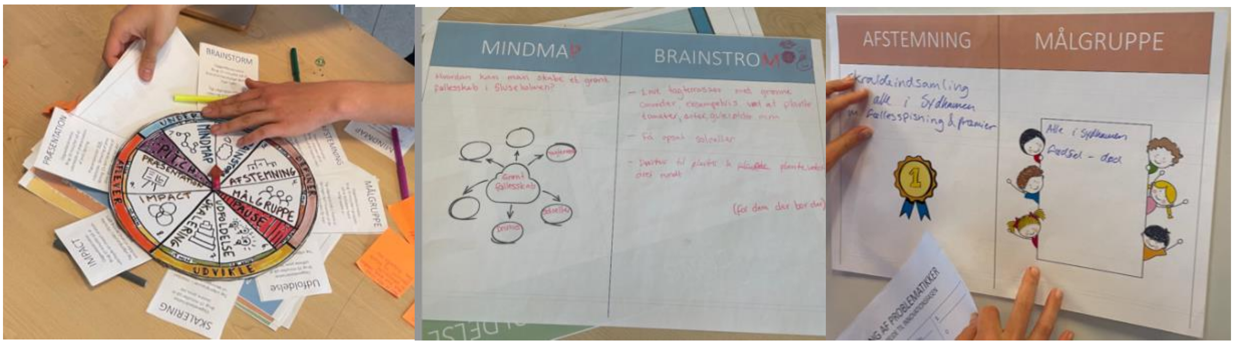


Figure 6. The design game and the four tasks. The four tasks are divided into a discover and define phase.

The design game was used to make the students explore hidden potentials and knowledge without taking their findings for granted before entering the ideation stages of the design process. It was a way to navigate the creative and exploration processes and guide them through all design stages. Through the gaming setup, students are invited into a temporary space where conventional rules and norms are suspended, which allows them to move fluidly between the past, present, and future. This setup fosters a creative environment where negotiations, interests, ideas, and solutions can evolve.

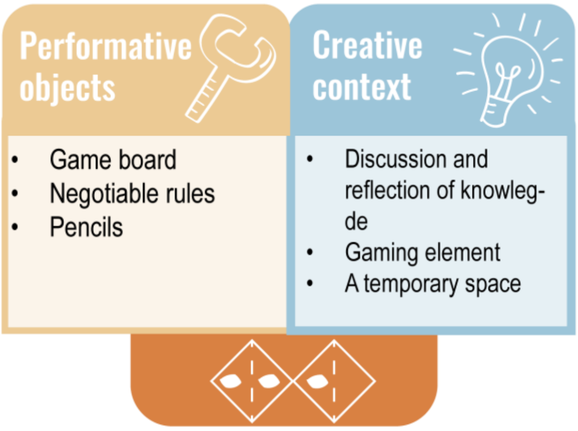


Figure 7. Overview of the performative objects and creative context.

Though the design game was used formally in the development phases of the design process, it nudges the youth to think about the early stages of their design process, negotiating their findings as a part of the innovation phase. The creative context is performed through the gaming element, where the students, through a game board, are navigated through all design stages. With a set time frame, the students were forced to think creatively to solve the tasks given. The worksheets served as a framework to support the youths' design work.

Many students skipped the first task during the game because they felt they had already done this in their previous work. This raised a discussion in class about the importance of revisiting data continuously and zooming out when working on something intensively. The discussion made the students reflect and return to the design game and worksheets. We argue that creativity emerges through playing the game but most notably through the discussions and negotiations developed through the game's stages.

The design game worked overall as intended, where all the students designed different initiatives, creating a difference in the community. Most importantly, the design game fostered a discussion about sustainability and innovation, where the individual student reflected upon their considerations and knowledge gained from previous interactions.

> *"Also, when thinking about skills and tools, I believe our project allows people to make their own mark on it, which could provide many young people with tools they can use professionally. It also fosters a do-it-yourself mentality—how do you achieve something on a small budget? That could benefit many, encouraging creativity while still reaching their goals" ("(focus group interview).*

Discussion

So far, the article has demonstrated the value of creativity in the early stages of the design process, particularly in understanding and defining problems. Drawing on Lambert's (2017) argument that creativity emerges at the intersection of attitude, process, and environment—where an individual or group produces a valuable outcome within a social context—the article defines creativity as a reflective process involving iterative interactions between humans and non-humans.

Throughout the article, examples illustrate how objects can help negotiate and shape spaces, making theories and methods tangible and enabling students to generate new ideas, perspectives, and critical thinking. Across these examples, some common themes emerge that may inspire further research:

- Engaging in activities collectively and without external interference
- Creating or opening new perspectives
- Emphasising tangibility
- Developing ideas and acting on them immediately

Creating a context where young people can work creatively and collaboratively influences their design process and encourages them to discuss and reflect on sustainable challenges in the early stages of design. The examples illustrate that fostering a creative context through performative objects can reveal new viewpoints and perspectives on familiar issues. This ability to move beyond preconceived notions is especially critical for sustainable transitions (EVA, 2020). Therefore, it is essential to facilitate educational situations where new perspectives and mindsets are nurtured through participatory approaches.

Recommendations for enhancing creativity in educational settings

The four above mentioned points are also to be seen as recommendations for teachers to implement in their teaching. EVA (2020) emphasises that teachers must receive support in becoming sources of inspiration for creative work, thereby fostering a safe and curious classroom culture. We hope this study can serve as an inspirational case for high school teachers and inspire other creative studies at different levels in the educational system. Because we acknowledge that creative processes often require a dynamic space that can sometimes be unpredictable, which can seem unmanageable for a busy teacher (EVA, 2020), we provide a tangible framework below, hopefully making it manageable for educators to implement.

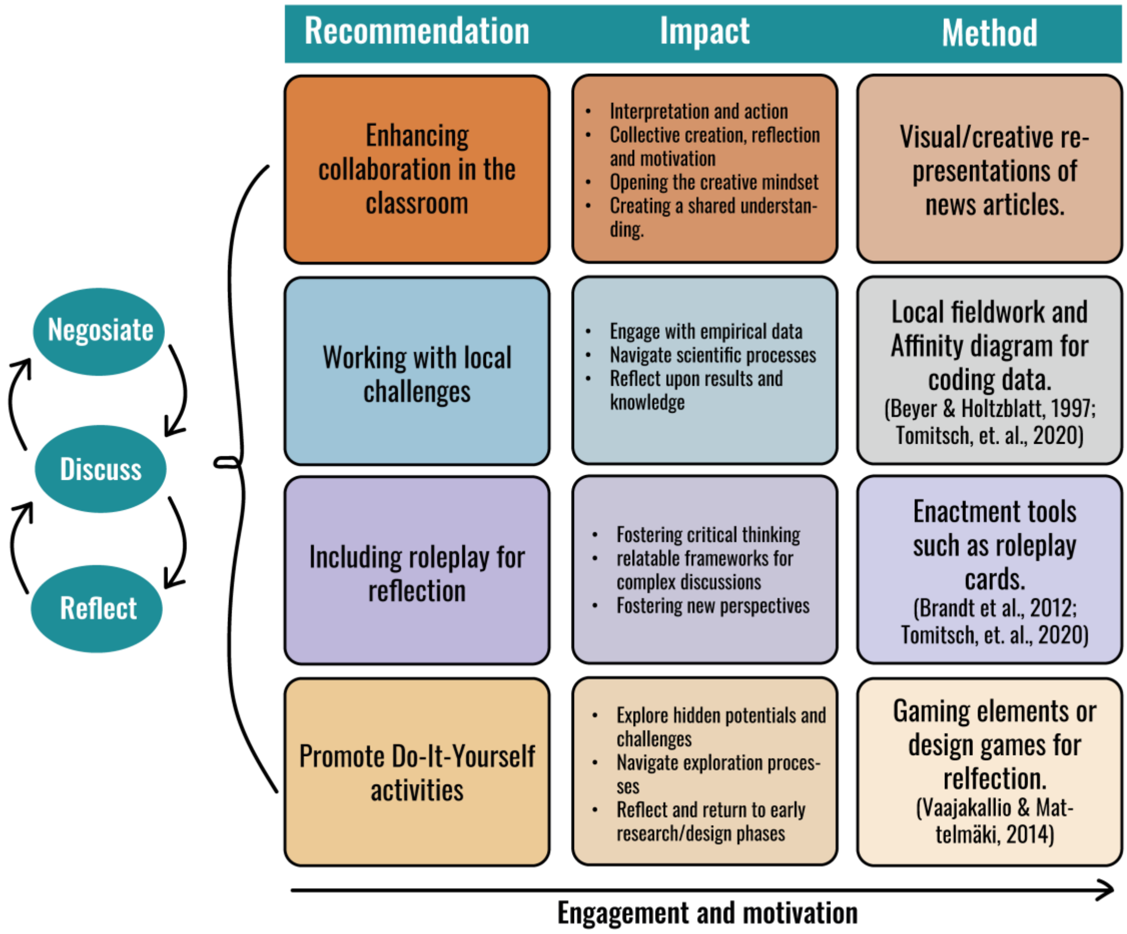


Figure 8. Recommendations for teachers at all levels to inspire creativity in the educational environment.

The framework consists of four concrete recommendations for staging creative spaces in teaching, the impact points of each recommendation, and tangible methods to follow when working with the early stages of design.

Through the research study, we investigated methods staged and facilitated by the researcher to foster creativity among youths, but it would be highly relevant to investigate further the importance of allowing the students to develop methods in the classroom to enhance creativity and motivation.

Challenges when introducing creative methods in an educational setting

Though we through the exercises have shown that there are great potential in using performative objects and participatory design to foster creativity in working with complex challenges in an educational setting, we also see different challenges. Many of the presented methods are staged to be open-ended and foster creativity through their loose frames. Though the methods' intentions are good, performing them in an educational setting was sometimes confusing for the students used to work within very fixed frames: "….This approach can be challenging, particularly in an educational setting where we are accustomed to clear distinctions between right and wrong answers, especially in nature-based subjects. I wish I had known from the outset of this project that there was no risk of doing something 'wrong' " (focus group interview).

Though much research shows the importance of enhancing creativity in educational settings and contemporary studies show great potential of alternative didactics, the students are used to working within fixed frames, which goes against the nature to work more open-ended and creatively. The quotes highlight a cultural embedded challenge that needs to be solved on a higher level. The challenges introduce a pressing need for more interventions and alternative teaching methods in high schools to make students confident with more creative methods. Therefore, more research is needed to investigate how to challenge the rigid system and secure more creative methods to be a part of the educational didactic and how to make both teachers and students confident in working in creative directions.

The examples shows that the students appreciate an alternative way of tackling scientific questions, where they move away from their traditional "ways of doing" to a more "DIY" mentality. However, the creative aspect made the tasks too broad. "Sometimes I thought the exercises were a bit broad, and knowing what to do and the collaboration's end goal was challenging. Especially in a school setting, you are used to having very fixed structures, and suddenly, when given more freedom, you might become a bit hesitant: Am I allowed to do this? Is this the right thing to do now, or is it a waste of effort?" (focus group interview).

We (both authors) come from a design engineer background and are used to teach design related topics at university. Reflecting upon the collaboration with the high school, we have taken the more independent way of working at the university for granted. High school students are used to being guided through the tasks they are given, whereas at the university, we enable the students find ways of working and understanding the world through different theories and methods. In further research, it would be beneficial to investigate how different educational levels can learn from each other and prepare students for the real world through creative approaches.

Supporting working with complex challenges through creativity

As discussed, the role of physical objects in fostering creativity remains relatively underexplored (OECD, n.d.; Pearson, 2022). This article has examined how performative objects used in participatory processes can create creative contexts in the early stages of design. However, asking how we can further support young people in confidently performing creative activities beyond the educational setting and fostering creative action remains relevant. From the examples and the student's reflections on the impact of the collaboration, we see great potential in promoting creative methods in educational settings. Due to the method's alternative performance and presence in the class environment, it made such an impression on the students that they remembered it 6 months after the collaboration ended.

> *"Just being aware of it, and talking about it—just the fact that I'm talking about it now—means that I'll talk to others about it later, and that's a good development" (Focus group).*

Though the study is relatively small, it shows that staging creative methods can bring long-term critical thinking that can support youth in their future encountering and working with complex challenges. When individuals can ask critical questions, they can challenge their own and others' perceptions and ideas.

Conclusion

Today's challenges call for innovative approaches that foster creativity, as argued by EVA (2020) and Lambert (2017). This article contends that creativity can support navigation through the early stages of design and research, allowing complex challenges to be explored in an open-ended, collaborative manner. Furthermore, it highlights the significant potential for integrating and experimenting with participatory design in education to foster creativity, enhance creative teaching practices, and encourage reflective thinking—supported using objects.

This article contributes to bridging a gap in the literature by exploring how creative participatory design methods in educational settings can be structured through performative objects to inspire mindsets conducive to sustainable transformation. It includes a discussion of creativity as a reflective process, characterized by iterative interactions between humans and non-humans. Central to creating these creative contexts is the purposeful staging of objectives that enable critical discussions and the generation of new ideas.

It is argued that objects can act performatively by fostering creative contexts through negotiation and engagement, allowing them to be staged and restaged by participants and facilitators. As authors, we see potential in further exploring enactment (roleplay) and gamification tools, as the examples in this article primarily focus on visual objects. While it may not be solely the exercises and alternative teaching approaches that motivate students to engage in sustainability discussions, we believe that performative objects hold promise for initiating creativity in the early stages of participatory design.

Creativity remains a diffuse and complex concept, but this article demonstrates ways to integrate creative contexts as an active part of teaching and education, showing that it effectively supports students' engagement with complex challenges. To further support creativity as a social practice and foster iterative interactions between humans and non-humans, additional research is needed to explore how teachers and the educational system can build confidence in actively incorporating creative and innovative contexts into their teaching.

Acknowledgement

The authors would like to thank all the students who contributed with their engagement and insights to the examples discussed in this article. We extend our gratitude to the 17 young co-researchers from Københavns Åbne Gymnasium for their participation in the YouCount project. Funding from the European Commission Horizon 2020 Programme Grant Agreement No. 101005931 made the first three examples possible.

References

Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes, M. A., Tamim, R., & Zhang, D. (2008). Instructional Interventions Affecting Critical Thinking Skills and Dispositions: A Stage 1 Meta-Analysis. *Review of Educational Research,* 78(4), 1102–1134. https://doi.org/10.3102/0034654308326084

Albert, A., Balázs, B., Butkevičienė, E., Mayer, K., & Perelló, J. (2021). Citizen social science: New and established approaches to participation in social research. In *The Science of Citizen Science* (pp. 119–138).

Austin, H. J. (2003). Chase, Chance, and Creativity: The Lucky Art of Novelty: Vol. vol 2. The MIT Press.

Brandt, E., Binder, T., Sanders, E. B.-N., Simonsen, J., & Robertson, T. (2012). Tools and techniques: ways to engage telling, making and enacting. In *Routledge International Handbook of Participatory Design* (pp. 165–201). Routledge. https://doi.org/10.4324/9780203108543-14

Bratteteig, T., & Wagner, I. Ina. (2012). Spaces for participatory creativity | Enhanced Reader. *Codesign*.

Caliskan, K., & Wade, M. (2022). DARN (Part 2): An Evidence-Based Research and Prototyping Method for Strategic Design. *She Ji*, 8(3), 319–335. https://doi.org/10.1016/j.sheji.2022.11.002

Carcasson, M. (2016). Tackling Wicked Problems Through Deliberative Engagement. *National Civic Review*, 105(1), 44–47. https://doi.org/10.1002/ncr.21258

Carlile, P. R. (2002). A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organization Science*, 13(4), 442–455. https://www.jstor.org/stable/3085976

Christiaans, H. (1992). *Creativity in Design*. Delft University of Technology.

Cozza, M., Cusinato, A., & Philippopoulos-Mihalopoulos, A. (2020). Atmosphere in Participatory Design. *Science as Culture*, 29(2), 269–292. https://doi.org/10.1080/09505431.2019.1681952

Csikszentmihalyi, M. (1999). Implications of a Systems Perspective for the Study of Creativity. In *Handbook of Creativity* (pp. 313–336). Cambridge University Press. https://doi.org/10.1017/CBO9780511807916.018

Cudowska, A. (2018). The Importance of Creativity in School Culture. www.kultura-i-edukacja.pl

Cummings, J. B., & Blatherwick, M. L. (2017). *Creative Dimensions of Teaching and Learning in the 21st Century*.

Dorst, K., & Cross, N. (2001). *Creativity in the design process: co-evolution of problem-solution*. www.elsevier.com/locate/destud

Duea, S. R., Zimmerman, E. B., Vaughn, L. M., Dias, S., & Harris, J. (2022). A Guide to Selecting Participatory Research Methods Based on Project and Partnership Goals. *Journal of Participatory Research Methods*, *3*(1). https://doi.org/10.35844/001c.32605

Edl, S., Benedek, M., Papousek, I., Weiss, E. M., & Fink, A. (2014). Creativity and the Stroop interference effect. *Personality and Individual Differences*, 69, 38–42. https://doi.org/10.1016/j.paid.2014.05.009

EVA, D. E. (2020). Kreativitet i gymnasiet *Gymnasielaereres arbejde med at styrke elevernes kreativitet*.

Framework for Innovation - Design Council. (n.d.). Retrieved July 3, 2023, from https://www.designcouncil.org.uk/our-resources/framework-for-innovation/

Franklin, A. (2022). *Co-creativity and Engaged Scholarship - Transformative Methods in Social Sustainability Research*. Springer Nature.

Glaveanu, V. P., Hanchett Hanson, M., Baer, J., Barbot, B., Clapp, E. P., Corazza, G. E., Hennessey, B., Kaufman, J. C., Lebuda, I., Lubart, T., Montuori, A., Ness, I. J., Plucker, J., Reiter-Palmon, R., Sierra, Z., Simonton, D. K., Neves-Pereira, M. S., & Sternberg, R. J.

(2020). Advancing Creativity Theory and Research: A Socio-cultural Manifesto. *The Journal of Creative Behavior*, 54(3), 741–745. https://doi.org/10.1002/jocb.395

Gray, A. (2016). *The 10 skills you need to thrive in the Fourth Industrial Revolution | World Economic Forum*. https://www.weforum.org/stories/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/

Jacucci, G., & Wagner, I. (2007). *Performative Roles of Materiality for Collective Creativity*. https://doi.org/10.1145/1254960

Lambert, P. A. (2017). Understanding creativity. In *Creativity dimensions of teaching and learning in the 21st century*.

Murgatroyd, S. (2010). 'Wicked Problems' and the Work of the School. *European Journal of Education*, 45(2), 259–279. https://doi.org/10.1111/j.1465-3435.2010.01428.x

OECD. (n.d.). *Teaching, Learning and Assessing Creative and Critical Thinking Skills | OECD*. Retrieved March 3, 2025, from https://www.oecd.org/en/about/projects/teaching-learning-and-assessing-creative-and-critical-thinking-skills.html

Pearson, K. R. (2022). imaginative leadership: a conceptual frame for the design and facilitation of creative methods and generative engagement. In *Co-creativity and engaged scholarship – transformative methods in social sustainability research*.

Pedersen, S. (2020). Staging negotiation spaces: A co-design framework. *Design Studies*, 68, 58–81. https://doi.org/10.1016/j.destud.2020.02.002

Pedersen, S., & Brodersen, S. (2020a). Ciculating objects between frontstage and backstage: collectively identifying concerns and framing solution spaces. In *Staging Collaborative Design and Innovation*. Edward Elgar Publishing. https://doi.org/10.4337/9781839103438.00014

Pedersen, S., & Brodersen, S. (2020b). Circulating objects between frontstage and backstage: collectively identifying concerns and framing solution spaces. In *Staging Collaborative Design and Innovation* (pp. 92-105Edward L). Edward Elgar Publishing.

Rahimi, S., Walker, J. T., Lin-Lipsmeyer, L., & Shin, J. (2024). Toward Defining and Assessing Creativity in Sandbox Games. *Creativity Research Journal*, 36(2), 194–212. https://doi.org/10.1080/10400419.2022.2156477

Runco, M. A., & Acar, S. (2024). *Handbook of Creativity Assessment* (M. A. Runco & S. Acar, Eds.). Edward Elgar Publishing. https://doi.org/10.4337/9781839102158

Sanders, E., & Stappers, P. (2012). Convival toolbox: *Generative research for the front end of design*. Bis.

Spradley, J. (1980). *Participant Observation*. Thomson Learning.

Steen, M. (2012). *Virtues in Participatory Design*.

Suciu, T. (2014). The Importance of Creativity in Education. In *Bulletin of the Transilvania University of Braşov Series V: Economic Sciences*, (Vol. 7, Issue 56).

Tomitsch, M., Borthwick, M., Ahmadpour, N., Cooper, C., Frawley, J., Hepburn, L.-A., Kocaballi, A. B., Loke, L., Núnes-Pacheco, C., Straker, K., & Wrigley, C. (2020). *Design. Think. Make. Break. Repeat. A Handbook of Methods*. BIS Publishers.

Vaajakallio, K., & Mattelmäki, T. (2014). Design games in codesign: as a tool, a mindset and a structure. *CoDesign*, 10(1), 63–77. https://doi.org/10.1080/15710882.2014.881886

Winther, C. M. S., & Søgaard Jørgensen, M. (2024). Engaging youth in the local environment. Promoting sustainability action competence in Danish high school teaching through citizen social science. IJAR – *International Journal of Action Research*, 19(3–2023), 238–260. https://doi.org/10.3224/ijar.v19i3.07

Zamenopoulos, T., Lam, B., Alexiou, K., Kelemen, M., De Sousa, S., Moffat, S., & Phillips, M. (2019). Types, obstacles and sources of empowerment in co-design: the role of shared material objects and processes Types, obstacles and sources of empowerment in co-design: the role of shared material objects and processes. CoDesign International Journal of Concretion in Design and in Arts. https://doi.org/10.1080/15710882.2019.1605383

Design and Technology Education: An International Journal

30.1

The teacher's guide's way of communicating with the teacher – within the subject of technology

Pernilla Sundqvist, Mälardalen University, Sweden
Susanne Engström, KTH Royal Institute of Technology, Sweden
Charlotta Nordlöf, Linköping University, Sweden

Abstract

The materials and artefacts utilized by teachers and students play a crucial role in education. In a subject like technology, where many teachers feel they do not have sufficient competence, curriculum materials such as textbooks and teacher guides provide important support for teachers. Teacher guides, in particular, have the potential to support teachers in different ways. The guidance provided in a teacher's guide can be either directive and talk through the teacher, i.e. telling the teacher what to do, or educative and talk to the teacher, i.e. telling the teacher how to do it and why to do it this way, thereby providing the teacher with knowledge to better understand the teaching of the subject. In this study, we analyze a teacher's guide for grades 7-9 to find out what kind of support it provides the teacher. An adapted framework for the design principles of educative curriculum materials was used. The analysis shows that this particular teacher's guide mostly talks through the teacher, giving the teacher directives on how to teach but without explaining why or suggesting other possible ways. The few educative features found are short and not very detailed. The support an educative teacher's guide could provide would give the teacher agency over their teaching and a better possibility to adapt teaching to situations and students. However, we see little of that kind of guidance in the teacher's guide analyzed in this study and conclude by outlining the possible consequences for technology education.

Keywords

Technology education, teacher guides, design principles, educative curriculum materials

Introduction

The materials and artefacts utilized by teachers and students play a crucial role in education. While curriculum materials like textbooks are important for students' learning, they also provide support for teachers (Oates, 2014; Graeske, 2021). Teachers in science and technical subjects appear to use textbooks extensively, but in different ways depending on the students involved (Bachmann, 2005; Schlag & Glock, 2023). Both textbooks and teacher guides provide support for teachers in planning and organizing teaching, especially teachers who are uncertain about their subject knowledge (Driscoll et al., 1994; Englund, 2006), which is likely the case for many technology teachers in Sweden since a large proportion are not trained in the subject. A recent study on four technology textbooks (Engström et al., 2023) revealed three different approaches to how the content (industrial processes) was presented, which means that choices made by the textbook authors entail that some content is made visible while some are overlooked. Hence, the textbook used by the teacher will affect how the content is presented to the student and therefore how the student can understand, in this case, industrial processes. This highlights the difficulty, or perhaps impossibility, of including all the relevant content for a technology topic in a textbook, and the importance for teachers to be aware of this and to complement the textbook with other relevant resources. To support teachers in this, such information could be provided in the teacher's guide.

In Sweden, around 50 % of the teachers who teach technology in years 7 – 9 (students aged 13-16) are trained in technology education, which is relatively low compared to other subjects (National Agency for Education, 2024a). One challenge is that the subject of technology is sometimes perceived to be overshadowed by other school subjects, for example, a perceived lack of resources or time for collegial meetings (Nordlöf et al., 2019, Skolinspektionen, 2014). In particular, new technology teachers describe feeling uncertain about planning, implementing, and assessing technology education, whereas experienced technology teachers describe challenges related to students' varying prior knowledge and lack of understanding concerning the subject matter (Fahrman et al., 2020). Both groups can utilize textbooks with accompanying teacher guides to create a comprehensive view of relevant technological knowledge and gain confidence in their teaching. Well-structured curriculum materials can thus help the teacher to plan and enact lessons that meet the objectives of the subject's syllabus and the needs of different students. Teacher guides, in particular, can potentially support teachers in different ways (Davis, 2021). Remillard (2000) distinguishes between teacher guides *talking through* the teacher*,* i.e. giving direct instructions*,* or *talking to* the teacher, i.e. explaining the rationale for the instructions, emphasizing the need for both in order to meet different teachers' needs, although the latter is the one considered to be educative for the teacher. However, little is known about how teacher guides in technology are designed. There is a solid knowledge base about curriculum materials in mathematics, language, and social sciences, but research is lacking for the subject of technology. A recent literature study concludes that the use of curriculum materials varies widely between subjects and that research from other subjects may not be transferable to technology education (Graeske, 2021).

This study analyzes a teacher's guide in the technology subject. The aim is to investigate how the teacher's guide communicates with the teacher and further discuss what this implies for students' learning possibilities. The research questions are:

1. What kind of support does the teacher's guide provide teachers in terms of talking through and talking to the teacher?
2. In terms of talking to the teacher, which design principles for educative curriculum materials can be identified in the teacher's guide, and what do these educative features look like?

Different characteristics of teacher guides and teachers' use of them

Typically, teacher guides are designed to help teachers in shaping lessons. However, they differ in the way they communicate with teachers and in the type of guidance they provide (Remillard & Kim, 2020). Remillard (2000) distinguishes between the teacher's guide *talking through the teacher* or *talking to the teacher* (Remillard, 2000). Teacher guides that talk *through* the teacher tell the teacher what to do, while teacher guides that talk *to* the teacher explain the underlying ideas of these suggestions. In the first case, the guidance is directive, specifying what teachers and students should do or say during or in preparation for the lesson (Remillard & Kim, 2020). In the second case, the teacher's guide has the potential to be educative, which would entail telling the teacher how and why to teach in a certain way, thereby providing the teacher with knowledge to better understand the teaching of the subject, giving the teacher a greater opportunity to adapt lessons. Remillard (2000) points out that teacher guides commonly talk through teachers but argues that they should be designed to speak *to* teachers. However, Remillard and Reinke (2012) suggest that a teacher's guide can also be educative by talking *through* the teacher. This is supported by Van Steenbrugge and Ryve (2018), who emphasize that teacher guides that talk through teachers can be a support for teachers who feel insecure about the subject or are unaccustomed to teaching situations. Therefore, they recommend that teacher guides use both types of communication, *through* and *to* the teacher, thereby providing both directions and the rationales for them. The recommendation is based on their study of how teachers use the different types of support in a mathematics teacher's guide. Although the teachers used some of the support that talked *to* them, their main focus was on the more directive support, such as lesson slides and exit tickets. Similar results have been presented regarding the technology subject. Although research on curriculum materials and technology education seems to be scarce, Given and Barlex (2001) studied how teachers used a set of curriculum materials including a student book, a study guide, and a teacher's guide, for students aged 11-14. They found that the teachers used the different components of the material to varying degrees. The students' book was used the most, and the teacher's guide was used the least. Also, the study guide was generally underused, but those teachers who did use it reported that it added value to the teaching and the students' work. Most used were the components of the materials that could easily be put into practice with little or no adaptation of the teacher's plan.

Janko and Pešková (2017) found in a literature study that teachers use curriculum materials in three different ways. First, there is the fidelity approach, meaning the teacher transmits the content from the materials to the students. Second, there is the adaptation approach, meaning the teacher undertakes curriculum adjustments. Finally, there is the enactment approach, meaning the teacher creates curriculum in action according to student experience. Brown (2009) also wrote about these approaches, calling them offloading, adaptation and improvising. Studies have shown that teachers apply these approaches in different ways. For example, some use all these approaches and can move between them during a lesson (Brown, 2009; Jukić Matić & Glasnović Gracin, 2021) while others only offload, i.e., apply the fidelity approach (Snyder et al., 1992). Van Steenbrugge and Ryve (2018) relate these approaches to the design of the teacher's guide and suggest that a teacher's guide that talks through the teacher in a directive way would support offloading a lesson, while a teacher's guide that talks to the teacher in an educative way is necessary for supporting adaptation.

The design of educative curriculum materials

Distinctive for educative curriculum materials is that they include educative features specifically designed to contribute to teachers' learning, both about the content and how to conduct teaching. Based on Ball and Cohen (1996) and research stemming from Ball and Cohen, Davis and Krajcik (2005) compiled nine design heuristics that can guide both the creation of educative features and provide context for discussions about the potential of educative curriculum materials to promote teachers' learning. The underlying ideas for these design heuristics, along with results and suggestions from other studies, have been applied by several researchers to develop design principles for how educative curriculum materials can be designed to promote teachers' learning in various subject areas, such as science (Davis et al., 2017; Englehart, 2010;

Roseman et al., 2017), mathematics (Fuentes & Ma, 2017), and language (Neuman et al., 2015) as well as in teacher education (Hanuscin et al. 2025; Melton & Mikeska, 2025).

In our analysis of a teacher's guide, we will use the design principles created by Davis and colleagues (2017) to interpret what can be said to characterize the teacher's guide. They present six design principles created within science education:

1. Teachers adapt curriculum materials based on factors such as time and students' knowledge and abilities. Educative features should provide suggestions on how lessons can be adapted in various ways without losing the intended purpose.
2. Educative features should present the reasoning behind pedagogical ideas included in the guide. Representations of practice can support teachers in adopting the ideas in the material. Therefore, educative features should be contextualized in the teachers' practice, designed, for example, as stories about teachers' work and annotated examples of students' work.
3. The demand for teachers' subject knowledge is increasing, and educative features should therefore help make important content visible and explain it, for instance, by showing how it can be described to students and how it connects across multiple lessons.
4. Different teachers have different needs and adopt different types of educative features depending on the knowledge they already possess. Educative curriculum materials should therefore provide a variety of different types of educative features to meet teachers' diverse needs and their students' different needs, for example, content struggles. The rationales of the recommendations in the various educative features should be given, as well as whether, and if so how, these differ from teachers' "usual" practices.
5. Teachers engage with the practice of scientific explanation in a limited capacity. Thus, educative features should assist teachers in (a) understanding the definition, purpose, and importance of creating scientific explanations and (b) learning how to help students participate in the construction of explanations and argumentation.
6. Certain scientific practices, including making and recording observations and making and justifying predictions, were taken up effectively by most teachers. Therefore, educative features should support easier-to-enact scientific practices, with the idea of moving incrementally toward more ambitious science teaching in elementary classrooms. Designers should connect to teachers' existing teaching practices to create leverage points while helping teachers recognize salient differences.

For our analysis, we have adjusted these design principles to fit the subject of technology. This is described in the Methods section.

Methods

For our analysis, we chose the teacher's guide from one of the most commonly used curriculum materials, a technology textbook for grades 7-9, adapted to the current syllabus. The teacher's guide is digital, and it follows the structure of the students’ textbook. The entire teacher's guide was analyzed.

To study how the teacher's guide communicates with the teacher, content analysis was performed in two steps. First, we coded each unit, that is each phrase, sentence, paragraph, or picture based on whether it *talks to the teacher* or *talks through the teacher*. Second, we looked at the units coded as *talking to the teacher* and further coded these units using an adapted version of the design principles created by Davis et al. (2017). We used the original design principles 1-4, but changed the last two to fit the technology subject as follows:

5. In technology education, students should try, analyze, and evaluate the working methods that occur in various technical areas. Working methods are, for example, design processes, life cycle analyses, and Environmental Impact Assessments. Thereby they can learn content, methods, and processes as they are understood within technical disciplines. *Educative features should provide teachers with examples of how work within various technical disciplines is carried out in practice, and how this can be part of the teaching.*
6. One objective of technology education is to prepare students to become conscious citizens in a society where technology plays a central role and is constantly developing. Examples encompass understanding why we recycle, different energy solutions, and transportation alternatives. Educative features must address teachers' need for support to *motivate the importance of technology education for societal and everyday life* and give examples that highlight the importance of technical knowledge to, for example, be able to make decisions both on an individual and societal level and to have a critical approach to technological phenomena.

Design principles 5 and 6 are developed by the authors. They are related to Roberts' Vision I and II (Roberts, 2007a, 2007b; Roberts & Bybee 2014). Roberts describes two competing visions of scientific literacy that are rooted in the history of school science education. He explains how Vision I derives its authenticity by looking inward to the products and procedures of the scientific disciplines themselves while Vision II is broader, deriving its legitimacy from the evident influence of science across a wide range of human endeavours, beyond just scientific practice.

In this study, the authors have drawn inspiration from Roberts' visions for science education and interpreted the content and aims within technology education, divided into two visions with similar meanings to those of Roberts. This aligns well with the curriculum for technology in Swedish primary education (National Agency for Education, 2024): one vision focuses on a more civic, educational purpose, while the other is oriented towards the working methods of technical fields and technology professions, among other things. Also, comparable divisions of the technology subject can be found in previous research (e.g., Nordlöf et al. 2022; Stoor & Popov, 2021).

The following coding scheme was used in the content analysis that was conducted:

For the first step

A. The text talks through the teacher
B. The text talks to the teacher

For the second step where we looked at the units coded as B in the first step

1. Suggestions on how lessons can be adapted in various ways without losing the intended purpose are given.
2. The unit presents the reasoning behind, and contextualized concrete examples of, the pedagogical ideas included in the teacher's guide.
3. The unit makes important content visible and explains it.
4. The unit provides support for teachers' different needs for themselves and their students.
5. The unit motivates the importance of technology education for societal and everyday life.
6. The unit provides teachers with examples of how work within various technical disciplines is carried out in practice, and how this can be part of the teaching.

To strengthen internal reliability (Robson, 2002), all three researchers started to code the first chapter both regarding step 1 and step 2. This first coding was followed by a meeting where we compared and discussed the coding. For step 1 the authors interpreted the texts with nearly 100 % alignment in the coding, as it is clear whether the content of the guide speaks through the teacher or to the teacher. For step 2, the initial coding agreement was 85 %. We discussed the coding until consensus on how to interpret the coding scheme was reached. Thereafter, the remaining chapters were divided among the researchers.

Results

The digital teacher's guide is just over 200 pages, consisting of an introduction and six chapters. The introduction describes the structure of the teacher's guide and the idea behind the textbook. It also includes a list of materials and equipment needed for the practical sessions. The following chapters are based on the structure in the textbook. In brief, the chapters cover the following content: 1) solid mechanics and materials, 2) design, constructions and drawings, 3) control and regulation technology and programming, 4) communication and internet, 5) technological systems, and 6) the relation between individuals, society, environment and technology. Each chapter in the teacher's guide has the same structure. First, there are three common parts: Introduction, Connections to the curriculum, and Assessment. This is followed by 10-12 subchapters, corresponding to the subchapters in the textbook, addressing the content in the chapter (facts and theoretical information) and projects (tasks and assignments). Throughout the teacher's guide, there is a strong link to the textbook, for instance, through images of book spreads to show the teacher which pages in the book are the focus of each section of the guide.

Text that talks through the teacher

Approximately 75% of the teacher's guide is text that talks through the teacher. A large part of the guide is the answer key to the textbook. There are also direct instructions for the teacher on how to conduct the teaching.

In each subchapter, there is a heading called *Teaching* where the guide provides direct instructions for the teacher. They follow the same structure, but subheadings can differ between subchapters. In one subchapter the subheadings are as follows: (1) read the texts, (2) explore, (3) use a checklist, (4) consider the objectives of the section, and (5) engage in a term hunt. Additionally, there is a section called *Keywords* offering suggestions for search terms and tips on conducting searches. The instructions in the guide are clear and straightforward. For example: "Let the students read the text on pages 48–55 silently or read the text aloud to them." Another example: "Use the worksheet and have students write a list of various technical solutions," or "Let students discuss and document their ideas on the worksheet." Yet another example: "Use image search and ask students to identify which term from the box on page 48 they think matches the image." The text under each subheading is structured in bullet lists. The excerpt below shows an example from another subchapter.

1. Read the texts
    - Have the students read the text on pages 10-14 silently or read the text aloud to the students.
    - Ask students to stop and answer the questions on each spread with a classmate while reading.
2. Concept associations
    - Ask students to think about what they associate the terms compressive strength, tensile strength, and flexural strength with.
    - Then have students share their associations with a classmate.
    - Collect the associations as a whole class and write them on the board.

In each subchapter, there is also an *Answer Key* that references the page in the textbook where the questions are found, restates the question, and provides the answers. The *Answer Key* thus presents answers to questions that technically do not have a single correct answer. However, it presents one answer without clarifying that there is only one possible answer and that there may be others. Of course, some questions do have only one correct answer, such as when students are asked to fill in the correct term from a list.

In all, most of the guide talks directly through the teacher, who can essentially use it as a script. Alternatively, it can be employed as a practical step-by-step guide: "Distribute the worksheet to the students, then ask them to answer the questions."

Text that talks to the teacher

The teacher's guide has a small amount of text that talks to the teacher, approximately 25 %. It is primarily in the *Introduction* sections, both the introduction to the chapter and the subchapter, where texts talking to the teacher can be found. The introduction sections outline the purpose of each chapter and subchapter, along with what the following sections cover. These sections may also describe how and why teaching can be adapted, emphasize certain key content, highlight specific challenges, or address what students may find difficult. The introduction talks to the teacher but primarily describes how the chapter is structured and what students are expected to take away. Some definitions of terms are also provided, for example: "The chapter begins with a section that describes the concept of design. Students need to understand that design involves both appearance and function. Students must also understand that design can involve a process.". The connection to core content and commentary material explains how the chapter relates to the syllabus in technology.

The assessment section in each chapter also talks to the teacher. These sections include a rubric that provides examples of student responses for the passing level and higher grade levels.

However, sometimes the text that talks to the teacher is so short or vague that it can be confusing rather than educative for the teacher. This first example is from the introduction to a section about controlling, regulating, and programming*:*

> *Different [programming]languages are suited to different tasks, and in technology [education] it is good to start learning a visual programming language.*

In the following text, there are no explanations as to why it is good to start learning a visual programming language. This information raises questions for the teacher rather than guiding how to teach.

A similar example is found in a section about a project assignment about a model of a process industry. In the student book, a visual model of a process is introduced. In the teacher's guide, the teacher gets the following information about the visual model:

> *The model lacks several steps that, for example, make the paper thinner, smoother, and whiter.*

After this, there are no further explanations. The teacher probably wonders why these steps in the model are lacking, but she will find no answers or explanations for this. In brief, the text that talks to the teacher is insufficient and thus makes the teacher's guide difficult to use.

In the following, we provide examples of how the six design principles were identified in the text.

Design Principle 1 (DP1) – suggestions on how lessons can be adapted in several ways without losing the intended purpose

DP1, which focuses on how teachers might adapt their teaching materials by providing suggestions for adjustments, timing considerations, and addressing diverse student needs, is not extensively covered. However, there are a few examples:

> *Keep in mind that this section may take more time depending on the students' prior knowledge*

> *As an alternative to the project on pages 82–83, students can design a [...], The main difference is that [...] can be placed on a frame with wheels. This way, the house can be moved between different locations.*

> *Students often find it challenging and complicated to create drawings. If they are given ample time, they usually manage to produce drawings that show simple objects with two views and measurements after some practice. Allow students extra time for this section.*

These examples illustrate occasional suggestions for adjustments based on time, alternative projects, and strategies to address common difficulties students face.

Design Principle 2 (DP2) – the reasoning behind, and contextualized concrete examples of, the pedagogical ideas included in the teacher's guide

DP2 is not very present in the teacher's guide overall. However, it is visible in the assessment section included in each chapter. The assessment sections are connected to the syllabus and its assessment criteria, presented in the teacher's guide as rubrics (see example in Figure 1). The assessment rubrics offer the teacher support in the form of examples of student answers at two levels, passed level and higher level, with examples of acceptable student answers on each level.

Objective	Passed level	Higher level
Explain how constituent parts work together in technical solutions	**Version of task 1 on page 33 in the student book:** You are tasked with constructing a bridge that is attached to a support at one end and protrudes over the water. Where should the reinforcement be placed for the bridge to have good strength? Motivate.	Same task
Assessment instructions	The student states that the bridge bends downwards at the far end and that the reinforcement should be placed at the top. **Example of student answer:** The pier is bent down at the far end and then the reinforcement must be placed at the top.	The student states that the reinforcement should be placed at the top with a clear justification linked to tensile strength. **Example of student answer:** The bridge is fixed at one end and then the bridge bends down at the far end. When the outer part of the bridge is pushed down, the upper part of the bridge is pulled apart. The steel rebars have good tensile strength and should therefore be placed at the top of the bridge.

Figure 1. Example of assessment rubric.

Moreover, DP2 is found in the introductions of the subchapters, albeit with limited examples. One such example is:

> *Many students prefer to make drawings on graph paper, which can be a good starting point. However, when adding measurements and drawing lines between the grids, a drawing on graph paper can become unclear. Drawings intended for production are always made on plain white paper. Make students aware of this and let them try drawing their sketches and drawings on white paper.*

This example illustrates how the guide occasionally provides pedagogical reasoning that connects teaching methods to practical outcomes, but these instances are sparse. DP2 often follows text that can be categorized under Design Principle 4. Frequently, a section begins by identifying something students find challenging (DP4), after which the guidance outlines a method or pedagogical approach to help the teacher guide students in understanding or completing the task.

An example of such a text is:

> *Explain to the students that there are often missing components, either due to a lack of knowledge or simply oversight. The important thing is that the students understand that these are models that can be used to explore the potential consequences a product may have for individuals, society, and the environment.*

This demonstrates how DP4 (identifying challenges) transitions into DP2 (providing pedagogical guidance to address these challenges).

Design Principle 3 (DP3) – supporting teachers' subject knowledge, making important content visible, and explaining it

DP3 appears, to varying degrees in different chapters and subchapters. For instance, in the chapter discussing technological development work, there is a stronger focus on essential subject content than in the other chapters. In the introduction, it is explained that "students must also understand that design can involve work, meaning creating new technical solutions." Furthermore, it is described that an important aspect is for "students to acquire the knowledge necessary to carry out their technological development projects." The process is depicted as a circular motion: "The circular motion refers to the frequent need to go back and improve technical solutions during development." It is also emphasized that "technological development work is not a linear process but rather consists of a circular model, involving transitions between different phases, where reflection is crucial for both the process and the outcome." The text provides a relatively detailed description of the essential content that students need to grasp. Other important elements include "understanding that a sketch is a simple drawing made freehand, while a technical drawing is precise and created with a ruler once the solution's design has been determined."

Although the other chapters contain less of DP3, some examples can be identified. In the introduction to each chapter, the text sets the scene for the teacher with a few short lines about the topic and the purpose and structure of the chapter. It is common to find examples of DP3 in these introductions, but the descriptions are seldom detailed, as exemplified in this excerpt about technological systems:

> *...what is typical for a system, is to have a purpose, parts that interact, some parts are more important, the system has a boundary with the outside world, they depend on the outside world in different ways and people are present.*

DP3 can also be observed when words and concepts are highlighted in the text. Sometimes the guide also gives a short explanation of the meaning, for example as follows, where the concept of a model is explained:

> *Students must understand that a model is a tool to try out a solution. It is therefore important that they learn to adapt their models if they do not work as intended. Point out that the model is not the same as a prototype or a finished product.*

Based on how DP3 is designed and constructed, no explanations longer than a sentence or two, to give teachers deeper knowledge of important content, are found. Further, there are no visible connections regarding important content between the chapters. Although there are examples of DP3, they are not visible throughout the texts but appear occasionally and to varying degrees in different chapters.

Design Principle 4 (DP4) – support teachers' different needs for themselves and their students

The core of DP4 is to pinpoint different needs among different teachers and different students, based on varying needs in different situations. However, this teacher's guide does not discuss this in the form of examples for different situations or comparisons for different solutions.

Examples of text talking to the teacher that can be related to DP4 are found when the guide points out content that may be difficult for students. For example, on technological systems: "To understand the system boundary can be difficult". In the following, the guide gives short examples of a mobile phone and a mobile system, but no support to the teachers in how to teach about this or explain boundaries in different situations.

Overall, the guidance focuses on supporting the teacher in addressing students' challenges, misunderstandings, and difficulties**.** For instance, the introduction to one section on the design process states that "many students are eager to draw sketches in perspective, and it is good if they practice drawing in perspective." Another example is that "students often find it difficult and complicated to create technical drawings."

Design Principle 5 (DP5) – provide teachers with examples of how work within technical disciplines is carried out in practice, and how this can be part of the teaching

DP5 is in general not very visible. There are examples in the teacher´s guide of links to various professions as a way of making technology lessons meaningful and relevant to the world outside school. Still, these examples are not discussed deeply. In one chapter, we found this example:

> *Students may think that block programming is something you do in school, but block programming is also common in industry, for example, to control industrial robots or manufacturing machines.*

However, in the chapter on technological development work, there is a significant amount that can be linked to DP5. This chapter includes an entire section on how architects work when designing a residential house, followed by a later section where the students themselves get to try working as architects. In the introduction to the subchapter, it is stated that "the purpose of this section is for students to gain insight into how one works when building a new house" and that "the architect's work is similar to industrial design, with the major difference being that the architect's work results in a single technical solution, a house, while the industrial designer's work results in many identical technical solutions."

Another example of students engaging in real-world work is a project where they are tasked with "solv[ing] problems faced by another person in their everyday life. The project involves designing an aid for a person with a functional variation." In the guidance, teachers are encouraged to emphasize that students should immerse themselves in the work of a designer.

A chapter on the consequences of technology and technological choices also describes that

> *technological development can become their future career. A large portion of job opportunities in Sweden are technology-focused, and education in technical professions is highly likely to lead to good employment. To encourage students to choose technical careers, schools need to highlight the diversity in the field and demonstrate that technology does not have to be dirty, heavy, or noisy.*

Design Principle 6 (DP6) – support teachers to make the importance of technology for societal and everyday life visible

In DP6 the core is to relate knowledge from technology education to society and everyday life. Overall, this principle is rarely noticed in the teacher´s guide. In certain chapters, DP6 is entirely absent, such as in the chapter on technological development work. However, in the chapter addressing the consequences of technology, technological choices, and sustainable development, some texts provide teachers with a foundation for the civic purpose of the content in technology education. For example, teachers are encouraged to "emphasize to students that the best approach is to minimize waste, meaning we should only buy products we truly need" and to urge students to "read about how recycling can work for materials such as plastic, cardboard, glass, metal, and food waste."

Another example is the discussion of societal implications, such as:

> *No one knows which jobs robots will handle in the future, making it difficult to predict the role humans will play. What will society look like when robots can drive our vehicles, write our newspapers and books, compose new music, or fight our wars? No one knows. One thing is certain: for us to move toward a bright future, machines must operate according to the principles of human rights and protect the environment.*

Additional examples that support civic purpose include historical perspectives, such as "a description of the combustion engine and generator that enabled transportation and electricity production" or "how the assembly line principle revolutionized manufacturing, leading to mass production during the 19th and 20th centuries."

Regarding technological systems, there are a few glimpses of DP6. In the introduction section, the aim of the chapter is related to this principle:

> *Students will also gain an understanding of how we depend on different technological systems and see examples of technological systems that they depend on in their everyday lives.*

There are a few more sentences that relate in a corresponding way to the content of the chapter on society, e.g., systems needed "for society to function well". However, except for in the introduction, the teacher's guide never takes this principle further by giving the teacher teaching support or examples of how to help students understand how to use knowledge from technology to make decisions in their everyday lives.

Discussion

As mentioned above, Remillard (2000) points out that teacher guides commonly talk *through* teachers and argues that they should be designed to speak *to* teachers to be educative, although Remillard and Reinke (2012) suggest that a teacher´s guide can also be educative by talking through the teacher. This is supported by Van Steenbrugge and Ryve (2018) who emphasize that teacher guides that talk through teachers can be a support for teachers who feel insecure about the subject or are unaccustomed to teaching situations. Here, we have analyzed a teacher's guide that predominantly speaks through the teacher and identified certain patterns that might have implications for technology education.

First and foremost, Van Steenbrugge and Ryve (2018) suggest that a teacher's guide that talks through the teacher will support in *offloading* a lesson rather than *adapting* it. Thus, we can see how the guide's structure and content shape the teacher's role in the classroom by providing direct instructions that leave little room for individual adaptation. This approach reinforces a particular view of the subject and its core content, while implicitly suggesting particular methods without explicitly explaining their purpose or rationale.

There is an imbalance in the support provided across different chapters, and we also observe that the analyzed teacher's guide aligns closely with the textbook chapters. Each chapter in the guide mirrors those in the textbook and primarily speaks through the teacher. In practice, this leads to different levels of support for teachers in different areas of technology education. Largely, the guide functions as a manual for teachers to follow. This type of teacher's guide, which mostly consists of "recipes" to follow, is suitable for inexperienced teachers who need hands-on instructions (Van Steenbrugge & Ryve, 2018). However, those seeking more in-depth information or deeper texts are left to search for other sources on their own. This approach risks reproducing the author's own experiences, perspectives, and views on the subject. We note that the guide's direct and concrete instructions to the teacher include a particular subject content and an implicit perspective on both the core content and necessary adaptations. This presents a challenge for technology education with such a teacher's guide. Teachers who do not have sufficient knowledge beyond the "manual" might struggle to answer questions and adapt tasks or content for a diverse group of students.

However, the introductory texts for each chapter and section talk *to the teacher* and follow a consistent structure. Design Principle 1, which focuses on how teaching can be adapted to time constraints, special needs, and similar factors, is largely absent and offers little or no guidance. Adaptations and important content are implicitly included in the instructions without explanation or awareness of why they are necessary. Design Principle 2, which aims to make pedagogical ideas explicit for the teacher, is often addressed alongside Design Principle 4, which highlights challenges or difficulties students may face. The assessment rubrics seem to be the primary contribution related to Design Principle 2. Texts linked to Design Principle 3, which emphasizes important content, are only a small part of the guide. This is significant because such content would be valuable for teachers responsible for delivering the material. While the guide's speaking through the teacher indirectly emphasizes important content, texts addressed directly to the teacher fail to highlight this prominently. The applications of Design Principles 5 and 6 vary between chapters. In some cases, goals related to these principles can be inferred from the introductions, but they are not presented in detail, except in a few cases. Overall, the guide is quite superficial in how it talks to the teacher. Moreover, when concrete descriptions are provided, they are sporadic and isolated.

Even though technology teachers seem to prefer curriculum materials that can easily be offloaded (Given & Barlex, 2001), other studies have shown that educative features are necessary to support teachers in choosing to complement resources to provide students with a broad and nuanced view of the topic. Engström et al. (2023) observed that technology textbooks cannot cover everything, requiring teachers to supplement them with additional materials. To support this, the teacher's guides must "speak to the teacher," which the analyzed guide fails to do.

To summarize, we can observe the following consequences for technology education: Teachers may rely too heavily on the guide, limiting adaptability to diverse classroom needs. Teachers may struggle to adapt lessons to the needs of diverse student groups, as the guide provides limited room for personal interpretation or modification. If the teacher's guide takes the form of "recipes", the teacher must remember that it is not the only way to teach. Teachers should treat it as an example and always adapt their teaching to suit their specific circumstances and the needs of their students.

Gaps in teacher knowledge or understanding could lead to inadequate explanations and support for students. Teachers, particularly those with less experience or limited subject knowledge, may become overly reliant on the guide, reducing their ability to address unexpected questions or challenges. A teacher's guide should not replace teacher education or professional development. However, it should still be functional for temporary substitutes, such as a substitute teacher, and could, if designed in an educative way, serve as part of professional development.

The emphasis on a fixed structure and specific instructions risks overlooking broader aspects of the subject, limiting students' exposure to diverse perspectives or approaches. The lack of explicit explanations for suggested methods and adaptations can hinder teachers' understanding of recommended approaches, reducing their capacity to make informed pedagogical decisions. With little guidance on adapting teaching to different experiences or needs, the guide risks failing to support inclusive teaching practices, potentially disadvantaging certain student groups.

These patterns highlight the need for a teacher's guide that not only provides structure but also empowers teachers to adapt and expand upon the material in meaningful ways.

Against this backdrop, and in agreement with Remillard (2000), we would like to emphasize the importance of designing teacher guides with more texts that speak to the teacher, not just through them. Teacher guides need to prioritize communication that empowers teachers to reflect and adapt, rather than merely follow a prescribed method. For teacher education programs we recommend providing students with opportunities to explore and compare different types of teacher guides. Encouraging them to reflect on the differences in approach and their implications for teaching practice will help them to understand and later choose curriculum materials for their teaching (Brehmer, 2023). This approach fosters a deeper understanding of the role of teacher guides and supports the development of flexible and reflective teaching practices.

The findings of this study highlight several important implications for school practice. Schools should be aware that the teacher's guide — when functioning primarily as a directive tool — may limit teachers' opportunities for reflection and professional growth. Therefore, teachers should be encouraged to use teacher guides critically and reflectively. While following clear instructions can be helpful, it is crucial that teachers see these materials as one of several tools in planning and enacting teaching. Teachers can benefit from engaging with questions such as: What is the purpose of this task? What might be missing? The study has limitations as it analyses one teacher's guide. We therefore chose the teacher's guide that accompanies the textbook most used in technology education in Swedish schools. While the study is not generalizable, we argue that it maintains a high level of credibility. Established qualitative methods and a strong contextual understanding have guided the work. Three researchers have reflected on interpretations and potential biases. The results may be applicable in other contexts, as we present the study's setting, methods, and scope. Our interpretations are firmly grounded in the data (Shenton, 2004). However, our intention is not to generalize the results but to qualitatively analyze and describe how a technology teacher's guide communicates with the teacher. With this contribution, we want to put the spotlight on curriculum materials in technology education and encourage others to start investigating the topic. We find the previous research on curriculum materials in technology education is almost nonexistent. Considering the impact curriculum materials have on how teachers plan and organize their teaching (Oates, 2014), more research is needed.

References

Bachmann, K. (2005). *Læreplanens differens. Formidling av læreplanen till skolepraksis. (*Doctoral theses). Pedagogisk Institutt, Norges Teknisk-naturvitenskaplige Universitet.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is–or might be–the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6–8, 14.

Brehmer, D. (2023). *Lärare lär av läromedel. Att förstå, utvärdera och utvecklas av läromedel i matematik.* [*Teachers learn from curriculum materials. To understand, assess, and develop through curriculum materials in mathematics*]. Studentlitteratur.

Brown, M. (2009). The teacher–tool relationship: Theorizing the design and use of curriculum materials. In J. T. Remillard, B. Herbel-Eisenman, & G. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (p. 17 – 36). Routledge.

Davis, E. (2021). Commentary: Instructional Materials Supporting Teachers' Professional Learning. *Journal of Science Education, 32*(7), 836-841.

Davis, E. & Krajcik, J. (2005). Designing Educative Curriculum Materials to Promote Teacher Learning. *Educational Researcher 34*(3), 3-14. https://doi.org/10.3102/0013189X034003003

Davis, E., Palincsar, A., Smith, S., Arias, A., & Kademian, S. (2017). Educative Curriculum Materials: Uptake, Impact, and Implications for Research and Design. *Educational Researcher 46*(6), 293-304. https://doi.org/10.3102/0013189X17727502

Driscoll, M. P., Moallem, M, Dick, W., & Kirby, E. (1994). How does the textbook contribute to learning in a middle school science class? *Contemporary Educational Psychology, 19*, 79-100.

Englehart, D. S. (2010). Contrast of the science teaching practices of two preservice early childhood educators. *Florida Association of Teacher Educators Journal*, *1*(10), 40-54.

Englund, B. (2006). *Vad har vi lärt oss om läromedel? En översikt över nyare forskning: underlagsrapport till Läromedelsprojektet [What Have We Learned About Educational Materials? An Overview of Recent Research: Background Report for the Educational Materials Project* (an electronic resource)]. Skolverket.

Engström, S., Sundqvist, P., Nordlöf, C., & Klasander, C. (2023). Approaches to industrial processes in technology textbooks. In S. Davies, M. McLain, A. Hardy & D. Morrison-Love (Eds.), *The 40th International Pupils' Attitudes Towards Technology Conference Proceedings 2023*. Liverpool John Moores University.

Fahrman, B., Norström, P., Gumaelius, L., & Skogh, I. B. (2020). Experienced technology teachers' teaching practices. *International journal of technology and design education*, *30*(1), 163-186. https://doi.org/10.1007/s10798-019-09494-9

Fuentes, S. & Ma, J. (2017). Promoting teacher learning: a framework for evaluating the educative features of mathematics curriculum materials. *Journal of Mathematics Teacher Education 21*(4), 351-385. https://doi.org/10.1007/s10857-017-9366-2

Given, N., & Barlex, D. (2001). The role of published materials in curriculum development and implementation for secondary school design and technology in England and Wales. *International Journal of Technology and Design Education*, *11*, 137-161. https://doi.org/10.1023/A:1011202516144

Graeske (2021). *Läromedelsbruk i skolan. En kunskapsöversikt – perspektiv och forskning*. Dnr. Komm2021/00295/U2019:04-26.

Hanuscin, D. et al. (2025). Designing Educative Curriculum Materials for Teacher Educators: Supporting Preservice Elementary Teachers' Content Knowledge for Teaching About Matter and Its Interactions. *International Journal of Science and Mathematics Education 23*, 193–213.

Janko. T., & Pešková, K. (2017). Exploring Teachers' Perceptions of Curriculum Change and Their Use of Textbooks during its Implementation. A Review of Current Research. *Zeitschrift für Geographiedidaktik | Journal of Geography Education*, *45*(1), 33–60. https://doi.org/10.18452/23097

Jukić Matić, L., & Glasnović Gracin, D. (2021). How do teacher guides give support to mathematics teachers? Analysis of a teacher guide and exploration of its use in teachers' practices. *Research in mathematics education*, *23*(1), 1-20. https://doi.org/10.1080/14794802.2019.1710554

Melton, J. C., & Mikeska, J. N. (2025). Variation in the Implementation of Educative Curriculum Materials for Elementary Science Teacher Educators in Two Course Contexts: An Exploratory Case Study. *Journal of Science Teacher Education*, 1–22.

National Agency for Education. (2024). *Curriculum for Compulsory School, Preschool Class and School-Age Educare, LGR22.* https://www.skolverket.se/publikationsserier/styrdokument/2024/curriculumforcompulsoryschoolpreschoolclassandschoolageeducarelgr22.4.7c808d9519080d9657c2.html

National Agency for Education. (2024a). Pedagogisk personal i skola och vuxenutbildning Läsåret 2023/24 [Teaching staff in schools and adult education - academic year 2023/24] https://www.skolverket.se/publikationsserier/beskrivande-statistik/2024/pedagogisk-personal-i-skola-och-vuxenutbildning---lasaret-2023-24

Neuman, S. Pinkham, A. & Kaefer, T. (2015). Supporting Vocabulary Teaching and Learning in Prekindergarten: The Role of Educative Curriculum Materials. *Early Education and Development 26*(7), 988-1011. https://doi.org/10.1080/10409289.2015.1004517

Nordlöf, C., Hallström, J., & Höst, G. E. (2019). Self-efficacy or context dependency?: Exploring teachers' perceptions of and attitudes towards technology education. *International Journal of Technology and Design Education, 29*(1), 123-141. https://doi.org/10.1007/s10798-017-9431-2

Nordlöf, C., Höst, G., & Hallström, J. (2022). Technology teachers' talk about knowledge: from uncertainty to technology education competence. *Research in Science & Technological Education*, *42*(2), 336–356. https://doi.org/10.1080/02635143.2022.2070150

Oates, T. (2014). *Why textbooks count.* Cambridge Assessment.

Remillard, J. T. (2000). Can curriculum materials support teachers' learning? Two fourth-grade teachers' use of a new mathematics text. *The elementary school journal, 100*(4), 331-350.

Remillard, J. T., & Kim, O. K. (2020). *Elementary mathematics curriculum materials: Designs for student learning and teacher enactment*. Springer Nature.

Remillard, J. T., & Reinke, L. (2012, April). Complicating scripted curriculum: Can scripts be educative for teachers. In *Annual Meeting of the American Educational Research Association.* Vancouver, BC.

Roberts, D. (2007a). Linné scientific literacy symposium. Opening remarks by Douglas A. Roberts. In Linder, C., Östman, L., & Wickman P-O. (Eds) (2007). *Promoting scientific literacy: science education research in transaction.* Proceedings of the Linnaeus tercentenary symposium held at Uppsala University, Uppsala Sweden, May 28-29, 2007.

Roberts, D. (2007b). Scientific literacy/Science literacy. In S. K. Abell & N. G. Lederman (Eds), *Handbook of research on science education* (pp. 729–780). Lawrence Erlbaum Associates.

Roberts, D., & Bybee, R. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman & S. K. Abell (Eds*), Handbook of research on science education* (Vol. Vol. II, pp. 545–558). Routledge.

Robson, C. (2002). *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*. Blackwell.

Roseman, J. E., Herrmann-Abell, C. F., & Koppal, M. (2017). Designing for the Next Generation Science Standards: Educative Curriculum Materials and Measures of Teacher Knowledge. *Journal of Science Teacher Education*, *28*(1), 111–141. https://doi.org/10.1080/1046560X.2016.1277598

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for information*, *22*(2), 63-75.

Schlag, S., & Glock, S. (2024). The roles that students' ethnicity and achievement levels play in teachers' choice of learning materials in online teaching: evidence from two experimental studies. *Instructional Science*, 1-19.

Skolinspektionen. (2014). *Teknik—gör det osynliga synligt.* http://www.skolinspektionen.se/Documents/publikationssok/granskningsrapporter/kvalitetsgranskningar/2014/teknik/kvalgr-teknik-slutrapport.pdf.

Snyder, J., Bolin, F. & Zumwalt, K. (1992). Curriculum Implementation. In P.W. Jackson (Ed.) *Handbook of Research on Curriculum* (pp. 402–435). Macmillan.

Stoor, M., & Popov, O. (2021). Societal Aspects of Technology: The Swedish Lower Secondary School Curricula in International Comparison. *Techne series: Research in sloyd education and crafts science. A*, *28*(2), 140-148.

Van Steenbrugge, H., & Ryve, A. (2018). Developing a reform mathematics curriculum program in Sweden: Relating international research and the local context. *ZDM*, *50*, 801-812. https://doi.org/10.1007/s11858-018-0972-y

Design and Technology Education: An International Journal

30.1

Three levels in culturally oriented product design: a participatory approach to cultural inspiration in design education

Weishu Yang, Yunnan University of Finance and Economics, Kunming, China & University of Helsinki, Finland
Henna Lahti, University of Helsinki, Finland
Pirita Seitamaa-Hakkarainen, University of Helsinki, Finland

Abstract
Culturally oriented product design relies on inspiration from the local cultural heritage in the creation of unique products with specific local features. An authentic experience of cultural design inspiration can facilitate novel design outcomes. However, only a few studies have investigated the acquisition of cultural inspiration from a participatory perspective in the field. To narrow this gap, a design workshop was organized with local government in China. Design students were asked to combine local cultural characteristics in everyday products and to generate new concepts that reflect cultural diversity and support local tourism development. We collected students' visual representations, text notes and recorded verbal explanations of the concepts behind the created product designs. The entire data was analysed following the method of holistic coding to identify the types of cultural inspiration and cultural levels. Data-driven analysis included two rounds of categorising. Using the product metaphorical mapping tool, we specified three cultural levels and the cultural elements related to them. The analytical method helped reveal students' design intentions in applying both tangible and intangible cultural elements The results demonstrated that design educators can support young designers to apply the participatory approach in bringing ethical cultural transformations regarding visual, behavioural and philosophical design features.

Keywords
cultural inspiration, minority culture, participatory approach, culturally oriented product, product design

Introduction
Interest in design education among the cultural industries and tourism has been growing in recent years, whereby traditional cultural artefacts inspire the creation of new culturally oriented products with unique traditional or ethnic characteristics (Luo & Dong, 2017; Qin & Ng, 2020). Cultural products could have high commercial value and market potential (Chai et al., 2018; Shin et al., 2011). According to Luo and Dong (2017), cultural inspiration (i.e., visual and textual sources) serves as input to the process of cultural product design when the output is a new culturally oriented product. Two terms have been used interchangeably in this context: culturally inspired design (Dong et al., 2023), culturally oriented design (Moalosi et al., 2010; Lupo & Giunta, 2016; Luo & Dong, 2017). In this study we adopt the concept of culturally oriented product design since it highlights the importance of investigation of regional and/or ethnicity-based cultural groups and provides a methodology to investigate culture, identify and

transform cultural values into product forms. In contrast to universal or mass-produced product, culturally oriented design places more emphasis on cultural diversity and actively incorporates it into design processes. Moalosi et al., (2010) have noted that globalization tends to create more uniform lifestyles and perceptions, as similar products spread worldwide, potentially leading to a shared global culture. Despite globalization, users retain their cultural preferences, and designers need to adapt product design to reflect culturally diverse values, norms, and behaviors. Luo and Dong's (2017) research concerns integrating historical originality into product design and focuses on cultural interpretation. They indicated that culturally rich and creatively reinterpreted designs are more appreciated than mass-produced approach. Using cultural features in the process of reinventing new products designers need to be sensitive, respectful and avoid unethical cultural appropriation. However, in design, it is sometimes difficult to identify the phenomena of cultural appropriation and its' nuances. Cultural appropriation means taking an ownership of things that are part of the culture which they do not belong. Sensitive culturally oriented design preserves the local culture and introduces it to the global market at the same time (Dong et al., 2023; Shin et al., 2011). Cultural product design should support culturally sustainable development (Luo & Dong, 2017; Chai et al., 2018; Qin & Ng, 2020; Yang, 2024).

In the present study we held a design workshop for design students that involved experiencing a living minority heritage to inspire new culturally oriented product design. Participating in Chinese minority communities enabled the students to recognize the various cultural activities of the heritage. Our participatory approach included field research involving observations and discussions with artisans to develop new design concepts. The study and the workshop for Minority Culture were run in collaboration with the university of Yunnan University of Finance and Economics (YUFE) and the local government of Maguan County, Yunan Province, southwest China. The study was part of a larger project entitled "Beautiful Villages Construction", conducted in cooperation with the local Culture & Tourism Bureau (MACTB). The project relied on a rural revitalization strategy and tourism development. This research addresses the following questions:

- What kind of cultural inspiration did the students gain from the local minority culture?
- How is cultural inspiration mapped onto culturally oriented product design?

In the following section, we first present our theoretical framework mapping sources of cultural inspiration. We then describe the context of the study, the participants and the data collection and analysis. Finally, we present the results and discuss the implications of the study.

Cultural inspiration and participatory approach

Cultural inspiration is a crucial factor in the ideation process across design fields (Luo and Dong 2017). Sources of inspiration are diverse, encompassing both material and non-material elements such as traditional artefacts, images, material collections, places different texts, rituals, and mythology (Eckert & Stacey, 2003; Yang and Cheng 2020). Ideation is strongly related to inspirational sources that have different roles in the design process, expanding the notion of space and helping to keep the design in its context, thereby triggering idea creation and anchoring designers' propositions. Designers interpret and adapt elements of inspirational sources, such as by simplification or association with new ideas (Eckert & Stacey, 2003). The act of designing is strongly image-oriented (Keller et al., 2006), and previous research has revealed that visual stimulation triggers analogical thinking (Goldschmidt & Smolkov, 2006). Using a variety of inspirational sources, designers are able to generate new ideas as well as to modify and assimilate specific characteristics in the form of design concepts.

Designers and design students learn to utilize inspirational sources from ethnic and/or local cultures with their unique styles, decoration or functions that are identifiable from the architecture, everyday objects, tools, textile fabrics, ceremonial equipment and pottery, for example. Cultural product design that incorporates local features emphasises cultural value, which is also a critical issue in design education (Hsu et al., 2011). Liu and Chang (2013) analysed the relationship between symbolic Chinese elements and product forms. In another study, Chai et al. (2018) assessed the usefulness of the mean as a doctrine in Confucian philosophy to product design, using students' chair designs by way of illustration. Confucian philosophical system highlights the importance of hierarchy and harmony in social interactions, moral cultivation, and respect for tradition influencing various design forms and creating a distinctive cultural identity (Chai et al. (2018). Cultural product design focuses on conveying profound cultural meanings and highlighting cultural values and traditions in the finished product.

There have been previous studies on the inspirational sources of designers and design students, and how they are adapted in practise (Gonçalves et al., 2014; Lou & Dong, 2017; Qin & Ng, 2020). Most studies related to inspiration rely on interviews with the designers, or on analyses of the use of inspirational sources in various experimental settings. Gonçalves et al. (2014) used questionnaire data to study the influence of different types of inspirational stimuli on the design process. They found that visual stimuli played the most important role for designers. Many previous studies have introduced frameworks for cultural product design (Hsu et al. 2011; Qin & Ng, 2020) or have provided guidelines on the use of historical literature resources for cultural inspiration. Some studies, such as those by Lou and Dong (2017) and Qin and Ng (2020), employed individual case studies to illustrate culturally inspired design processes. Importantly, participatory design studies (Mavri et al., 2020; Moalosi et al., 2016) have involved various participants to engage with local cultural heritage and customs through direct contextual experiences. These studies include ethnic cultural immersion (Lemon et al., 2023) and community-based practical participation (Mavri et al., 2020; Moalosi et al., 2016). However, Lemon et al. (2023) argued that indigenous knowledge of curricula is controversial in countries where the minority indigenous population has minimal power and authority. According to them the decolonisation of technology education involves balancing and negotiating the tensions between local indigenous knowledge and general western knowledge.

In the study by Mavri et al. (2020), design students interacted directly with industry professionals through participatory communities that offered authentic learning experiences and bridging the gap between academic practice and professional expectations. According to Mavri et al. (2020), novel design outcomes can only be achieved in authentic contexts, and by taking a participatory approach. Similarly, in the study by Moalosi et al. (2016), the designers immersed themselves in the handcraft community and identified cultural memory factors associated with local traditional crafts and cultural events.Thus, instead of seeking inspirational sources solely from visual and written historical literature or museums in the present study we utilized the authentic cultural context, and we adopted a participatory observation within ethnic minority communities, integrating both visible and nuanced cultural elements into the student designer's product designs. The participatory approach (Roque et al., 2023; Van Oorschot et al., 2022; Manzini, 2016) which includes the use of informants, field observations, and active participation in real-life cultural activities can provide design students with richer, more locally embedded inspirational stimuli within minority community-based cultural contexts.

Sources of cultural inspiration and metaphorical mapping

Culturally oriented products draw on traditional cultural elements, such as form, decoration, and technique, to inspire both designers and consumers. For example, inspiration is sought from the nation's antique artifacts in the creation of cultural products with distinctive ethnic characteristics: in other words, "ancient cultural artifacts" work as "cultural inspiration" (Luo & Dong, 2017). The traditional culture and its artifacts, like other sources, inspire the localization of product design. By referencing local heritage, folklore, and cultural artifacts, these products provide a fertile ground for innovation across handicrafts, the creative economy, and cultural tourism (Summatavet & Raudsaar, 2015). In particular, heritage products function as bridges linking heritage, craft, and design, fostering collaboration between designers and craftspeople through boundary objects that serve as design tools (Suib et al., 2020).

Previous research has illuminated various ways designers engage with traditional culture. Kouhia's (2016) study underscores how material engagement through craft making and a range of traditional resources, from visual material, tactual and structural elements to personal interpretative associations, stimulate creative design. Kouhia and Seitamaa-Hakkarainen (2017) further identify three key strategies: a preservation strategy that faithfully reproduces traditional details; an application strategy that combines tradition with new materials and elements; and a transformative strategy that generates innovative concepts and entirely new product ideas. Rynning (2021) adds that national culture continues to inspire graphic designers even as they navigate the tension between globally accessible digital influences and local, traditional sources. Her findings suggest that designers integrate their cultural heritage into modern designs, blending national identity with global trends. Students are aware of their own cultural heritage and manage to balance national elements with global trends (Rynning, 2021). Gimeno-Martinez (2016) also discusses the importance of everyday objects as carriers and signifiers of national cultures.

Cultural elements tend to be adapted for its outer (visceral) appearance (i.e., colour, texture and form), emphasizing the aesthetic aspect. Within academic design settings, however, inspiration often comes from literature-based sources rather than participatory approaches, which can inadvertently foster design fixation. Seeing visual examples could halt the search for new inspiration and prevent the exploration of new possibilities. To counteract this, researchers such as Suib et al. (2020) emphasize the importance of real-world contexts and participatory approaches that engage tacit cultural knowledge and hands-on skills, helping students draw meaningful inspiration from traditional cultural narratives. Zhu (2020) examined the impact of visual and textual sources, or triggers, as cultural stimuli in cultural product design, using experiments to explore the impact of this information on the creativity of novice designers. The results of the study showed that the visual triggers, especially partial images with low pictorial richness, were more effective than textual triggers in stimulating creativity among novice designers. Complementing these insights, Lou and Dong (2017) reveal that different types of cultural triggers (pictorial and textual) impact creativity differently, with cultural-textual sources fostering deeper engagement and more innovative outcomes by tapping into the symbolic and historical dimensions of cultural artifacts.

Lou and Dong (2017) analysed the role of various forms of cultural inspiration in the designing of cultural products. They distinguished two types of inspiration: cultural-pictorial including shapes, decorations, colours, lines and textures) and cultural-textual (including information about usage, symbolism and aesthetics, technological information about materials and workmanship, as well as historical information such as folk stories). The experimental setting reflected the nature of the inspirational sources i.e., visual vs textual. The students produced a similar number of cultural features, but those who worked with cultural-textual inspiration produced more creative outcomes than those who worked with pictorial inspiration. Furthermore, those in the cultural-textual group tended to focus on the inner level of a cultural object, such as the connotation that made them think more about the internal elements of a product. In the other study, Dong et al., (2023) analysed differences among students engaged in cultural product design in experimental settings with two conditions: a guideline-aided condition and an unaided condition. The aim was to find out whether design guidelines for traditional cultural artefacts are useful and effective as a tool in the process of designing cultural products. Dong et al., (2023) concluded that the design guidelines for cultural products promoted deeper analysis of cultural features and increased the novelty and quality of the outcomes. More specifically, the guidelines were more supportive during the identification stage than in the translation stage.

Dong et al., (2023) proposed that the cultural design process had three phases: identification (extracting cultural features from an original cultural object), translation (transforming these features into design information and design elements) and implementation (designing the cultural product). Conceptual frameworks for cultural product design focus on how designers extract typical features through inspiration derived from culture. Qin and Ng (2020) adapted the concept according to previous research Siu (2005), who emphasized the layered mapping of intangible and tangible aspects between traditional culture and modern lifestyles. They introduced the metaphorical mapping framework, which is considered for designers to introduce traditional cultural elements into a product design to create novel cultural meaning (see Figure 1). The idea is based on guidelines concerning the use of traditional cultural properties to assess and protect objects rooted in local historical beliefs, customs and practices.

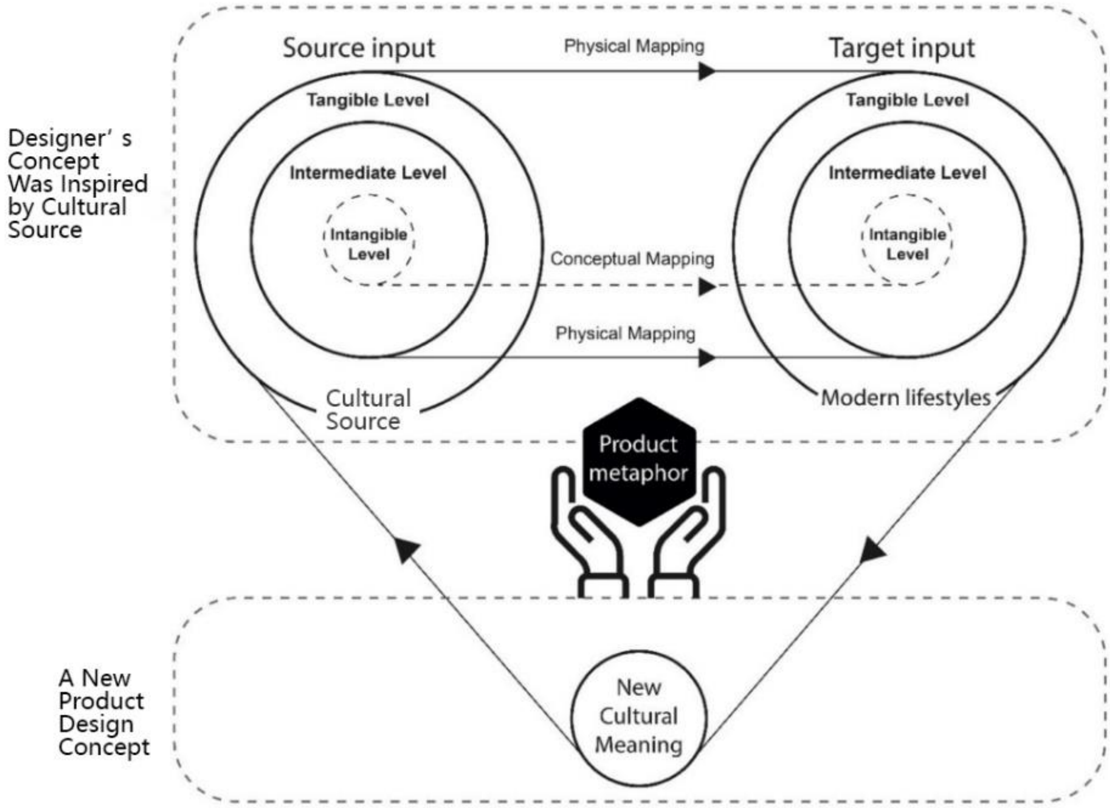


Figure 1. Conceptual framework for designing metaphorical mappings between cultural sources and modern lifestyles adapted from Qin and Ng (2020).

According to Qin and Ng (2020), the metaphorical mapping model distinguishes three layers of culture. (1) The outer layer corresponds to the tangible category and is related to physical and material culture, such as daily objects and tools. (2) The intermediate layer corresponds to the social and behavioural activities (i.e., rituals and customs) required to build a connection with the outer layer and the inner conceptual layer. (3) The inner layer corresponds to an intangible category (spiritual or ideal culture) that works as the core value to stimulate cultural thinking and association. The basic idea behind new cultural product design is to apply metaphors to map two distinctive, previously unrelated thoughts to produce a new hybrid idea. The three levels provide the designer with the physical experience needed to trigger the metaphorical connection. In other words, the new cultural meaning is stimulated when the source element's cultural features and the target element of modern lifestyles are mapped onto each other. The outer layer concerns visceral aspects such as colour, texture, form, decoration and surface pattern; the behavioural level concerns function, usability and safety; and the inner level concerns reflective design with special content, such as stories, emotions and cultural features. The diagrammatic tool enables researchers to interpret the designer's intention by analysing the levels of cultural sources. It was tested on students of product design in Qin and Ng's (2020) study, the aim being to analyse different historical Chinese cultural elements in new design concepts. Yang et al. (2022) used the three levels of cultural hierarchy to provide new insights into improving and adapting teaching practices in the field of cultural design.

Methods

Participants and the studied context

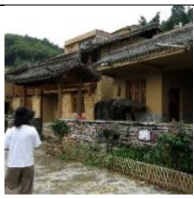
The aim of the study was to analyse how design students who participated and familiarized themselves with minority communities utilized resources of cultural inspiration for designing cultural products. The research design was based on the participatory approach, that incorporating informants, observations, and active participation in ethnic cultural activities, can provide expanded resources for understanding traditional cultures and provide design students with rich sources of inspiration. The study was conducted as part of a design course for fourth-year undergraduate students, namely Cultural and Creative Product Design. As part of the course, a Design Workshop for the Minority Culture was organized in collaboration with the university (YUFE) and the local government (MACTB) of Maguan County, Yunan Province, China.

Eight participants who were not familiar with the minority culture voluntarily attended the design workshop. The first author, who was responsible for the course and participatory field study, organized the workshop. It was based on the sociocultural learning approach, according to which learning is viewed as a deeply social process (Manzini, 2016; Mavri et al., 2020; Roque et al., 2023). In the design task, students were asked to combine local cultural characteristics into products for daily life, to generate new product concepts, and to consider how cultural product designs could be created to attract the tourism market.

During the participatory field study, the students visited two heritage villages and five different local sites. Southwest China is known as a multi-cultural and multi-minority area, and the traditional cultural forms of the ethnic Zhuang minority and Dai have been explored in Chinese studies (Bai, 2012; Sun & Ren, 2017; Li & Liu, 2021). Zhuang people are one of the largest ethnic groups in China and they belong to the Tai-Kadai linguistic group. Dai people belong to the Tai linguistic family and they have a rich cultural heritage rooted in Buddhism and indigenous religious practices. Zhuang people have strong cultural ties to agriculture, nature worship, and traditional festivals. Both minorities have strong tradition on craft cultures such as brocade weaving, embroidery and silver jewellery making. During the preparation stage, several meetings were held to formulate the field survey among the Masa Village committee and MACTB, and the first author searched for relevant literature of the ethnic cultures and visited local sites to plan the course agenda. Xiao Magu and Masa Villages were selected for the participatory observation including documentation and residents' interviews, because the rich territorial capital provided the students with a sociable element in the minority community.

The five-day field study comprised the visits described in Table 1. During designing, identifying socio-cultural factors is an essential phase of the design process (Manzini, 2016; Roque et al., 2023). The students were asked to make observation notes, take photos, interview residents and conduct online literature research for their project work. They also carried out a survey in the marketing area addressing the target products so as to understand user needs and relevant contexts of use. During the field visit, they met various local experts, artisans, museum curators, shopkeepers, and villagers; walked across tourist attractions; and participated in various events with the local people. These interviews and participatory observation focused on local minority traditions such as rituals, music and sports (sources of intangible cultural inspiration), as well as on tangible sources such as buildings, tools and traditional clothing. The participatory documentation focused on their memorable experiences and in-depth learning about the local environment and the design context.

Table 1. The schedule and basic information about the field

Schedule	Places	Basic information	Cultural Sources
The first day at the Maguan Area History Museum		The museum shows the development of the society in the Maguan area. It introduces visitors to the multiple aspects of Maguan society.	Various aboriginal objects including historical relics and productivity tools, as well as daily-living products, minority fashions, craftsmen and skills.
The second day at Xiao Magu Village		Xiao Magu Village is the biggest region for the Dai people and one of the aboriginal culture villages that has been assessed as a 3A scenic spot.	Dai Minority living heritage, folk houses, living heritage activities, original architecture, customs and clothing.
The third day in the Aboriginal Clothing Street Area		The street is famous as a marketing centre in Maguan County. The local government emphasizes features of the Zhuang nationality, combining their culture and clothing, and accessories for sustainability.	Most of the stores had many handcrafted fabric products, supplying all kinds of materials, clothing, and accessories related to the minority culture and heritage.
The fourth day at Masa Village		The village has more than 400 years of history and the ethnic Zhuang minority live in the area. At present, it is designated a 3A scenic spot, but it lacks tourism facilities, services and products.	Zhuang Minority living heritage and environment, folk houses, minority customs, artisans and traditional skills, village museum and various heritage objects.
The fifth day in the Cultural Core Area at Zhongshan Park		The garden is culturally oriented and promotes nature and the charm of the ancient. Zhongshan Pavilion stands on the top of the hill and people climb up to gaze at the panoramic view of the county.	Some buildings represent Chinese traditional architectures by combining elements of the local minority culture.

The local guides in the different villages were responsible for assisting the students by guiding them into the village. The Masa Village and its surroundings are rich in intangible and tangible cultural heritages, where the students participated in a traditional Zhuang minority wedding event (see Figure 2). There are also other various types of traditional music and dance rituals, such as the paper horse dance, the handkerchief dance and the “Nong Ren, 侬人” music concert. For example, the design students were able to join in the Masa dance and use headwear worn by the Zhuang minority (Figure 3). They learned traditional wood-cutting techniques, such as “A Er, 阿峨Woodcut”, and took part in daily life on the farm.


Figure 2 and 3. Students participating in a traditional minority wedding (figure 2); one tried on the minority headwear (figure 3)

After the field visit the students returned to their school campus to sketch culturally oriented new products. The product-design concepts they introduced were analysed.

Methods of data collection and analysis

For the data analysis we collected visual representations, text notes and recorded verbal explanations of the novel product concepts. We recorded the verbal explanations during interview meetings, which were later transcribed. Each of the interviews lasted approximately thirty minutes. The entire data was analysed following the method of holistic coding, as outlined by Saldaña (2009), to identify the types of cultural inspiration and cultural levels. Data-driven analysis included two rounds of categorising. The first step in the data analysis was to identify the design students' sources of cultural inspiration from notes, photos, and verbal explanations. Secondly, we used a metaphorical mapping tool (Qin & Ng, 2020) to specify the cultural levels and cultural elements of their design concepts. It is noted that these cultural levels are not necessarily mutually exclusive.

Table 2. The three-level structure and its subcategories

Cultural Level	Cultural Elements
Outer level: Corresponding to the tangible category, such as visual symbols, artifacts, normally in response to graphic elements.	Colour, Pattern, Materials, Form, Structure
Intermediate level: Corresponding to behavioural activities in a traditional institution or a contemporary lifestyle, which could be selected to build a connection with the outer layer and the inner layer.	Craft skills, Operation, Function, Expression of customs
Inner level: Corresponding to the intangible-implication category with a reflective design, and serving as the core value (e.g., beliefs among the minorities to stimulate cultural thinking and reflection).	Spiritual values, Religion, Philosophical thinking, Aesthetics

Results

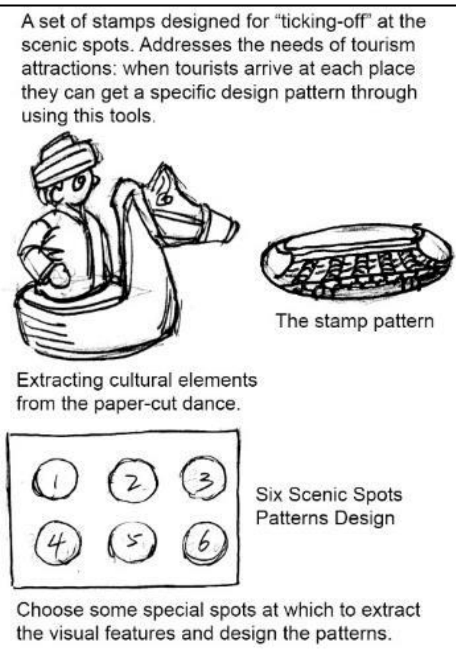
Eight student designers completed the task, producing a total of 13 sets of new culturally oriented product concepts (see the Appendix for an overview of the product-design concepts reflecting the source of cultural inspiration and the cultural levels). As predicted, most of the concepts were on the outer level, and the product's features derived from visual elements of the minority artifacts, sculpture and fashion, among other things. For example, the make-up set design (a bag for cosmetic tools) and red envelopes (to be used during the Chinese Lunar New Year) clearly reflected the visual element of embroidery patterns in minority clothing. In the same way, the toiletry designs were visually inspired by the artefacts in Xiao Magu village. Only a few of the design concepts were inspired by behavioural aspects of the rituals and the artefacts used in them. One example was the souvenir concept of a bull's head for home decoration and bracelets inspired by the minority wedding and the headwear used during that event. In addition, two of the design concepts referred to the inner level that represented the spiritual values or philosophical thinking of the minority culture. Thus, the main results indicate that cultural product design focuses on the use of apparent (superficial) cultural features such as shapes and patterns (cf. Qin et al. 2019). However, the direct visual-tangible outer elements can be transformed in a new setting or context. In the following we describe three examples of culturally oriented product concepts representing three cultural transformations with visual, behavioural and philosophical design features, respectively.

Masa Village seal set design derived from the outer level

The seal set design was inspired by the Masa artifact - a horse feature made by paper-cutting for a local traditional dance event. Related to the cultural source, the Masa artifact in traditional dance rites reflects the minority's ancestor worship (Bai, 2012). Nowadays, the dance combines physical activity, pleasure and education in minority living, and sustains such a cultural heritage. This new design concept - a seal set design (see Table 3) was intended for tourists visiting different scenic spots; they collect a distinctive stamp at each location and experience the visit as well-structured. Thus, the new product idea was mapped onto the modern tourism context. The student explained her idea:

> *This is used for "ticking off" at the scenic spots. When you arrive at a special spot, the seal is used to stamp the pattern according to your location, stating that you are there. We can select various scenic spots and extract the features from these places for special patterns, which can be stamped on the card.*

In the analysis of the metaphorical mapping the outer level was connected to creating a seal set design by using visual elements of the specific cultural inspiration (Masa paper horse) to map onto the product's features. The graphics on the stamps derived from the selected scenic spots and were deemed valuable for supporting present-day local tourism. The various cultural features of the site are presented through these vivid stamps with their specific graphics. Product features in the sketch solutions such as the stamp's shape, patterns and structure derived literally from the visual elements of the Masa artifacts.

Culture Source	Created New Product
	
The inspiration derived from a physical artifact called Masa, a horse feature made by paper-cutting for traditional dance events. Both young men and women of Zhuang minority enjoy dancing with the Masa tool.	
Cultural Transformation with Visual Features	

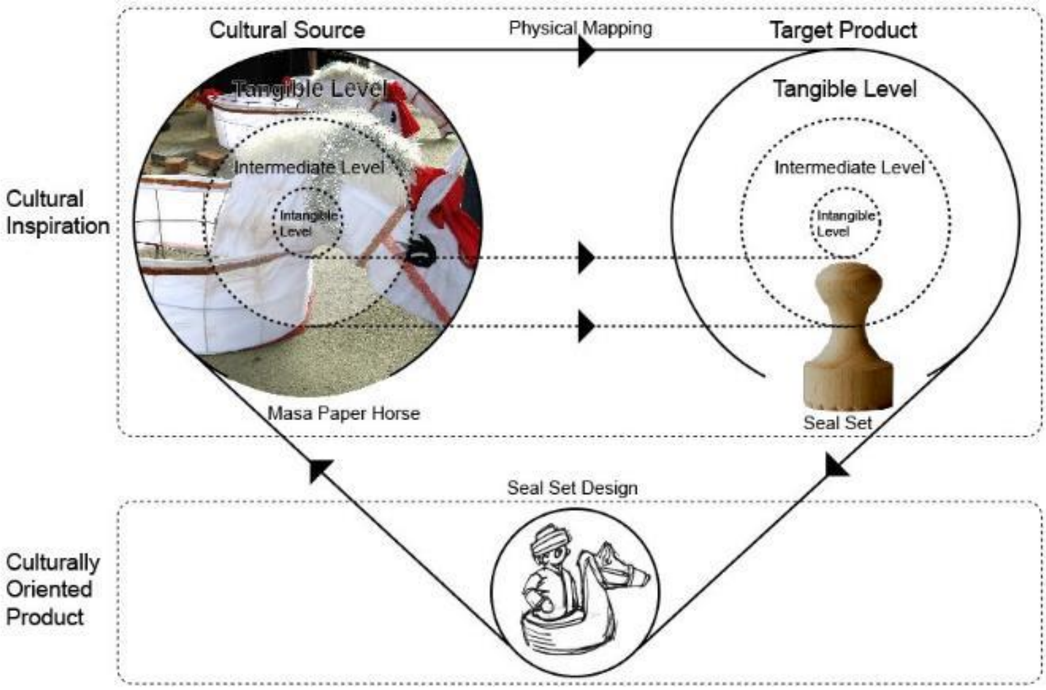


Figure 4. Seal set design with its cultural inspiration

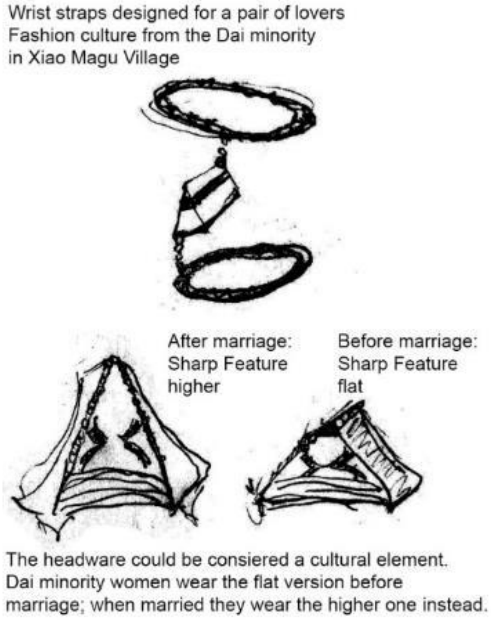
This seal set design follows the three stages: identification, translation, and implementation, to integrate cultural elements into a daily product. The seal set design started by identification of cultural inspiration source from the Masa paper horse tradition, in which key visual elements such as shape, color, patterns, and materials were recognized and analyzed. These traditional motifs were reinterpreted and transformed into new product (i.e. translation to seal set). Elements from the Masa paper horse informed the shape, pattern, and modular structure of the product, allowing cultural symbols such as the horse, human figure, and base to be embedded in the product's functional components. The visual design implementation focused on the development and refinement of sketches, ensuring both aesthetic and functional harmony.

Jewellery design for lovers derived from the intermediate level

The concept of jewellery design for young people is embedded in family values from the Dai Minority. The design concept was inspired by the headwear and its context. During a traditional wedding ceremony, the bride is adorned with beautiful headwear, the metaphorical meaning of which is that no matter where she is after her marriage, her family always accompanies her (Sun & Ren, 2017). However, before she marries, she wears a flat version of the headwear rather than the more elaborate one. In this case, the headwear as a symbol plays a significant role in signifying that the original family relationship could be sustained. The student designed a pair of triangular-shaped bracelets to combine the functions of the product. He explained it as follows:

> *It is possible to assemble two objects for jewellery design. For example, they can be separated to become flat in each one. They were assembled here to become sharp. The hat that is put on before marriage is flat. After marriage, women wear a hat with a sharper shape. I am interested in how meaning can be used when one is designing for a pair of lovers.*

The "wrist straps" set was designed to acknowledge the close relationship between a pair of lovers by emphasizing the connection on the bracelets (see Table 4). When used, each can be snapped into two parts. When the two straps are not in use, they can be detached and reconnected as a whole, symbolizing the close relationship between the lovers. The student's idea concerned the cultural elements in the use of headwear, functions and craft techniques connected with the minority's wedding custom. Related to the intermediate level, this metaphorical design reflected the close relationship behind the wedding custom whereby a pair of bracelets connoting the specific cultural inspiration (the headwear) was created to map onto the features of the jewellery design.

Culture Source	Created New Product
	
The beautiful headwear is the inspiration for Dai minority fashion. The shape resembles the rooftop of a folk house, metaphorically putting the family on her head to signify their certain family value.	
Cultural Transformation with Behavioural Features	

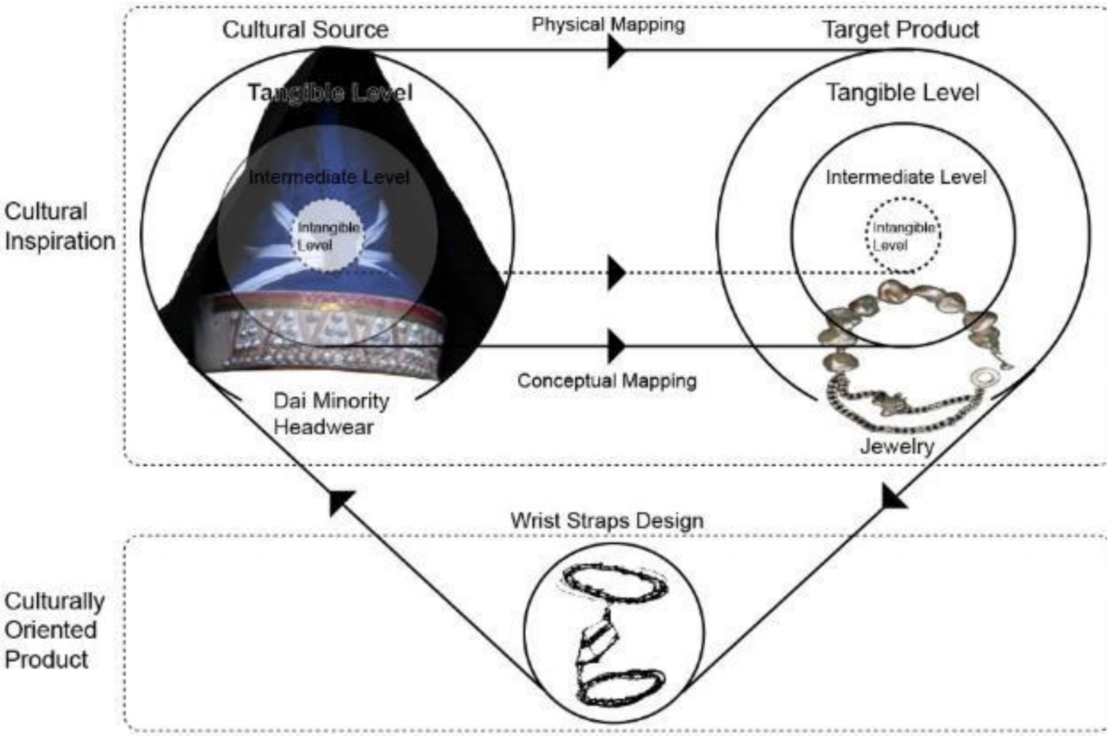


Figure 5. Culturally inspired jewellery design

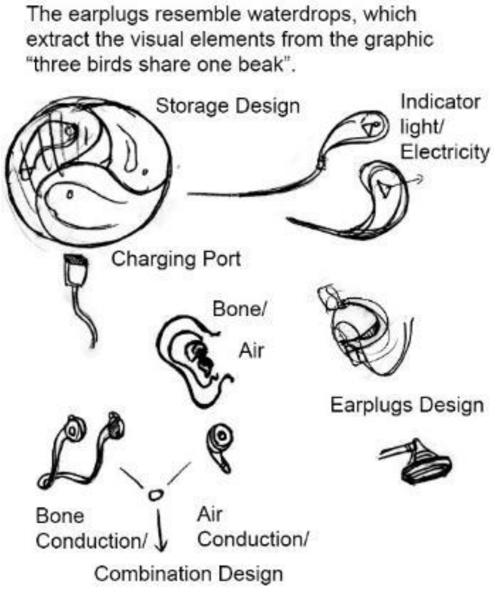
In the jewellery design process, the outer and intermediate levels were clearly combined. The intermediate layer refers to the social and behavioural activities such as custom of traditional minority wedding and requires building the connection with the outer layer (headwear). The process started by identifying and extracting outer level cultural elements of the Dai wedding ceremony such as the headwear and its decorative components (e.g., embroidery, metal ornaments, wrapping forms). These outer elements were applied to product features, e.g., connecting parts and beads. In the translation process the behavioral activity (close relationship between the lovers) was integrated into the product's structural aspects including multiple parts, e.g., bracelets, beads, and various connection components and methods.

Earphone design derived from the inner level

The earphone design was inspired by the image of three birds sharing one beak, a symbol in Zhuang national territory that represents the origin of life in their philosophy. They believe that the universe is divided into three worlds: the upper sky, the middle earth and the low water. Gods, people and creatures exist separately on the different levels (Qin, 1990). However, these connotations reflect their philosophical thinking, and are embedded in the graphic (see the photo in Table 5), whereby the three birds are abstracted and intertwined, metaphorically implying sky, earth and water. The shapes and their connotation of the sign map onto the visual features of the ellipse. The student wrote in the final report:

> *My research emphasized an example called "Three birds share one beak". The colours of the three birds are separately seen as blue, red and striped black and red, these mean that sky, earth, and water are the elements in nature to nourish the minority people [Zhuang minority]. This graphic is widely applied in the scenes of their daily life, such as the traditional concert hall and the central square. It is distinctive with auspicious implications and sustainable value when utilized for creating cultural products.*

Figure 5 shows how the inner level was connected for creating an earphone by using connotation of the specific cultural inspiration (the sign) to map onto product's features of the earphone design.

<table>
<tr><th>Culture Source</th><th>Created New Product</th></tr>
<tr><td></td><td rowspan="2">
</td></tr>
<tr><td>The inspiration is from the image "three birds share one beak", which is a known symbol in Zhuang national territory. It gives an insight into life's origin in the Zhuang minority's philosophy.</td></tr>
<tr><td colspan="2">Cultural Transformation with Philosophical Features</td></tr>
</table>

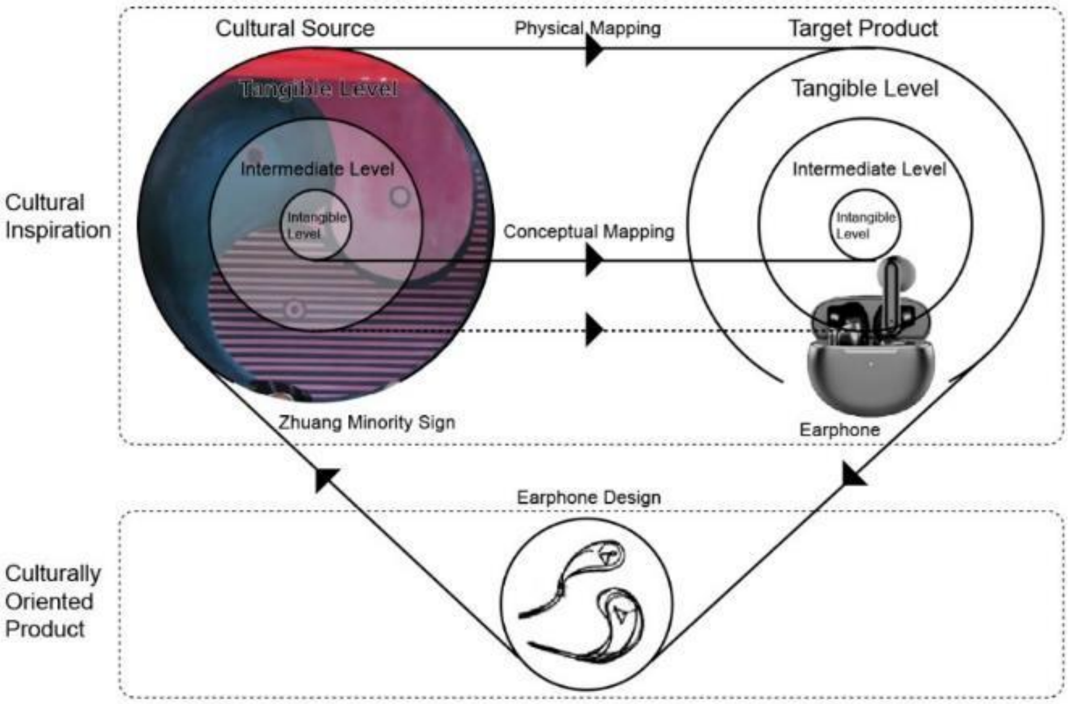


Figure 6. Culturally inspired earphone design

On the inner level, the intended meaning of "heaven's blessing" was to apply the product design through dividing and assigning the cultural elements to its different parts, namely aesthetic manner (water-drop shape), spiritual culture (nature worship) and philosophical thinking (belief in three worlds). The intended design context is a subway journey with the considered problems of machine vapidity and noise from people. Thus, the design solution toward the non-in-ear concept (bone conduction) is reflected as part of people's urban sound context and health issues:

> *I think it's possible to combine using bamboo-carbon fiber (material) for the health-related earphone product, such as applying it to the earplug or an outer layer, and considering the shape of the graphic (the three birds), like this...*

The transformation process of earphones connected the traditional cultural elements (philosophical thinking of Zhuang minority and symbol of Zhuang national territory) toward totally new product (earphones). It conveyed culturally enriched concepts that symbolizes the relationship between sky, earth, and water. Specifically, the metal symbolizes the earth and acquired expression through the earplug components, which were assigned with a metallic material, also involving relevant product attributes. The water element was intended through the charging display indicator and cultural waterflow-pattern features were considered taking on the outer shell.

Discussion

The present study highlighted the importance of inspirational sources of minority heritage for culturally oriented product design. According to Qin and Ng's (2020) diagrammatic tool for specifying culturally oriented design elements and how they could be analysed on tangible-intermediate-intangible levels. We used the findings in addressing two research questions: What kind of cultural inspiration did students of product design gain from the local culture? How is cultural inspiration mapped onto culturally oriented product design? The focus was on the cultural experiences of the students, and the metaphoric mapping method was utilized to analyse their new design concepts. Our findings indicate that the field study to minority villages and active participation in the minority heritage played significant roles as inspirational sources for new product design.

Culturally oriented product design has emerged as a desirable technique, and there is increasing demand for cultural products that incorporate specific cultural knowledge into their design (Luo & Dong, 2017). Guidelines and historical literature as inspirational sources could help novice designers to deepen their knowledge of cultural features, but do not sufficiently support idea transformation to culturally oriented product design. As ancient cultural artifacts are usually located in museum collections, designers acquire pictorial and textual information more easily than a physical (tangible and visible) object in this process. However, traditional villages and minority cultures offer a more authentic experience. Furthermore, the participatory approach has been used successfully in the designing of events for tourism experiences (Tussyadiah, 2014). Thus, in line with the participatory approach adopted in the present study, design students were required to participate actively in the local culture (such as in festive ceremonies, craft workshops), observing and documenting events, touching and using physical objects, as well as interviewing residents and artisans. Participation means participatory engagement in the context and the design process (Van Oorschot et al. 2022). The results demonstrated that design students are able to use local cultural sources of inspiration together with participatory observation, and to apply acquired knowledge to meet the demand for local tourism products. MACTB officers and guides (such as village tour leaders, curators, museum guides and artisans) acted as informants, and shared knowledge of their cultural inheritance regarding crafts, tools, habits and rituals.

Culturally oriented design always requires sensitivity and empathy for the indigenous cultures, backgrounds, and ethnicities and avoid unethical cultural appropriation. However, there is always a danger of superficial cultural appropriation to a product designed for commercial outcomes if the students are not familiar with the minority culture and are immersed in it for only of a limited period of time. As designers naturally gain cultural inspiration and build on existing ideas the line between inspiration and appropriation is blur. Navigating between this delicate balance requires careful consideration and a deep appreciation for cultural heritage from the design students. Cultural appropriation occurs when designers adopt elements of a minority culture without understanding or acknowledging the community from which they originate. In the present study, the students were familiarized to the cultural contexts beforehand, and the participatory approach relied on the official collaboration between Yunnan University of Finance and Economics (YUFE) and the local government of Maguan County. In the present pedagogical setting, there was not an extension with long-term collaboration. Through direct engagement, design students actively participated in cultural heritage and tourism contexts, adopting more sensitive, respectful, and collaborative design methods. Thus, participatory approach can help prevent harmful misinterpretations by allowing participants to directly correct or adjust aspects of the design (Mavri et al. 2020). It is important to develop pedagogical approaches that guide students in creating sustainable, innovative, and culturally sensitive products (Yang, 2024).

The cultural sources of the tangible and intangible features were revealed in the design concepts, including the artifacts, behaviours and values of the minority. Furthermore, the traditional artifacts that were intricately connected to the people, their environment, social contexts, histories and cultural heritage, inspired product development (Suib et al., 2020). Interestingly, an open formulation of the given design task—designing daily products—also expands concepts such as user and use contexts, and brings out new ideas to enhance user experiences. The student who designed the Masa Village seal set considered broader aspects of sustainable tourism and the attraction of the minority's cultural heritage. Most of the students' culturally oriented design concepts relied on the outer cultural level. Those focusing on devising appealing tourism attractions needed to rely on the tangible and visible aspects of cultural artifacts (i.e., the Masa horse), so that the seal set could later evoke memories of the visits. Similarly, the jewellery design has visible inspirational features from the heritage artifact (headwear), which was transformed into other objects such as bracelets. Significantly, however, the bracelets included the intermediate level expression of the local wedding custom—symbolizing the close connection of the young couple. Sustaining the cultural elements in these design concepts could have allowed more combinations between contemporary and minority heritage in both examples. There were far fewer intermediate- and inner-level culturally oriented product-design concepts. The third example, the earphone product, represents the inner philosophical level of local heritage. The earphones carried the tangible, visual symbols and inner-level heritage features in their new design. The user and user context (subway) exemplified modern, everyday products with the new non-ear function. In other words, some of the culturally oriented product designs rely on a preservation strategy that approached tradition, reproductively focusing on the outer level of detail. Some product designs rely on an application strategy that hybridized tradition with function, whereas the transformative strategy generated new innovative concepts whereby inspiration was gained from the inner level (cf. Kouhia & Seitamaa-Hakkarainen, 2017).

The findings of this study open new perspectives on stimulating creativity in the design of cultural products, and three-level metaphorical mapping could be used also as a pedagogical tool to analyse the sustainable value linking the cultural aspects and the target products. Metaphorical mapping could be used in teaching design to analyse the relationships among various product elements of the cultural heritage. The metaphorical mapping framework emphasizes the creation of new meaning during the design process, whereas cultural inspiration from minority traditions could help to stimulate design. Our results imply that the intermediate or inner level could trigger realization of the metaphorical connection, rather than focusing only on the visual or physical aspects of the artifacts. Further, to better support students inner level designing, the design process could be more scaffolded to support new ways of thinking. These prompts could help students to move beyond the outer level in their design thinking. Also, developing deeper cultural understandings might require more extensive time frame and more intensive co-designing sessions with minority people to understand and connect the inner level in the new cultural products.

The present study has its limitations. The qualitative data analysis was limited to the sketches, notes and voice-recorded explanations. The study would have benefited from more longitudinal data on the participatory approach from site visits to feedback with local participants. It would also have been useful to analyse differences in culturally oriented product design between expert professional designers and novice student designers. Finally, it would be beneficial to extend co-designing among participants, as well as to maintain longer-term collaboration. This could result in more extensive collaboration and synergy among designers, local artisan groups and authorities that would stimulate the development and preservation of heritage crafts.

To conclude, our findings shed new light on student creativity in culturally oriented product design. Student designers should use minority capital to stimulate tangible and intangible cultural inspirations and thereby enhance their creativity. Furthermore, minority behaviour, thinking and beliefs should be considered in creative concepts to realize product usability and aesthetics. Collaboration between academics and local government is vital to ensure an inspirational cultural context. The cases under study serve as examples of how design students are inspired by collaboration with local governments and communities. Active participation in various attractions and events offers experiences and ideation activities. Specifically, future study contexts with territorial capital could also be more participatory in design or designer-artisan collaboration to vitalize local crafts. Inspiration for developing new products stems from participating in minority cultures, which are unique cultural assets with social and innovative value, and serve as a basis for design practice. Such participation could maximize the potential to create viable designs and contribute to the sustainable development of local crafts.

Funding

This research was funded by the study programs of Yunnan University of Finance and Economics, Research on the Pedagogy of Cultural and Creative Product Design Based on the Beautiful Villages Construction: Case Study of Masa Village, Maguan County (grant number 2020C01). It was also supported by Yunnan University of Finance and Economics under the

2025 Undergraduate Education and Teaching Reform Projects (University-Level): Service Design Course Pedagogy Reform Based on Digital Ethnography Methods and Metaverse Application Technology.

References

Bai, Y. W. (2012). "试探云南文山壮族纸马舞." [On the paper-horse dance in Wenshan of Yunnan Province]. *文山学院学报* 25(2), 14–16.

Chai, C., Shen, D., Bao, D., & Sun, L. (2018). Cultural product design with the doctrine of the mean in Confucian philosophy. *The Design Journal*, 21(3), 371–393. https://doi.org/10.1080/14606925.2018.1440842

Cheng, P., Mugge, R., & Schoormans, J. P. (2014). A new strategy to reduce design fixation: Presenting partial photographs to designers. *Design Studies*, 35(4), 374–391. https://doi.org/10.1016/j.destud.2014.02.004

Dong, Y., Zhu, S., Li, W., & Lin, M. (2023). How does the design guidelines for traditional cultural artefacts inspire design in a culturally inspired design process? A comparative study with novice design students. *International Journal of Art & Design Education*, 42(1), 49–68. https://doi.org/10.1111/jade.12448

Eckert, C., & Stacey, M. (2003). Adaptation of sources of inspiration in knitwear design. *Creativity Research Journal*, 15(4), 355–384. https://doi.org/10.1207/S15326934CRJ1504_5

Gimeno-Martínez, J. (2016). *Design and national identity*. Bloomsbury Publishing.

Goldschmidt, G., & Smolkov, M. (2006). Variances in the impact of visual stimuli on design problem solving performance. *Design Studies,* 27(5), 549–569. https://doi.org/10.1016/j.destud.2006.01.002

Hsu, C. H., Lin, C. L., & Lin R. T. (2011). A study of framework and process development for cultural product design. In Internationalization, *Design and Global Development* (pp. 55–64). Springer. https://doi.org/10.1007/978-3-642-21660-2_7

Keller, A., Pasman, G., & Stappers, P. (2006). Collections designers keep: Collecting visual material for inspiration and reference. *CoDesign*, 2(1), 17–33. https://doi.org/10.1080/15710880600571123

Kouhia, A. (2016). Roots in tradition: Karelian tradition as a creative resource for Finnish craft designers. *The Design Journal*, 19(5), 725–745. https://doi.org/10.1080/14606925.2016.1196090

Kouhia, A., & Seitamaa-Hakkarainen, P. (2017) Towards design hybridity: Negotiating traditions through contemporary craft making in Finland. *Craft Researcher*, 8 (2), 169-192. https://doi.org/10.1386/crre.8.2.169_1

Lemon, R., Trinick, T., & Lee, K. (2023). Challenges and opportunities in the indigenisation of the Marautanga Hangarau (the Māori-medium technology curriculum): Indigenous knowledge and an emerging philosophy of Hangarau. *Australasian Journal of Technology Education,* 9. https://doi.org/10.15663/ajte.v9.i0.91

Li, C. Y., & Liu, G. (2021). "文山壮族铜鼓舞的视觉审美元素及静态传承" [Visual aesthetic elements and static inheritance of Wenshan Zhuang bronze drum dance]. *文山学院学报* 34(4), 31–35.

Liu, L. L., & Chang, K. (2013). An analysis of product design based on traditional Chinese culture. *Applied Mechanics and Materials*, 397–400, 878–881. https://doi.org/10.4028/www.scientific.net/AMM.397-400.878

Lupo, E., & Giunta, E. (2016). "Contemporary Authentic": A design driven strategy for activating intangible heritage and craft knowledge. In A. Palmsköld, J. Rosenqvist, & G. Almevik (Eds.), *Crafting Cultural Heritage* (pp. 55–73). University of Gothenburg.

Luo, S-H., & Dong, Y-N. (2017). Role of cultural inspiration with different types in cultural product design activities. *International Journal of Technology and Design Education* 27, 499–515. https://doi.org/10.1007/s10798-016-9359-y

Mavri A., Ioannou A., & Loizides F. (2020). Design students meet industry players: Feedback and creativity in communities of practice. *Thinking Skills and Creativity*, 37, 100684. https://doi.org/10.1016/j.tsc.2020.100684

Manzini, E. (2016). Design culture and dialogic design. *Design Issues*, 32(1), 52-59.https://doi.org/10.1162/DESI_a_00364

Moalosi, R., Popovic, V., & Hickling-Hudson, A. (2010). Culture-orientated product design. *International Journal of Technology and Design Education*, 20, 175–190. https://doi.org/10.1007/s10798-008-9069-1

Moalosi, R., Setlhatlhanyo, K. N., & Sealetsa, O. J. (2016). Cultural memory, an asset for design-driven innovation within the creative industries sector: Lessons for design education. *Design and Technology Education: An International Journal*, 21(2), 9-22. https://openjournals.ljmu.ac.uk/DATE/article/view/1588

Qin, C. L. (1990). "壮族自然崇拜简论" [The introduction on the nature worship of Zhuang Nationality]. *广西民族研究* 4, 46–53.

Qin, Z., & Ng, S. (2020). Culture as inspiration: A metaphorical framework for designing products with traditional cultural properties (TCPs). *Sustainability*, 12(17), 7171. https://doi.org/10.3390/su12177171

Qin, Z., Song, Y., & Tian, Y. (2019). The impact of product design with traditional cultural properties (TCPs) on consumer behavior through cultural perceptions: Evidence from the young Chinese generation. *Sustainability*, 11(2), 426. https://doi.org/10.3390/su11020426

Rynning, M. (2021). Local traditions and global inspiration: Design students in Singapore and Norway. *International Journal of Art & Design Education*, 40(1), 216–231. https://doi.org/10.1111/jade.12346

Saldaña, Johnny (2009), *The Coding Manual for Qualitative Researchers*, Thousand Oaks, Ca: SAGE Publications.

Siu, K. W. M. (2005). Culture and design: A new burial concept in a densely populated metropolitan area. *Design Issues*, 21(2), 79–89. http://www.jstor.org/stable/25223995

Shin, M. J., Cassidy, T. & Moore, E. M. (2011). Cultural reinvention for traditional Korean bojagi. *International Journal of Fashion Design, Technology and Education*, 4(3), 213–223. https://doi.org/10.1080/17543266.2011.579578

Suib, S. S. S. B., Van Engelen, J. M. L., & Crul, M. R. M. (2020). Enhancing knowledge exchange and collaboration between craftspeople and designers using the concept of boundary objects. *International Journal of Design*, 14(1), 113–133. http://www.ijdesign.org/index.php/IJDesign/article/view/2876

Summatavet, K., & Raudsaar, M. (2015). Cultural heritage and entrepreneurship – Inspiration for novel ventures creation. *Journal of Enterprising Communities: People and Places in the Global Economy*, 9(1), 31–44. https://doi.org/10.1108/JEC-03-2013-0010

Sun, D. T., & Ren, X. B. (2017). "文山马关黑傣服饰及其艺术特征" [The ethnic costumes and their artistic features of the Black Dai Nationality in Maguan County of Wenshan]. *玉溪师范学院学报* 33(9), 66–69.

Tussyadiah, I. P. (2014). Toward a theoretical foundation for experience design in tourism. *Journal of Travel Research*, 53(5), 543–564. https://doi.org/10.1177/0047287513513172

van Oorschot, R., Snelders, D., Kleinsmann, M., & Buur, J. (2022). Participation in design research. *Design Studies*, 78, 101073. https://doi.org/10.1016/j.des tud.2021.101073

Yang, Z., Bao, D., & Shen, D. (2022). Exploring design students' cognition and application of different levels of Chinese cultural elements. *International Journal of Technology and Design Education*, 32, 645–665. https://doi.org/10.1007/s10798-020-09606-w

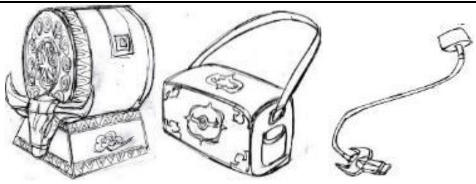
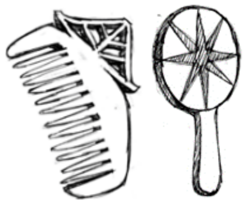
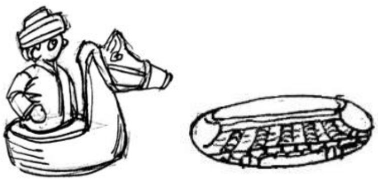
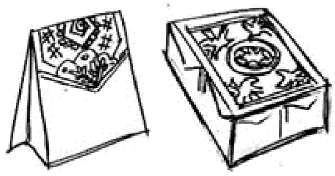
Yang, X., & Cheng, J. (2020). Impact of Inspiration Sources on Designer's Idea Generation Strategy. In Advances in Human Factors in Communication of Design: *Proceedings of the AHFE 2019 International Conference on Human Factors in Communication of Design*, July 24-28, 2019, Washington DC, USA 10 (pp. 42-52). Springer International Publishing.

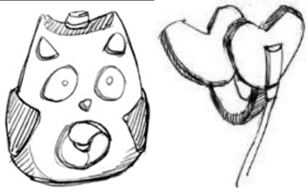
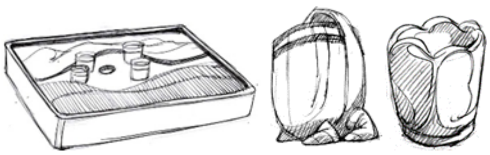
Yang, W. (2024). Sustainable product design of innovative design methods and case studies. In *Design Studies and Intelligence Engineering*, IOS Press, p. 28-38. http://doi.org/10.3233/FAIA231422

Zhu, Y. (2020). Comparing the effects of different types of cultural inspiration on design creativity. *The Design Journal*, 23(6), 919–930. https://doi.org/10.1080/14606925.2020.1825173

Appendix (Product Design Concepts)

Cultural Level	Product Designs	Cultural Inspiration	Cultural Elements
Outer Level	Makeup Set (Cosmetic storage bags) 	Minority fashion (textile)	Embroidery of patterns and graphics
	Red Envelopes 	Minority textile artefact	Embroidery of patterns and graphics
	Electronic Products	Minority artifacts and embroidery	Embroidery of patterns and graphics

		
Toiletry Products 	Minority artefacts from Xiao Magu village	Local artifacts e.g., headwear and the bronze drum to form and decorate the products
Seal Set 	Masa paper horse dancing	Form of the ritual artefact
Packaging Bags 	Minority artefacts/fashion	Minority embroidery of patterns and graphics
Sachet Set 	Minority artefacts/fashion	Minority embroidery of patterns and graphics
Incense Burner 	Minority artefacts	Form and pattern from the bronze drum, and musical instruments
Sleeping Aid	Sign of the graphics	Minority sign of "three birds share one beak"

			
Intermediate level	Wrist Straps 	Wedding rituals	Minority headwear
	Home Decoration 	Buffalo soul festival rituals	Form and pattern of bull heads
Inner level	Tea Set 	Minority's philosophy	Public sculpture, forms of the frog shape and lotus leaves
	Earphone Set 	Minority's philosophy	Minority sign of "three birds share one beak"

Artificial Intelligence as a Tool for Individual and Collaborative Creativity in Design Education

Miroslava Petrova, University of Monterrey, Mexico
Claas Kuhnen, Wayne State University, USA

Abstract
Integration of Artificial Intelligence (AI) in the design process is a growing area of research interest. Three years after its public launch in 2022, AI has already established itself as the most disruptive tool revolutionizing how designers conceptualize, iterate and innovate. As AI technologies continue to evolve, it is pertinent that design students are acquainted with the potential of the technology and how it can be integrated in their professional practice. The objective of this paper is to explore the role of AI as a conceptualization and research tool in interior design. We aim to examine its effectiveness in enhancing the ideation process and facilitating collaboration and knowledge sharing in intercultural design teams. The case study presented is a collaborative online international learning project (COIL) with the participation of interior design students from the University of Monterrey (Mexico) and Wayne State University (USA). Students were involved in experimentation with various AI tools and platforms in the early stage of designing children's spaces in commercial interiors. Through meticulous documentation and evaluation of all design variations generated were gained valuable insights on the impact of AI on the evolution of the ideas. To collect research data on how students' creativity, idea exchange and decision-making were affected, surveys and reflection writings were distributed. The findings confirmed that students developed a greater understanding of AI as an essential tool in the design process. They acquired skills in utilizing it to aid the decision-making during the conceptualization phase. Furthermore, AI fostered their self-confidence in communicating within culturally diverse teams. The conclusion discusses the challenges encountered and lessons learned from the integration of AI technologies into the learning process.

Keywords
artificial intelligence, creativity in design, design education, intercultural design teams, interior design

Introduction - The Rise of AI and Design Education
Integration of Artificial Intelligence (AI) in the design process is a growing area of research interest. Initiated with OpenAI's ChatGPT public launch in November 2022 (Marr, 2024), AI has rapidly established itself as the most disruptive force, revolutionizing how designers conceptualize, iterate and innovate. ChatGPT's success has accelerated advancements in the development of diverse AI tools, while its versatile applications across industries highlight its pivotal role in transforming workflows and fostering creativity. However, despite its growing influence, there remains a significant gap in research exploring how AI can be effectively integrated into design education. This lack of investigation leaves educators and students with limited guidance on leveraging AI to unlock its full potential and prepare future designers for the evolving demands of the profession.

The first industry-wide survey on the opinion of architects on AI, carried out by RIBA in November 2023, indicates that 41% of the architectural practices in the UK have adopted AI for occasional projects, while 2% use it for every project (RIBA AI Report, 2024). A more recent research on the use, types of applications and expectations for the future use of AI by Architizer and Chaos revealed that 46% of the respondents are currently using AI tools and 23 % are planning to use AI in the near future (Architizer, 2024). These findings confirm that AI has emerged as an indispensable digital tool in architects' and designers' workflows and that its transformative potential is yet to unfold. Though doubts were expressed that AI poses threats to the architectural and design profession, the majority believe it will play a significant role in the future. Those who have already implemented it in their practice report that it has improved the efficiency of their design process and has enhanced the accuracy of architectural modelling and simulations (Architizer, 2024). Both studies confirm that the most common use, with greatest satisfaction of the quality of the AI-generated renderings is for the early stages of the project development. AI provides greater flexibility by enabling designers to rapidly generate innovative designs, which can later be explored, refined and optimized.

However, the majority of the professionals (60 %) have not received any formal training on how to use AI in their design projects, and 37 % indicate the lack of suitable training resources as a significant challenge faced in adopting AI tools. Consequently, designers mainly rely on self-learning and experimentation (Architizer, 2024). This gap underscores the need for design education to address AI training in its curriculum. As AI technologies continue to evolve, it is pertinent that design students are acquainted with the potential of the technology and how it can be integrated in their future professional practice. Understanding AI and acquiring the knowledge and skills necessary to adequately assess, interpret and analyse AI-generated visuals according to the needs, context and specifics of use can ensure that students are more competitive and better prepared for the job market. Long and Magerko refer to these competencies required for the future as "AI literacy", which is defined as

> *"a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace" (Long & Magerko, 2020).*

Markauskaite et al. (2022) explored what kind of capabilities people need to interact with AI and how learners can develop them. Conceptualized from different perspectives these capabilities are grouped in three interrelated orientations: cognitive, humanistic and social. From a cognitive perspective, in the human-AI system, AI is viewed as a teammate that affects individual cognition, metacognition and behaviour. Self-regulated learning and creativity exemplify key individual capabilities within this orientation. The humanistic perspective centres on human values and individual capabilities to use and shape AI to contribute to personal and collective well-being. The social perspective focuses on shared meaning-making and collective practices. In the context of design education, the development of these skills is henceforth to be researched. Vinchon et al. consider that the "human-AI collaboration can be extraordinarily productive" (Vinchon et al., 2023). AI can produce a large number of proposals quickly, thus providing a vast field for exploration of possibilities, but it is the human who plays a central role at the two critical phases of the creative process - at its beginning and end. Designers define the objectives and set the parameters of the AI-generated ideas and make decisions by evaluating, selecting and validating the output.

Research Purpose and Context

The objective of this study is to explore the role of AI as a conceptualization and research tool in the field of interior design.

The following research questions have guided the study:

- How can AI enhance the creative ideation process in interior design?
- How can AI be utilized as a tool in interior design to support research and concept development and inform decision-making?
- What impact can the integration of AI have on the dynamics of intercultural design teams in terms of creativity, communication, and project outcomes?

To address these research questions, a collaborative online international learning project COIL project was designed as a practical setting for exploring the potential of AI in interior design. This collaborative initiative involved interior design students from the University of Monterrey (UDEM) in Mexico and Wayne State University in the United States, who worked together remotely on a project focused on the design of a children's space. Inherent characteristic of the COIL format, “also referred to as globally networked learning and virtual exchange” (Rubin, 2022), is that when exposed to diverse perspectives, students strengthen their skills to work in multicultural environments, broaden their global understanding, improve their critical thinking and adaptability. The project, which was specifically designed to pair COIL with AI-driven design not only offered a memorable learning experience for our students but also simulated a real-world, cross-cultural teamwork in a digital environment. Through this hands-on experience, the study aimed to gather insights on how AI can shape the dynamics of intercultural design teams and its overall impact on the creative and decision-making processes within interior design.

Research Method

The research method selected was grounded theory (Glaser and Strauss, 1967) and more specifically constructivist grounded theory (Charmaz, 2006, 2008) since it allows the development of theories grounded in the data collected from the experience and interactions of the participants. This approach is particularly suitable for studying dynamic phenomena, like the integration of AI into design education, as it allows for new properties of this speculative and yet current topic to emerge throughout the research process.

We systematically collected qualitative data through multiple methods, including observations, design diaries, surveys, and reflective writings from participants. The data were continuously analyzed and refined in an iterative manner to uncover patterns and develop theoretical categories. This process allowed us to construct a comprehensive framework explaining how AI influences students' learning outcomes, competencies, and collaborative dynamics in design education. The grounded, data-driven nature of this methodology ensures that our findings are directly informed by students' lived experiences and perspectives, making the results both relevant and meaningful to the broader field of design education.

Data collection

Research data were collected during the project development using a multi-faceted approach.

First, observations were conducted throughout the project to capture real-time insights into students' interactions, team dynamics, and behaviors. This involved the faculty actively observing the students, paying close attention to how they experimented with various AI tools to respond to the project’s demands, what problems they found and how they dealt with collaboration challenges.

Secondly, visual diaries were prepared by the students, which served as a personal narrative record of their design process. These diaries included evidence of all design variations developed, supported by notes and reflections that captured the evolution of the ideas and the decision-making rationale. The visual diaries offered a unique, student-centered perspective on the design process, allowing us to document both the conceptual development of the projects and the ways students articulated their thoughts visually and textually.

Additionally, surveys were distributed to gather quantitative data on students’ experiences and opinions at various stages of the collaboration. The surveys allowed us to systematically assess aspects such as students’ perception of AI’s role in their creative processes, their satisfaction with teamwork, and the challenges they encountered. This provided a structured way to compare the responses of the students with our own observations.

Finally, reflection writings were collected at the end of the collaboration, which provided an opportunity to obtain information on students’ thoughts and learning outcomes expressed in a more personal and detailed manner. These writings focused on students’ experience, their perception on the knowledge and skills gained and overall understanding of AI tools integration in the design process and their potential applications.

Together, these methods provided a robust set of data that captured both the qualitative and quantitative aspects of the students' experiences, allowing for a nuanced analysis of the project’s influence on their learning.

The “Children’s Spaces” Project

Project Objectives

The “Children’s spaces” project objective was to explore how the utilization of AI in the design of a children’s interior space can impact student’s creativity and decision-making. The design brief gave students the freedom to select the context in which the project would be implemented - within any type of larger facility, such as a library, office building, community centre, educational institution, etc., but delimited the target group - children aged 3 to 10 years and the designated area - 500 sq. m. The design should comply with safety regulations and guidelines for children’s spaces, and to consider the creation of an inclusive environment for children of diverse backgrounds, abilities and interests.

Participants

Fourteen fifth semester students from the University of Monterrey and fifteen students from Wayne State University participated in a four-week COIL project. The Mexican students were in their fifth semester of the interior design program in the Department of Art and Design at UDEM. The class in which the project was implemented was Institutional Spaces Studio. In this class, students experiment with various design strategies to create innovative and inspiring interiors addressing the physiological, psychological, social, cultural, and environmental needs of contemporary society. They explore the experiential aspects of the space and learn how to create a sense of place and memorable spatial experiences. The partnering students from the United States were junior students in the interior design program at Wayne State University. They were taking their second interior design studio course, which focuses primarily on experience design. In this class, students explore the relationships between users and the space to create immersive spaces, which are not only functional and aesthetically pleasing but also deeply memorable and impactful.

AI Tool Selection

The AI engines used in this collaboration can be categorized into two groups:

- Conversational AI Models: These models are designed to engage in natural language conversations, answer questions, and provide information. They generate text-based responses in a dialogue format. Conversational AI models, such as OpenAI's ChatGPT, Google's Gemini, and FabriAI, assisted students in their primary and secondary research. These models supported tasks such as gathering information, analysing data, creating mind maps, and discovering project opportunities.
- Image AI Models: These models are designed to generate images based on text prompts or input images. They specialize in creating visual content through AI-driven artistic interpretations, translating textual descriptions or visual inputs into detailed and unique images. Image AI models, such as DALL-E 2, PlaygroundAI, and VizcomAI, enabled students to rapidly generate conceptual images of their design ideas. These tools facilitated an iterative process, allowing students to explore various design variations efficiently.

Cultural Dimensions

One of the major benefits of the implementation of the COIL project is that it enriches the students' educational experience by providing opportunities to learn about other cultures, establish cross-border partnerships and exchange knowledge to achieve the project goals in a cross-cultural context. Students become familiar with diverse cultural perspectives, thereby fostering their identity as global citizens who are open-minded and respectful toward differences. This exposure broadens their understanding of the world and enhances their abilities to collaborate effectively in an increasingly interconnected and multicultural environment.

A particularly interesting challenge was addressing the diversity of cultural preferences among students and the inherent biases in AI models. Overcoming these biases and synthesizing new interpretations required careful consideration. AI models generate results based on the data on which they were trained. Students often draw inspiration from their own cultural backgrounds, which can influence their preferences. To address this, student groups were intentionally mixed to maximize the diversity of opinions. Additionally, they were encouraged to use multiple AI engines to explore the differences in the outputs and develop their individual proposals. Similar to human perspectives, AI engines can be directed to generate work based on specific inputs, such as reference images used as style guides. This approach facilitated a richer exploration of diverse interpretations and perspectives.

Project Implementation

The dynamics of the collaboration began with an ice-breaker activity in which teams, composed of students from both universities, shared information about themselves. This is an important step in the formation of a friendly and inclusive environment. Through learning about each other's background, interests and motivations students build mutual trust, which can further facilitate teamwork and enhance conflict resolution.

To structure the course and foster collaboration, we employed modern presentation and discussion tools, which generated an accessible and productive class experience. We utilized MIRO as an online collaboration whiteboard platform, enabling students to upload their work, engage in discussions, and receive feedback from their peers. It allows users to create and share visual content such as diagrams, mind maps, and sticky notes, enabling teams to work together seamlessly from different locations. Using Discord, we facilitated a space for real-time meetings, chats, and discussions. Through the use of open groups and public discussion rooms, we created an inclusive environment where all students, rather than just individuals, could benefit from collective insights. This platform allowed faculty to address individual group questions and, if deemed valuable, share these responses with all students. Considering the time zone differences, Discord was an instrumental tool in ensuring effective and timely communication across the course. For the synchronous meetings we used Zoom. Zoom offers significant advantages, such as allowing participants to share their screens and granting faculty remote access to interact directly with software on students' computers. Additionally, Zoom enables the creation of online recordings of the meetings, which can be accessed for later review. Zoom was instrumental in enabling students to present their work, facilitate discussions, provide feedback, and receive training on the use of AI engines. Since all AI engines used were accessible online, students were introduced to AI as a research and design tool through live demonstrations during class. This approach allowed faculty to create a workshop-like environment and provided students with the opportunity to experiment with the tools. Based on students' questions communicated via Discord outside of class, additional video tutorials were recorded using Zoom and made available online to ensure students could review the material as needed.

The actual work on the project began with thorough research on the target users, their specific needs, interests and preferences. The analysis encompassed both the functional and emotional aspects of the space to ensure it will be interactive, inclusive and appealing. Key considerations included safety and ergonomic requirements, sustainability, technological integration, etc. To organize and visualize the research findings, students utilized ChatGPT within Fabri to make mind maps, which facilitated the comprehension of the various factors that impact the design of the children's space (figure 1). In the conceptualization phase, students began brainstorming ideas about the functionality, interactivity and user experience of the space. They were encouraged to experiment with the various AI tools that had been introduced to them earlier to generate concept images. We required that they document meticulously each stage of the design process, including research findings, design iterations, AI tools used, and insights gained. Moreover, we asked students to reflect on the results obtained and note the benefits they observed, as well as the challenges and limitations they encountered in the AI-generated renders.

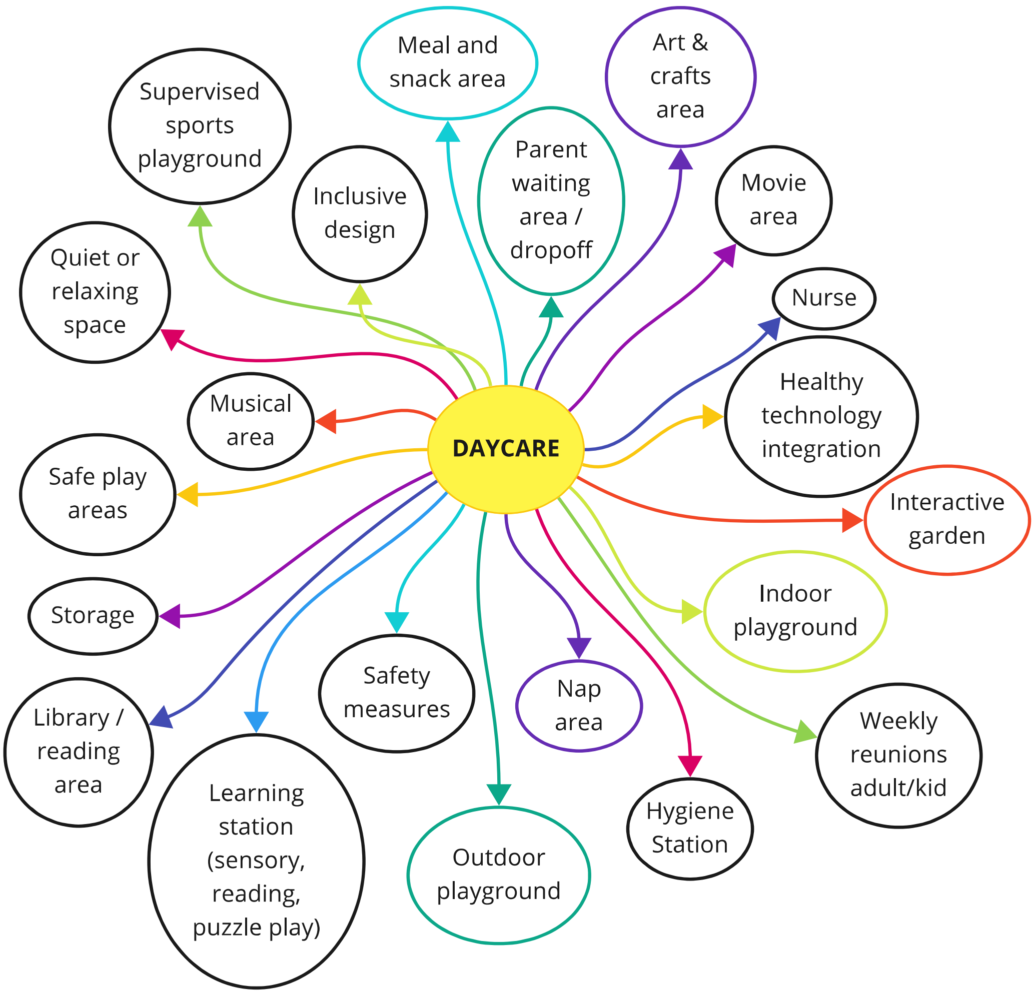
For the final presentation of the spatial concepts AI engines like VizcomAI were used to produce more accurate representation of the ideas. These AI-generated visualizations were combined with 3d models and other conventional techniques to create a more refined and comprehensive design. As a final deliverable each team submitted a visual diary showcasing all variations of the design developed throughout the process, including all the visual representations of the design concept and its iterations, as well as the prompts and the AI tool used (figure 2). Students provided descriptions explaining the rationale behind each design variation and the evolution of ideas leading to the outcome.

Conceptualization *Ideas*

Design Development

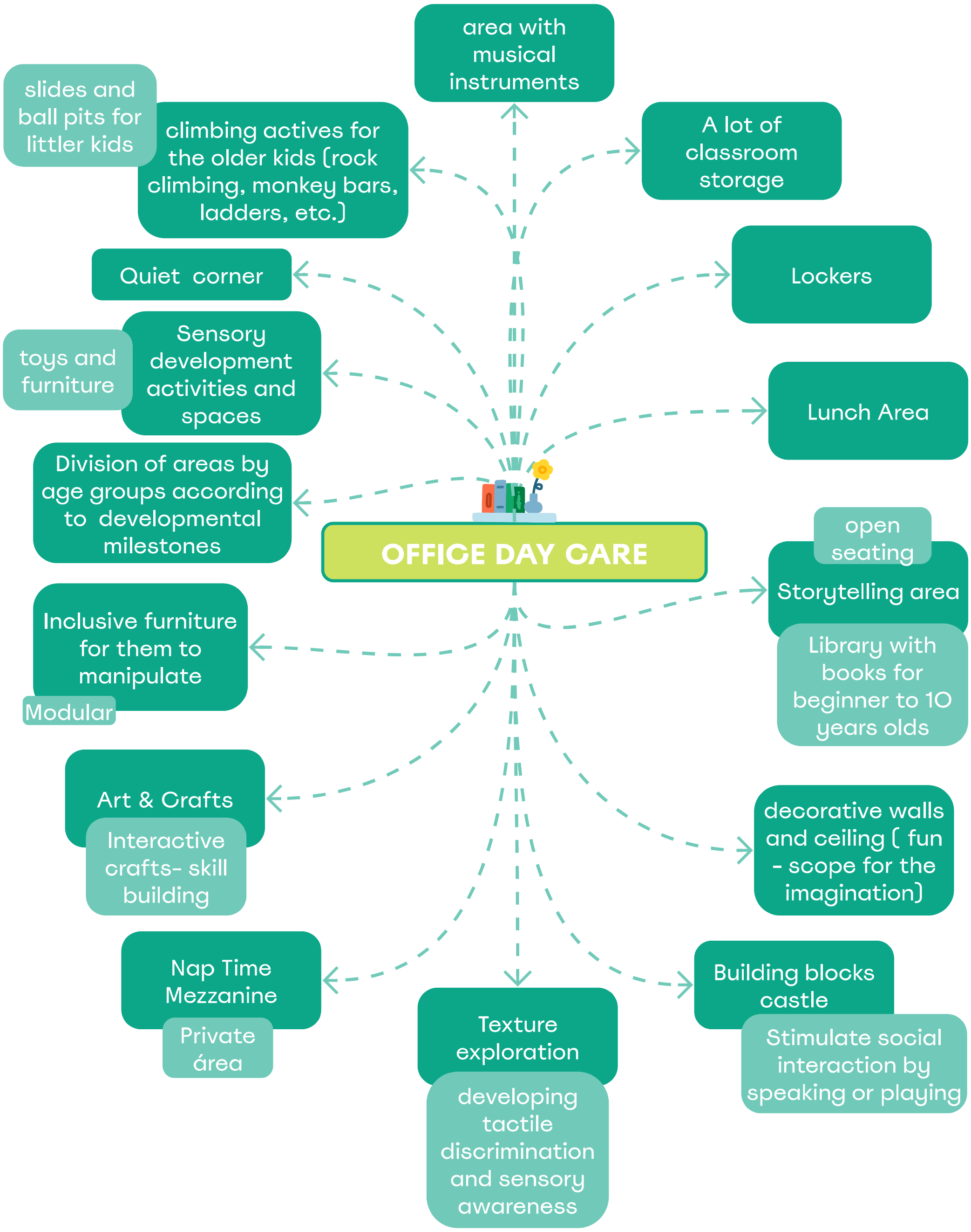
Conceptualization

Brainstorm ideas about the functionality, interactivity, and user experience of the space while promoting creativity, learning, and play.



Design Development

Conceptualization ideas



Conceptulization

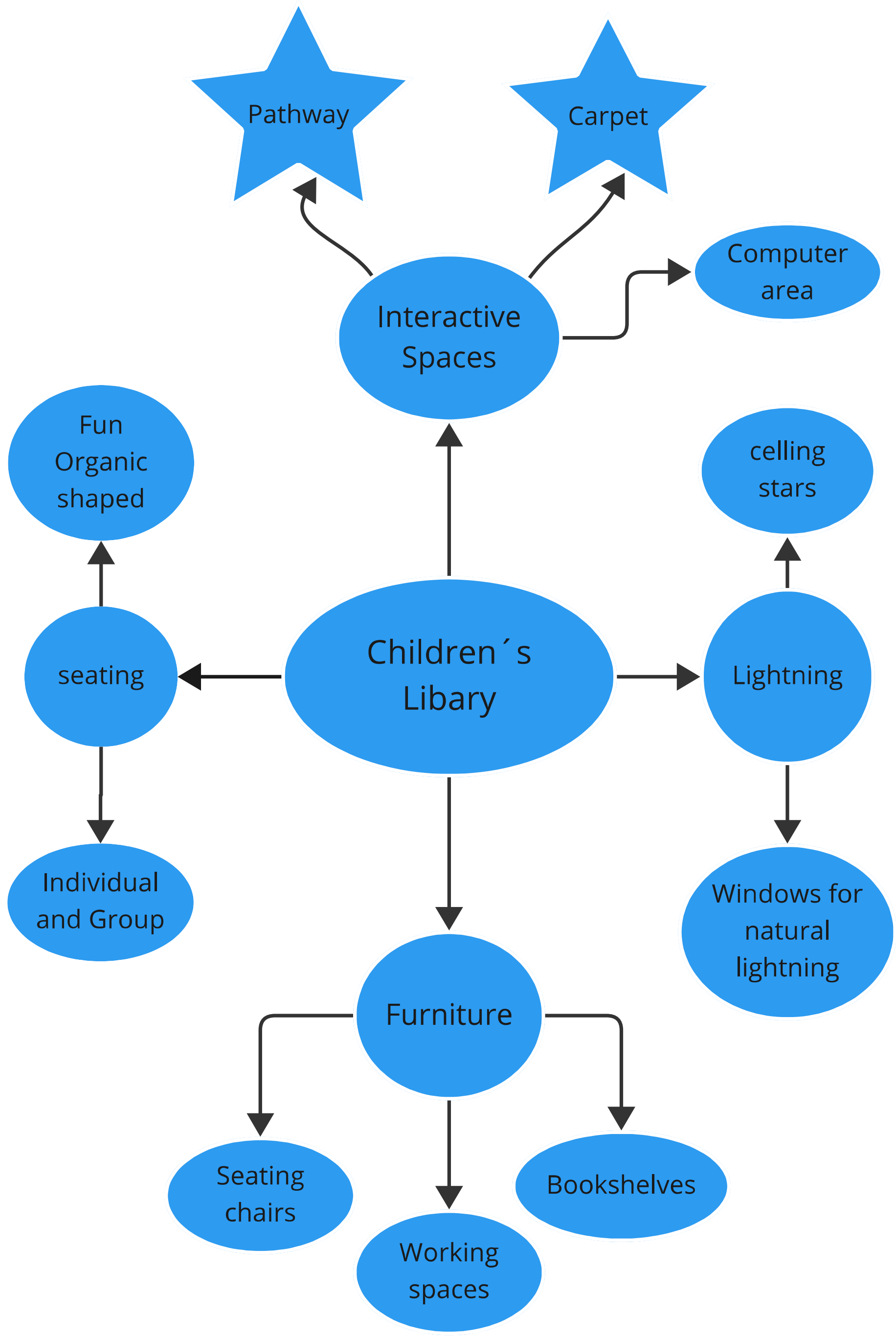


Figure 1. Mind-maps developed by students

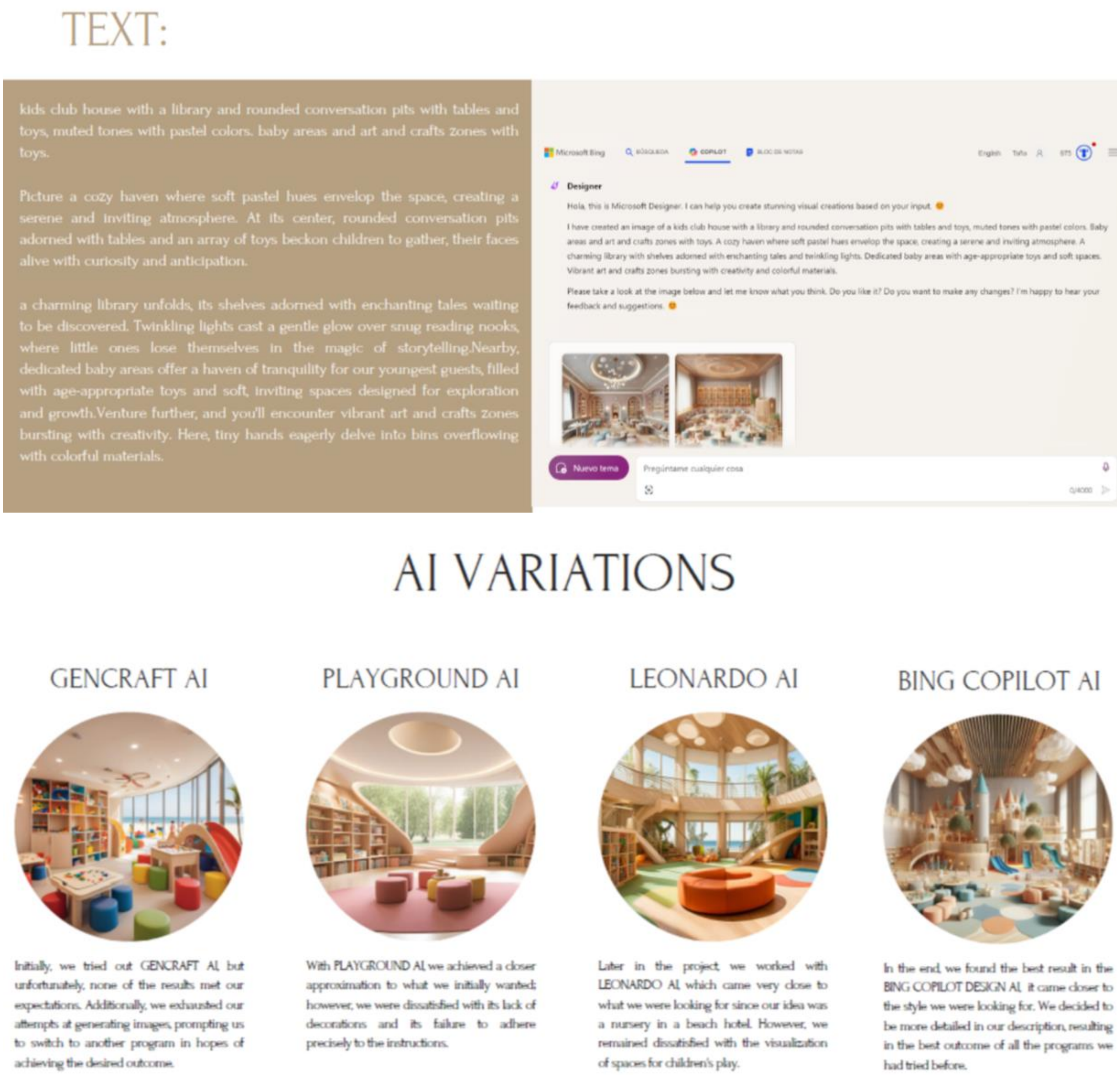


Figure 2. Visual diaries documenting the design process

Results

The first interesting finding was that though the students were familiar with various AI tools, the majority of them have not used these technologies in an integral way for design projects. In that regard, the children's space project contributed significantly to their understanding of AI technologies in design and their potential application. This is evident from the following reflections written by students: *"It* [the project] *helped me completely since I had never used those programs before, I learned from scratch and I think I did a good job,"* and *"[we] gained a deeper understanding of AI technologies in design. Previously, I was unsure of their practical applications, but now I realize how effortlessly they can be employed. It's remarkably convenient to generate quick, visual representations of projects, facilitating pre-visualization with ease."*

In their evaluation of the overall experience of the COIL project, students shared the following opinions: *"The AI generator was amazing, I had never done that, and I really enjoyed it,"* and *"I* *liked it very much. It was a different approach to interior design, and I actually found it very helpful to use AI tools to my advantage to create a space in a more efficient and fast way."*

Besides the speed at which AI produces images, among the AI features which students appreciated the most, were the ability to overcome brainstorming fatigue, AI capacity to generate unique images, the use of traditional image montage concepts to produce AI renderings, and its effectiveness as a research tool for data finding and analysis. The excitement with which students approached the project was evident in their enthusiastic participation, willingness to experiment with the different AI tools and their proactive engagement in the collaboration. Some unexpected results emerged such as a proposal for an AI-generated business model of an office day care. This showcased student's ability to think creatively and their disposition to explore further the application of their design concept with the help of AI. When asked to describe the most engaging and enjoyable aspects of the project students indicated: *"I really liked that we got to explore different types of AIs and working on the project with no expectations on the outcome helped me truly explore the different features of the AIs."* However, the ability to write prompts to feed the AI engine was observed as a major obstacle in obtaining results relevant to the project specifics. Inappropriately written prompts led to inappropriate AI-generated renders, so students revised them using ChatGPT to clarify and refine their requests. These iterations helped students learn how to better communicate their design intentions in a written form, which subsequently improved the quality and accuracy of the visualizations. Furthermore, students evaluated positively that we encouraged them to utilize the same prompts with various AI tools and to compare the outcomes: *"Seeing the results of the prompts that we made were very interesting, and using that same prompt for other AI pages was very cool and pleasing to see how each of them managed to create different aesthetics and different proposals with the same text."*

Despite the overall positive opinion of the use of AI in design, students indicated some shortcomings such as limited options for floor plan generation, isometric drawings, furniture proposals, controlling the lighting of the scene, etc. However, the fact that they realize the constraints of AI tools, demonstrates their awareness of the importance of critical thinking and knowledge on design principles for decision-making. *"We looked for visual ways to reach the desired results and although the AI pages gave an approach, it could not give an exact representation of what we wanted for this space, but we really enjoyed being able to experiment and find these tools as a basis for brainstorming and moodboards".* Another aspect, which students disliked, was that each AI engine has a different visual style, which can be confusing and requires familiarization with the specific interface to fully utilize their potential.

In regard to their experience of working in intercultural teams, some students reported difficulties related to communication, especially outside class hours, as well as challenges stemming from the differing opinion of their partners. Nevertheless, they acknowledged the necessity of effective communication for the success of the project, as expressed in this student's reflection: *"Collaborating as a team for this project was exciting as it highlighted the importance of communication and taking advantage of the strengths of each team member."* In order to overcome the challenges of the collaboration students were actively engaged in discussions and critical reasoning to reach a consensus, which contributed to the development of communication skills and a deeper understanding of diverse perspectives in the design process.

Lastly, with this project students not only overcame their uneasiness to work remotely with designers from different countries, but also embraced the opportunity to experiment with new technologies. This experience helped them build confidence in integrating AI in their design process: *"Before COIL I thought of AI as scary to some level because of how it's really becoming better and better every day. After COIL I feel at ease and happy to have learned a new area of design and acquired a new work tool."*

Discussion

Project Impact

The children's space design COIL project was our first attempt to implement AI in a structured way as a co-creation tool in the development of an educational design project. Motivated by the question whether our students are prepared for the new AI reality of the design profession, we designed a learning experience which encouraged them to experiment with various AI tools and explore their potential in transforming traditional design methods.

The results highlighted a positive impact on the design workflow and acquisition of AI literacy.

Impact on the design workflow and efficiency

The impact of AI on modernizing the design workflow was significant. AI's ability to produce results in seconds enabled students to work more quickly and focus on creative aspects rather than labour-intensive tasks. Additionally, AI tools allowed students with less developed skills in manual sketching or 3D modelling to generate high-quality visual images. This is crucial because, as designers, our primary task is to produce effective solutions rather than art, and high-quality visuals are essential for successful project storytelling.

To remain competitive, the field of design must continually innovate and adapt to new processes. Image-generating AI engines offer an attractive additional tool for designers, providing a workflow that can be significantly more efficient and effective at times. However, these engines still rely on the data provided. Thus, it is crucial to understand that AI does not replace the need for students to learn manual sketching and 3D modelling. For tasks such as 3D rendering and the development of conceptual images, which are very labor-intensive, AI rendering now offers a workflow that is faster, more intuitive, and produces significantly better visual results.

To produce initial conceptual images as part of the initial project exploration, students utilized DALL-E 2 and PlaygroundAI. By using basic text prompts, students were able to contextualize their envisioned topics. The use of various AI models and style descriptions allowed them to explore different artistic interpretations and visual styles. This process was instrumental in understanding AI biases and overcoming inherent user preferences.

VizcomAI played a significant role in modernizing the workflow for developing and exploring specific design solutions. Students were able to combine basic hand sketches, 3D model screenshots, and traditional photo collage techniques to instruct the AI in producing high-quality architectural renderings. By using layers and quick sketches for furniture or human figures, students created realistic representations in seconds. The use of reference images helped maintain desired visual styles and address AI biases. This iterative process facilitated effective exploration of different design solutions. Notably, VizcomAI offered a very low learning curve for students and significantly enhanced productivity compared to the traditional workflow of manually 3D modelling interior spaces and their assets. While manual 3D modelling remains essential for final project delivery, it is less efficient during the exploratory phase.

Acquisition of AI literacy

Undoubtedly, AI augments the traditional design process by transforming how creativity emerges from text to generate a visual representation of design ideas. In this new AI-human collaboration, the competences of the designer to write prompts and to critically analyse the AI-generated renders are crucial. Our students discovered the importance of breaking down the design brief into distinct components that can be communicated to the AI in a concise, unambiguous and specific way to ensure the outcomes would closely align to their expectations. Through continuous experimentation and iteration, they refined their prompts to improve the quality and relevance of the AI-generated renders. The self-regulated learning process enhanced students' understanding of the capabilities of AI but also aided them in recognizing the value of the human perspective. Students acknowledged that creative criticism plays an important role in evaluating and analysing whether the image proposed by AI aligns with the design brief and to what extent it corresponds to the designer's vision and the design goal.

Furthermore, in this collaborative endeavour it was important not only for the individual to appropriate knowledge on how to incorporate the use of AI in the design process, but also how the team is engaged with AI and what joint actions can be taken to achieve the desired results. Integrating the views of the others and exploring alternatives to respect the differences are some of the approaches towards enhancing teamwork.

Limitations, Challenges and Future Work

From a pedagogical perspective, the systematic implementation of AI in the project development helped us analyse both its potential limitations and strengths in the preparation of our students. For example, AI aided the exploration of unexpected concepts, color schemes, age-appropriate design elements but failed to optimize the spatial arrangement and comply with codes, ergonomic and safety requirements. In addition to functionality, aspects such as design's emotional impact and sustainability are considerations, which rely mainly on human critical judgement and expertise. We obtained valuable insights on the capabilities of the students to interact with AI tools, which gave us ideas about areas to focus on in future projects. A strategy to better support students in utilizing AI in their creative process is to include writing exercises to improve the accuracy and clarity of their prompts. This will ensure a more relevant and effective AI-generated output and will equip them with confidence in troubleshooting unexpected results. Additionally, the incorporation of activities to evaluate AI-renders and compare them against design briefs and project goals, will further enhance students' critical thinking skills. While AI produces excellent renders, it falls short in developing traditionally needed media in interior design, such as plan views, sections and axonometric drawings, which demonstrates that AI cannot replace the work of the trained designer.

One of the challenges we encountered was determining how to evaluate whether the students have achieved AI literacy and the level of mastering the competencies required to work effectively with AI. We used traditional evaluation indicators such as depth and relevance of the research, creativity and originality of the design concept, functionality and aesthetics of the design, detail and accuracy of the design documentation. However, to ensure comprehensive evaluation of the AI-aided design process and outcomes, we consider that the assessment criteria need to be refined and updated. Providing a reliable method for the evaluation of the AI literacy of design students, including prompt formulation, critical evaluation of AI outputs, ethics and responsible use of AI, etc. could be the objective of future research. Though the ethical considerations of the utilisation of AI as a design tool were outside of the scope of the presented study, we recognize their importance. We plan to provide special guidance and recommendations for our students to address these issues in subsequent projects.

Conclusion

Contrary to the belief that AI might threaten creativity, with the implementation of the children's space project, we demonstrated that it can foster both individual and collaborative creativity and can be successfully used as a research and conceptualization tool in design. AI tools offer numerous advantages that modernize the design process. However, it is important to note its drawbacks and limitations, which highlights the necessity of human criticism. We can conclude that students developed essential skills to interact effectively with AI, which respectfully had a positive impact on their design skills. We exposed them to a new environment where they had to solve problems in a new way, which inherently requires a creative approach. Furthermore, student's unique skills and different cultural backgrounds contributed to the creation of a richer project. The overall positive evaluation we received as feedback from the participants emphasized that the project is timely and quite necessary. As one student shared: *"AI is the future so it makes sense that we start learning about it in class, it was a good way to learn about actual things, not just a program."* We will continue observing how AI technologies mature to explore further the opportunities it offers for design education and the design profession.

References

Architizer, (2024) The State of AI in Architecture. Available at: https://www.chaos.com/state-of-ai-architecture

Charmaz, K. (2006) Constructing Grounded Theory: A practical guide through qualitative analysis. Thousand Oaks, CA: Sage.

Charmaz, K. (2008) Grounded Theory as an Emergent Method. In S. N. Hesse-Biber & P. Leavy (Eds.), *Handbook of emergent methods* (pp. 155–170). New York: The Guilford Press.

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

Long, D. & Magerko, B. (2020). What is AI Literacy? Competencies and Design Consideration. CHI '20: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, pp. 1 – 16. https://doi.org/10.1145/3313831.3376727

Markauskaite, L. et al. (2022). Rethinking the entwinement between artificial intelligence and human learning: What capabilities do learners need for a world with AI? Computer and Education: Artificial Intelligence 3 (2022) https://doi.org/10.1016/j.caeai.2022.100056

Marr, B. (2024) A Short History of ChatGPT: How We Got To Where We Are Today. Forbes, 19.05.2024. Available at: https://www.forbes.com/sites/bernardmarr/2023/05/19/a-short-history-of-chatgpt-how-we-got-to-where-we-are-today/

RIBA, (2024). RIBA Artificial Intelligence Report. Available at: https://www.architecture.com/knowledge-and-resources/resources-landing-page/riba-ai-report-2024

Rubin J. (2022) Faculty Guide for Collaborative Online International Learning Course Development. Available: http://www.ufic.ufl.edu/UAP/Forms/COIL_guide.pdf

Vinchon, F. et al. (2023) Artificial Intelligence & Creativity: A Manifesto for Collaboration, The Journal of Creative Behavior, Vol. 57, Iss. 4, pp. 472–484. https://doi.org/10.1002/jocb.597

Looking, Experimenting, Creating, Telling – Testing a Pedagogical Model for Design Learning

Kathryn McSweeney, ATU St Angelas, Sligo, Ireland
Lorraine Portelli, University of Malta, Malta
Riikka Räisänen, University of Helsinki, Finland
Mari Kosunen, University of Helsinki, Finland
Zoi Arvanitidou, University of Malta, Malta
Päivi Fernström, University of Helsinki, Finland
Kaisa Hyrsky, University of Helsinki, Finland

Abstract
This article shares the outcomes of international workshops focused on traditional costume construction and surface embellishment techniques and designs. These workshops were inspired by the findings of the Creative Europe TRACtion (Traditional Costume Innovation) project. The latter motivated students and adult learners in the Republic of Ireland, Finland, and Malta to develop creative, sustainable, and innovative responses to traditional textile artefacts. The Finnish Association of Design Learning (SuoMu) Design Learning Model was applied to support the development of creative thinking in the workshops. Additionally, teaching strategies developed by textile educators and craftspeople in each context complemented the SuoMu Design Learning Model, facilitating interactions between workshop ideas, materials and participants. The workshops aimed to foster design, creative thinking, sustainability, innovation, and a deeper appreciation of textile heritage. Participant feedback was analysed through thematic data analysis, and the visual outcomes were examined for indicators of creative thinking, such as fluidity, flexibility, elaboration, and uniqueness. The SuoMu model played a key role in guiding the design process and developing creative thinking skills. Sketching and brainstorming techniques sparked a wealth of ideas, while group activities and practical and experiential learning supported the ideation process. The workshops led to numerous fluent and flexible responses and ideas, many of which evolved into unique and innovative designs. Participants developed visual literacy skills and textile cultural empathy while achieving sustainability in material usage.

Keywords
traditional costumes, intangible cultural heritage, textile education, design learning process, creative thinking

Introduction
Creativity is culturally defined (Sawyer & Henriksen, 2023), and because culture is continuously re-created by people (Van zanten, 2004), various conceptions of creativity exist. Many creative products are “collaborative, group creations” (Sawyer & Henriksen, 2023, p. 245) and traditional craft outcomes provide valuable information about cultural practices. This study was underpinned by the need to build awareness, especially among younger generations, of the importance of our textile cultural heritage and the need to safeguard it (UNESCO, 2003). We

wanted to bring to light tacit knowledge and skills relating to traditional textile costume artefacts in three contexts. To that end, textile costume artefacts from the 19th and 20th centuries were selected for analysis by the Creative Europe TRACtion project research team (Portelli et al., 2024) in the Republic of Ireland (RoI), Finland and Malta (Figure 1).

Embroidery and lace designs used in Irish costumes constructed during the early 1900s were analysed for the TRACtion study. Four costumes were selected (Figure 1, Row 1) and included: 1) a wedding gown with Irish crochet lace and whitework embroidery (Images 1 and 5); 2) a whitework child's dress and cape (Images 2 and 6); 3) a skirt with Irish crochet and Mountmellick whitework embroidery (Images 3 and 7); and 4) a Carrickmacross appliqué lace skirt (Images 4 and 8). Irish crochet was commonly used as a trim or insert feature in clothing. Mountmellick embroidery, originating in County Laois, is a distinctive Irish whitework embroidery due to its implementation on a larger scale, floral designs and the contrast between matt background fabric and shiny mercerised cotton stitching (Stanton & Scott, 2009). Italian lace designs and techniques influenced lace production in Carrickmacross, County Monaghan, owing to the travels of an Anglo-Irish philanthropist, Mrs Grey Porter, who recognised the value of lace in providing a family income in rural areas. She acquired Italian lace samples for analysis and supported the education of lacemakers who adapted many designs by including traditional symbols (O'Neill, 2023).

Traditional folk costumes in Finland refer to traditional festive and everyday clothes worn by the peasant population in the 18th and 19th centuries (Valkeapää, 2023). The Finnish component of the study focused on native Äyrämöinen women's folk costumes originating from Koivisto and Heinjoki in the Karelia Isthmus (Figure 1, Row 2). The Isthmus, which previously belonged to Finland until the Second World War, is located between the Gulf of Finland and Lake Ladoga and is now a part of northwestern Russia. Owing to multiple conflicts, the Karelia region was isolated from European cultural life, and consequently, its costumes remained traditional until the beginning of the 20th century (Hollmén, 2009). The clothes were skilfully made, and much effort was invested in decoration. The embroideries that stood out from the generally simple clothing were the defining characteristic of the vibrantly coloured Äyrämöinen costumes. Numerous hand-woven and braided colourful ribbons were used in the costumes for various functions, including belts, headgear, sock ribbons, and clothing fasteners.

The Għonnella (Figure 1, Row 3), a traditional Maltese costume, was analysed owing to its unique form and construction processes. The voluminous, cape-like garment was draped over the head by the wearer. It was constructed from cotton, corded silk, or linen (Azzopardi, 2022) and reinforced with materials such as cardboard and whalebone to provide structure and flexibility, which were essential characteristics of this garment (Portelli et al., 2024). The design evolved owing to social and cultural influences while maintaining its significance as an emblem of Maltese heritage. Its use gradually declined, disappearing almost entirely by the 1970s and ultimately by the end of the 20th century (Azzopardi, 2022).

Following the selection of costumes in each context, the costumes' structural and technical construction processes, including fabric manipulation and embellishment techniques, were scientifically analysed and represented using two and three-dimensional methodologies. The traditional costume analyses informed the design of a series of innovative face-to-face workshops for adults and young learners in Ireland, Finland, and Malta, as well as online workshops for a broader international audience.

Figure 1. Selected TRACtion traditional costume artefacts (Top - RoI: Private collection photographed by Kathryn McSweeney & Donal Hackett; Middle - Finnish Koivsto and Heinjoki costumes (Museum artefacts (South Karelian Museum, Lappeenranta) photographed by Riikka Räisänen); Bottom - The Għonnella – the Maltese costume (Photos (1-3) courtesy of the National Archives of Malta photographic collection, images 4 – 7, photographed by Lorraine Portelli).

In addition to developing an appreciation of textile cultural heritage using traditional costume artefacts, the TRACtion project granting body (Creative Europe) stipulated a focus on sustainability. A critical goal of the project was to promote sustainable textile production approaches and thinking, including considering the processes and resources required to make clothing. Another TRACtion project requirement was the development of creativity and innovation. In Ireland, Finland, Malta, and other contexts, there is a movement in education away from routine knowledge (Sahlberg, 2011), routine skills (OECD, 2024b) and cumulative knowledge and learning (Konst & Kairisto-Mertanen, 2020; Vincent-Lancin et al., 2019) toward the facilitation of learning situations that foster broader and deeper learning (Fullan et al., 2018; Koli, 2017). Contemporary primary and post-primary educational frameworks in Ireland, Finland, and Malta identify creativity as a key skill and competency and include it in learning outcomes (DES, 2015; Finnish National Board of Education, 2016; MATSEC, 2024; Ministry of Education and Employment, 2012; NCCA, 2023a, 2023b, 2024). In alignment with current educational trends in the above contexts, the project team designed learning experiences that had the potential to foster an appreciation of textile cultural heritage, sustainability values and creative thinking.

Literature Review

Cultural heritage and sustainability

Traditional craft outcomes provide valuable information about cultural practices. These practices, including expressions, knowledge, and skills, are often recognised as part of a cultural legacy by communities, groups, and sometimes individuals and are recognised by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as intangible cultural heritage (UNESCO, 2003). Textile culture is an integral part of people's way of life. UNESCO's recognition of cultural sustainability as a dimension of sustainability (UNESCO, 2019) has generated a greater awareness of the importance of intangible cultural heritage and action towards its safeguarding. In addition to promoting cultural sustainability, this project incorporated sustainable production processes. We aligned with Treggiden's view (2020, p. 119) that "sustainability is not the main driver of our creativity, but it has definitely become a factor in our design process." The traditional costume artefacts selected for the study were "slowly made, mended by hand and cherished for generations (Treggiden, 2020, p. 114)." Through exposure to costume artefacts and their inherent qualities and techniques, we aspired to develop an appreciation for their utilitarian and aesthetic value, illustrate and promote the skills used in their production, and consequently counteract disposable trends and a "throwaway culture" (Fletcher, 2016). We used textile artefacts to generate "emotive orientations", as the works were "experientially and emotively real" (Pallasmaa, 2015, p. 9), as well as innovative and creative responses.

Creative thinking

The Organisation for Economic Co-operation and Development (OECD) define creative thinking as producing diverse and original ideas and evaluating and improving others' ideas (OECD, 2024a). The ability to engage productively in generating, evaluating and improving ideas "can result in original and effective solutions, advances in knowledge and impactful expressions of imagination" (OECD, 2024b, p. 42). Creative thinking skills use divergent thinking and involve cognitive processes such as generating and integrating ideas and seeing things in new ways (Johnson, 2010). It is widely recognised as a 21st century key skill (Dufva & Rekola, 2023; OECD, 2024a; World Economic Forum, 2023), a higher-order cognitive thinking skill (Anderson et al., 2001; Bloom, 1984; OECD, 2024b) and a global competence (Fullan et al., 2018). In 2022, the OECD Program for International Student Assessment (PISA) measured 15-year old students' creative thinking abilities for the first time, illustrating the value placed on creative thinking in today's world, one that requires new methods and perspectives to tackle emerging challenges (OECD, 2024a) and wicked problems (Thuan & Antunes, 2024). Additionally, digitalisation and artificial intelligence advances provide evidence of the importance of developing innovation, creativity and critical thinking skills over routine skills (OECD, 2024b).

Vincent-Lancin et al. (2019, p. 27) explain that creative thinking in an educational context can foster a profound understanding of "knowledge and solutions, and thus deeper learning." Positively, creative thinking can promote learning and engagement, deepen a student's absorption in their learning, activate higher-order cognitive skills and stimulate emotional development, resilience and well-being (OECD, 2024b). Similarly, Ireland's National Council for Curriculum and Assessment (NCCA) (NCCA 2023a, p. 9) states that "unlocking and promoting children's creative potential" positively impacts motivation and self-esteem.

Much creativity research has focused on the cognitive processes involved when creating. The literature distinguishes two types: big-C and small-C. The former relates to breakthroughs or masterpieces, and the latter refers to "everyday creativity" (OECD, 2024b, p. 143). Divergent thinking elements are often attributed to JP Guildford and EP Torrance from the 1960s. Torrance (2008) distinguished four creative thinking skills: fluency, flexibility, originality, and elaboration and these measures are frequently used when assessing creative behaviour in ideation tasks (Arefi & Jalali, 2016; Handayani et al., 2021; Johnson, 2010; Runco et al., 2010; Salemi, 2010; Trisnayanti et al., 2020). Fluency can be defined as the ability to produce as many ideas as possible without evaluating them (Johnson, 2010). Flexibility involves generating varied ideas, changing "the course of a person's thoughts", changing the "viewing angle" (Trisnayanti et al., 2020, p. 3), or creating a variety of different approaches (Johnson, 2010). Originality is developing new, unusual, or unique ideas (Johnson, 2010). Finally, elaboration is the development of "ideas along with details" (Handayani et al., 2021, p. 3) and the ability to add detail and expand ideas or embellish an original idea (Johnson, 2010). Trisnayanti et al. (2020, p. 3) equate elaboration with making the idea "richer, more exciting, or more complete."

The creative process is multi-faceted. Resources needed to support the creative process include domain-specific knowledge and skills, creative thinking processes, task motivation and a supportive environment (OECD, 2024b). Similarly, Kim (2017) identifies three features of innovation: cultivating creative climates, nurturing creative attitudes and applying creative thinking skills. Creative climate includes the educational and family environment, creative attitudes relate to talent, interests and personality, and the application of creative thinking skills is linked with the ideation process.

Developing creative thinking

The OECD PISA study conducted in 2022 (OECD, 2024b) looked at students' creative thinking performance and attitudes, as well as school leader and teacher attitudes towards creative thinking, and they provided a commentary on opportunities for student engagement with creative thinking. Only 50% of students believed they could change their creativity which is surprising as the OECD argues that all students have the potential to demonstrate creative thinking (OECD, 2024b, p. 38) and that "creative thinking skills can be taught" (OECD, 2024b, p. 5) – "developed through practice and honed through education" (OECD, 2024b, p. 143). The World Economic Forum (2023) recommends providing opportunities to create and innovate and freedom to make choices, developing a growth mindset, allowing time to focus, providing appropriate challenges, guiding discovery and fostering reflective reasoning and analysis. Developing creative thinking in the classroom using textile artefacts as a source of inspiration was a key focus of our study. We were curious to learn more about effective teaching approaches, models and strategies that support the development of creative thinking. To that end, the following subsection presents teachers' key role in unlocking creativity, Johnson's Thinking Frame for Creative Thinking Skills (2010), the OECD Centre for Educational Research and Innovation (CERI) project rubric (Vincent-Lancin et al., 2019) and the SuoMu (Finnish Association for Design Learning, 2023) Design Learning Model.

In the recent PISA study (OECD, 2024b), schools faring well in creative thinking value creativity. Teachers encourage original answers and support the expression of ideas in classes. Teachers have a key role in unlocking creativity, which can be achieved by encouraging exploration, generation and reflection upon ideas (OECD, 2024b). Supporting intuition, animating imagination, revealing possibilities, broadening perspectives and generating unexpected ideas can support the development of creative thinking (Johnson, 2011). The qualities associated with the creative process can be developed using different frameworks and well-established pedagogical and design learning models.

Johnson (2010) developed a thinking frame for creative thinking skills. The framework identifies seven creative thinking skills and 'frames' or ideas to support the design of classroom teaching. The framework illustrated in Table 1 includes cognitive processes such as generating and integrating ideas and seeing things in new ways. The frame shows specific steps that can be used to support the development of the creative thought process.

Table 1. Thinking Frame for Creative Thinking Skills (CTS), adapted from Johnson (2010)

CTS	Definition	Thinking Frame
Fluency	Generate as many ideas as possible without evaluating them.	Look at the idea or problem. Do not worry about good or bad ideas. Add as many ideas as quickly as you can.
Flexibility	Create a variety of different approaches.	Look at the original. Find other ways for it to be used, solved, or applied.
Elaboration	Embellish an original idea.	Look at the idea. Add things to it to make it better or more interesting.
Originality	Create new ideas that are unusual or unique.	Find an idea or problem. Think of solutions or applications that nobody else has thought of before.
Integrate	Connect, combine, or synthesise two or more things to form a new whole.	Look at all things. Select interesting or important parts from each. Combine to describe a new whole.
Brainstorming web	Create a web to generate ideas relative to a given topic.	Look at the original ideas. Analyse to identify 2 – 5 related ideas for subheadings. Brainstorm to generate ideas for each subheading. Describe.
Generating relationships	The student will try to find related items or events.	Look at the item or event. Generate attributes. Find items or events with similar or related attributes. Describe the relationship.

Another interesting approach, developed by the OECD CERI project team to support creative and critical thinking in teaching and learning, was a rubric for teaching and learning with four categories (Table 2). The four creativity categories include inquiring, imagining, doing and reflecting. The rubric is intended to support educators in their identification of student skills related to creativity that can be nurtured by educators in teaching and learning rather than assessment. Creativity aspects presented in Table 2 can occur at different points in the learning process and may not happen in a definite order.

Table 2. OECD Creative Thinking Rubric, adapted from the OECD CERI report (Vincent-Lancin et al., 2019)

Categories	Creative Thinking Rubric
Inquiring	Feel, empathise, observe, describe relevant experiences, knowledge and information. Make connections to other concepts and ideas, and integrate other disciplinary perspectives.
Imagining	Explore, seek and generate ideas. Stretch and play with unusual, risky or radical ideas.
Doing	Produce, perform, envision, prototype a product, a solution or a performance in a personally novel way.
Reflecting	Reflect and assess the novelty of the chosen solution and of its possible consequences. Reflect and assess the relevance of the chosen solution and of its possible consequences.

Based on initial research with teachers using the rubric provided in Table 2, the OECD CERI project team developed more comprehensive design criteria for developing pedagogical activities underpinned by learning science and formative assessment principles (Vincent-Lancin et al., 2019). Sample criteria include creating students' need and interest to learn, offering challenges, supporting the acquisition and practice of content and procedural or technical knowledge, developing a product to make the learning visible, addressing problems that have several possible solutions and using many techniques to solve them, leaving room for the unexpected and including space and time for students to reflect and give/receive feedback (Vincent-Lancin et al., 2019, p. 31). The frameworks and rubrics presented thus far provide a reference point for educators when planning lessons.

One design learning model suited to developing creative thinking skills is the Finnish Design Learning Association (SuoMu) pedagogical model. The pedagogy gives students the tools to think, ideate, and create solutions, supporting the development of knowledge and skills. Experiential learning and learning by doing are used. Learners and teachers are encouraged to experiment, take initiative, exchange perspectives, and share their ideas. The process can nurture independence and courageous thinking, idea exchange, and using mistakes (Finnish Association for Design Learning, 2023). The design learning pedagogical model comprises four steps: Look, Experiment, Create, and Tell (Figure 2). According to Rönkkö et al. (2016, pp. 49-50), the Design Learning Process is holistic, as responsibility for ideation lies with the craft maker rather than "following someone else's plan and adapting a ready-made design." The holistic craft process involves brainstorming to generate ideas and designs, research, experimentation, problem-solving and reflection.

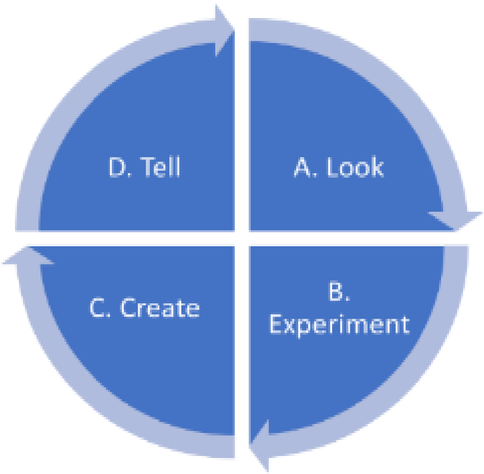


Figure 2. Design Learning Process, an adaptation of the SuoMu Finnish Association of Design Learning Model (Finnish Association of Design Learning, 2023)

The literature review informed our research design approach, providing insight into the creative thinking process, teachers' key role in unlocking creativity, and frames and models to support creative thinking development. The following section outlines the workshop design approach.

Methodology

The systematic steps of our qualitative study are illustrated in Figure 3.

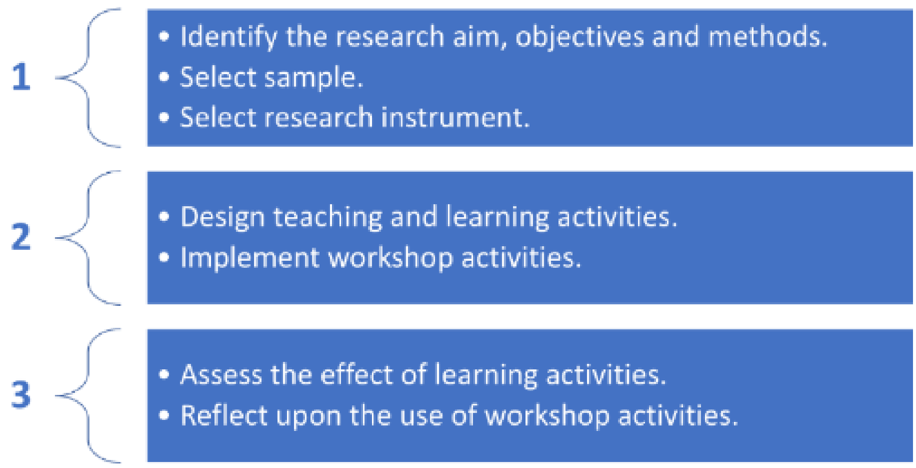


Figure 3. Systematic research steps

Step 1

Research aim, objectives and methods

The project aimed to develop an appreciation for traditional textile artefacts and heritage, support creative thinking development and facilitate sustainable and innovative responses to traditional designs and motifs.

Sample

The sample included young and adult learners from post-primary and initial teacher education and tertiary sectors in the RoI, Finland, and Malta. We used a purposive convenience sampling approach. Students studying textiles and adults interested in textiles were invited to participate in the research study. See Table 3 for a further breakdown of the sample in each context.

Table 3. Sample Composition

Context	Number	Sample Breakdown
RoI	33	Adult learners, including National Learning Network learners (n=12) (back to work upskilling context) and adult learners (n=21), including young adults, textile enthusiasts, university craft education alums, artists, and textile artists
Finland	48	Craft education pre-service teachers (university level)
Malta	46	Teachers (n=10), pre-service teachers and university students (n=20), secondary school students (n=16)
Online	76	Members of the general public, including participants from the face-to-face workshops

Instrument

We focused on developing creative thinking using workshop strategies and illuminating creative behaviour in ideation tasks. Creative behaviour in workshop ideation tasks was informed by Torrance's four measures of divergent thinking framework (Torrance, 2008) and Johnson's (2010) thinking frame for creative thinking skills (Figure 4). The creative thinking measures include fluency, flexibility, originality and elaboration.

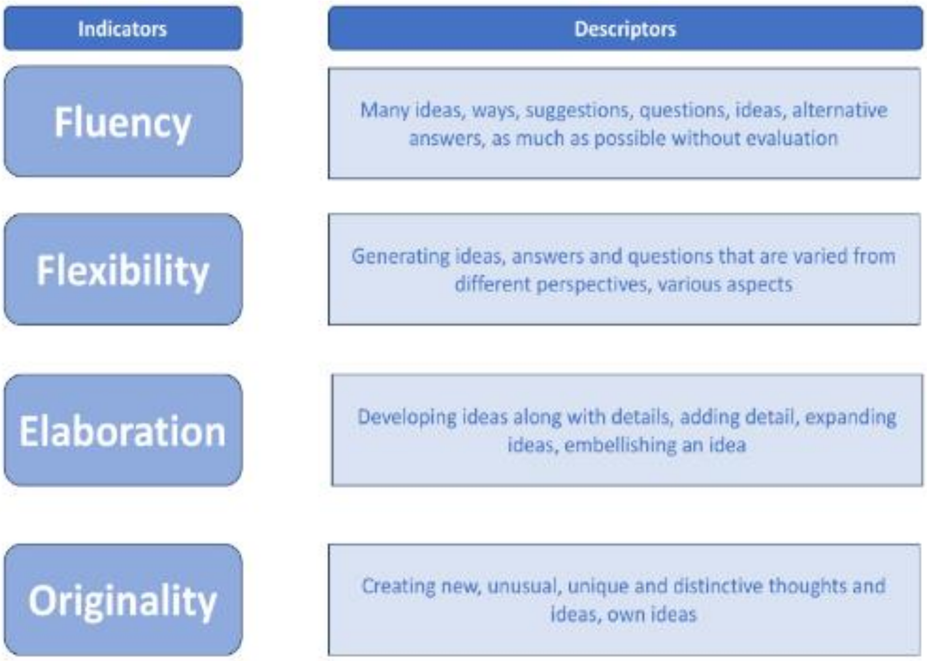


Figure 4. Measurement points for creative thinking indicators, adapted from the work of Torrance (Torrance, 2008) and Johnson (2010)

Step 2

Teaching and learning activities

The workshop instructors used the SuoMu (Finnish Association for Design Learning, 2023) Design Learning Model (Figure 2) when planning learning activities. The first stage, 'Look, ' involved a brainstorming strategy to quickly generate a bounty of ideas based on materials they got acquainted with. In the RoI, participants engaged in a sketching challenge involving selecting a costume design and drawing for three minutes. They used mixed media when drawing and worked on paper and fabric. Using mark-making and words, they individually documented their observations, emotions, and ideas. The participants proceeded to another design, repeated the task and shared their sketches with the group. Following the presentation of sketches, participants individually recorded any new ideas that occurred to them. They developed responses without censorship or evaluation. Essentially, we provided an alone-together-alone structure to support interaction between ideas and group synergies and to allow for independent solo work and ideation. Workshop participants in Finland used the brainstorming strategy to generate ideas, variations and possible solutions for hand-dyed tablet-woven belts and jewellery. Karelian folk costumes and jewellery served as a source of inspiration during the 'looking' stage. Ideation was upgraded to the next level using brainstorming. Similarly, Maltese participants used the brainstorming strategy to generate ideas for contemporary Għonella designs.

Following the brainstorming phase, participants experimented and created (Steps 2 and 3). The ideas generated from the brainstorming activity were classified to find the best ones for further development. Participants were free to respond in any direction, using various media, and abundant resources and materials were available, including fabric scraps (RoI and Malta), wool remnants and natural dyeing materials (Finland), to promote sustainable design responses. The workshop facilitators asked questions to support the design process. Finally, Step 4, 'Tell', involved participants showcasing advanced ideas using mood boards, sketches, and prototypes. After the workshops, participants had time to work on their designs, which resulted in numerous artistic creations in each context. Exhibitions were held in each county from May to August 2024 in addition to a combined virtual reality exhibition (https://tractionproject.eu/news/traction-joint-digital-exhibition/).

Practical, experiential learning

In the RoI, workshops focused on volume, specifically textile tucks and gathers, design ideation and development, including costume stitched responses, patterning inspired by costume motifs, media explorations and linkages, and experimentation with mixed media. Finnish craft workshops focused on traditional Finnish and Karelian textiles, colours and colouration techniques. Follow-on workshops focused on contemporary ideation and accessory prototyping. Similar to the RoI, in Malta, workshops focused on volume and the use of gathers to create different forms and structures. In each context, a guided teaching approach and brainstorming strategy were employed to encourage the development of fluent, flexible, elaborate and original ideas.

Implementation

20 hours of workshop activity were completed in Ireland, 27 hours in Finland, and 4 hours in Malta. The project team implemented two online workshops totalling 3 hours. 54 hours of direct workshop input were delivered during the project. Learners in the RoI used mixed media

when developing design ideas and prototyping. They created patterns, costume embroidery samples, and lace using crochet, tatting, and free-machine embroidery techniques and recorded their processes and ideas as they evolved during the workshop. They also presented workshop notebooks, prototypes, textile art, and mixed-media installation pieces. Finnish workshop outputs included sketches, drawings, photo collages, mood boards, portfolios, prototype artefact samples, finished products, jewellery, and dyed and woven belts. Using portfolios, participants explained their design and production processes with pictures, photographs, and text and documented everything from inspiration and ideation to the final finished output. Ideation steps were illustrated with photos that inspired the work. The participants illustrated different stages, variations and iterations in the design development and how the plan was concretised into the final craft product. Additionally, participants reflected upon their learning during the process and at the end. Maltese teaching plans provided contextual and technical content, visual imagery, digital resources, costume artefacts, and interactive opportunities where participants experimented, prototyped, reflected, created, and evaluated.

Step 3

Assess the effect of learning activities

We employed a qualitative thematic analysis approach (Braun & Clarke, 2022) involving a detailed description of textual workshop feedback and oral recordings. Workshop outputs, including design drawings, notebook pages, prototypes, and products, were analysed using a descriptive thematic visual analysis approach (Literat, 2013), which focused on describing the indicators of creative thinking (Handayani et al., 2021; Johnson, 2010; Torrance, 2008). The analysis of drawn images complemented with a discussion of the drawings is a non-mechanical visual research method (Coyne et al., 2021; Literat, 2013) suited to various cultural contexts. The method can potentially reveal "a more nuanced depiction of concepts, emotions, and information in an expressive, empowering, and personally relevant manner" (Literat, 2013, p. 84).

Conclusion

Reflect upon the use of workshop activities

The project team considered the use of learning activities to support creative thinking. We noted the learning gained from using the design learning model, practical and experiential learning tasks, sketching and brainstorming strategies.

Results

Workshop outcomes

We gathered oral (pseudonymised) and anonymised written feedback from the workshop participants (RoI (n=19), Finland (n=16), Malta (n=20)). The process was designed to be voluntary, which meant that feedback was not received from every participant.

Effectiveness of the teaching and learning strategies

The brainstorming and sketching activities created energy and anticipation among the participants. The experience was articulated by Aisling (RoI) as follows:

> *"The idea of having structure and surrender is what I feel is happening here today. Surrender – enjoying the whole atmosphere – this beautiful history and fine work*

> *combined with five minutes – voom, voom, voom- so we didn't get stuck. I find it so joyous."*

The participants enjoyed the "freedom of expression" (RoI, Participant (P) 1, P16), "learning techniques freely" using an experimental process (RoI, P7), having the "freedom to play" (RoI, P8) in an interactive (Malta (M), P2, P19) and positive learning environment (RoI, P15). The participants welcomed the "hands-on part" (M, P8), "hands-on activities" (M, P12) and "the practical aspects" (M, P14, P18), including "designing and sewing" (M, P14), "the making of the mini Għonella model" (M, P17, P16) and "learning by doing" (Finland (F), P8).

> *"The hands-on approach and learning through doing were synergistic. Casual discussions, insights, and thought processes that followed were fruitful and valuable for me." (F, P10)*

The alone-together-alone brainstorming approach was effective. One respondent commented that she enjoyed the "collaboration with others to form new ideas" (RoI, P7).

The participants welcomed the "opportunity to learn different things and ways of doing things" (RoI, P2), using mixed media and freely available resources to support their work in different directions. An environmentally conscious approach was evident in many responses. For example, "recycling materials represents sustainability to me, which is an important value (F, P15)." One participant spoke about repurposing materials that are "no longer used … giving them a new life as I no longer found them visually appealing in their previous form (F, P15)." Another participant noted the environmental issues surrounding using metal mordants when dyeing fabric and the need to look "for ways to use organic substances for mordanting that would be less harmful" (F, P2). The economic value of dyeing with natural materials and without "large quantities of chemicals" (F, P4) was mooted. "Finding ways to replace synthetic dyes with environmentally conscious alternatives" was a key takeaway from the Finnish workshops (F, P4).

The participants welcomed the group approach, which was a "social process" as "ideas and skills were shared and developed together (F, P14)." They enjoyed "bouncing ideas off each other" (RoI, P10), which supported the ideation process (RoI, P13, P14, P15) and produced a variety of "rich and diverse" outcomes (F, P10). "The shared ideas have inspired us to continue experimenting with different techniques" (M, P3) and "viewing the work of others supported the ideation process (M, P1)."

> *"We learned from each other. We shared various emotions- challenges, successes, and techniques and observed each other's experiments." (F, P15)*

> *"Since I didn't have time to try everything myself, observing the work and processes of others made the course content more diverse." (F, P16)*

Overall, it is evident that the group workshops were enriching and enlightening (M, P2), and the group process was social, interactive and productive.

The experimental process was especially evident in Finnish responses. They were noticing and making decisions about the next direction to take (F, P2). Skills were acquired through "trial and error" (F, P2, P16), and actions were taken based on developing procedural knowledge. For example, different yarns were used to produce different colour effects, and the decision to use -materials was "intentional" and informed by knowledge of how the "materials absorb the colour differently (F, P2)." Three further examples (F, P8, P15, P16) evidence students' "learning by doing":

> *"Early in this course, the very pale beige tones taught me to study plants more carefully and get to know their properties." (F, P8)*

> *"I didn't set out to create any specific form but rather let the process guide me, and I am pleased with the results." (F, P15)*

> *"The process of making the jewellery was quite organic, as I was guided more by trial and error than by following a precise plan." (F, P16)*

Part of the experimental process involves problem-solving and overcoming challenges. One Finnish participant illustrates her learning as follows:

> *"I feel that trying and failing were key parts of my learning process. By continuing to experiment, I started finding plants in nature that could produce colour." (F, P5)*

Participants reflected upon mistakes occurring during the prototyping and production stages. One Finnish participant observed that "making a tablet weaving band requires a calm space and concentration, especially if you're creating a pattern" (F, P1). The participants reflected deeply upon their processes. One Finnish participant (F, P1) felt that the final result was "a bit restless. The shades are beautiful but didn't create the clearer stripes I hoped for." Another response illustrates the participants' engagement in dialogical reflection:

> *"I also had a small test sample of wool yarn in the same dye baths, with which I conducted an experiment. I wondered what would happen if I neutralised the oxalic acid from the rhubarb with baking soda as a base." (F, P2)*

Additionally, elements of critical reflection were evident:

> *"I remember a statement I read suggesting that artisans who "talk" with their materials do not necessarily separate thinking from making but rather create through a collaboration of hands and mind (Atkas, 2018). I found myself identifying with that idea. My design process is childlike and playful. There is spontaneous enthusiasm for making and experimenting, but there is always a vision behind it about the theme I'm exploring and where I am heading." (F, P12)*

The students commented on new learning and "surprises" (F, P1), and their enjoyment of the experimental process was palpable.

> *"There is a primal, almost magical aspect to plant dyeing, seeing the colour change as it dries." (F, P4)*

> *"The enthusiasm for exploring plants and walking attentively in nature that the course fostered was refreshing. Dyeing with natural dyes in schools could also spark interest in nature." (F, P8)*

Another Finnish pre-service teacher had similar ideas for classroom teaching. She developed a worksheet for a group of young learners "to guide them, where they could colour in their hypothesis about the expected colour of the fabric and compare it to the actual results (F, P5)." One pre-service teacher alluded to her frustration with her "lack of skill" or level of procedural knowledge about dyeing and noted that she would keep the experience in mind when, as a teacher, "encountering students who are uninterested or unmotivated by certain [craft] techniques (F, P10)." Finally, participants' confidence in their creativity grew during the workshops. For example:

> *"Creating was easier for me than I had thought." (RoI, P1)*

> *"I am not afraid to try things out." (RoI, P11)*

> *"I was much freer in my creative process. Usually, I overthink and stress, but in the workshops, I just did it." (RoI, P19)*

> *"The phrase "just start" was so empowering. There was no pressure to produce anything in particular." (RoI, P9)*

> *"We were free to do what we wanted" (M, P15) … "allowed one to be creative." (M, P20)*

Textile cultural heritage appreciation

All participants were inspired by the costumes, their history and the different styles. Many participants (RoI) remarked on the value of costumes in revealing a story such as "the use of needlework as a means to freedom- a ticket to America for a woman in Ireland (Aisling, RoI)." For many Maltese participants, learning about the Għonella costume, its cultural and historical context (M, P13), and its construction was "new" (M, P9). Additionally, nature as a common source of inspiration was noted as a "really beautiful line of thread from them to us (Silvana, RoI)." The majority of participants noticed the natural and environmental design connections:

> *"I noticed how informed these women [craftspeople] were by the landscape around them, which we still share today. This piece [wedding dress] – the back of the dress and the threading through here, and the fine squares are like cells (Figure 5). For me, the spaces here are like the fields of the Irish landscape, and the hedges create the cells that make up nature – all the boxes you see between the threads. Everything they experienced [in the past] we still experience today. I could see it in the work; what the women saw back then, such beauty that we encounter daily, is recorded on the cloth. They told us their story through the cloth. It is just so exciting and beautiful that you can immerse yourself in that today." (Silvana, RoI)*

> *"Upon inspection of the traditional lace, we learned that the creators used inspiration from all around them in their work and often worked in groups like this." (Saoirse, RoI)*

“These pieces often feature strong themes of nature, which led me to further observe plants and natural forms during walks outside.” (F, P15)

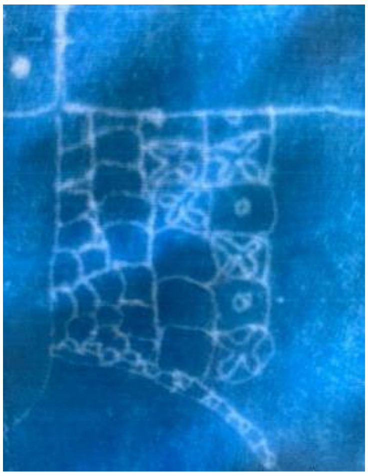


Figure 5. Lace Cells by Silvana Zec (RoI), Cyanoprint inspired by Irish lace

The participants alluded to looking at and exploring the designs and lacework in a new way (RoI, P4, P9). They recognised costume imperfections and realised that “mistakes are not a bad thing or a fault” (RoI, P11).

Inspired by the embroidered patterns of traditional Karelian folk costume, one Finnish participant designed a two-finger “statement ring with a large decorative plate covering four fingers" (F, P14).” In his view, the innovative design honoured the traditional folk costume patterns (Figure 15).

“By combining traditional patterns with modern design, I created a piece that is both visually attractive and culturally meaningful. Through my ring, I emphasise values such as respect for tradition, appreciation for craftsmanship, and the preservation of cultural heritage.” (F, P14)

“It helped me build a certain kind of identity as both a craftsperson and an artist – someone who respects tradition while seeking new ways of expression. The ring became, in a way, personal to me. I am originally from North Karelia, and it was fascinating to immerse myself in the design, crafting, and making of the piece. In a certain sense, it tells the story of my own roots and artistic journey.” (F, P14)

The international online workshops helped the project team in their dissemination of project outcomes and to further advance learning and an appreciation of costume techniques. One participant commented on the similarities of the methods, particularly the use of pintucks and gathering. They explored traditional fabric manipulation and Karelian embroidery techniques (Figure 6).

Figure 6. Karelian Kivennapa coat embroidery (South Karelia Museum) inspires international workshop participants and sample by XXX.

Creative Thinking Skills

Fluency and flexibility

The textile costume artefacts inspired different responses. Each costume resulted in "vastly different products at the end," and it was interesting "seeing how everyone interprets things differently (RoI, P8)." In response to the sketching activity (RoI), some participants recorded very accurate details and representations, and other responses were looser, freeform or abstract (flexibility). Figure 7 illustrates group fluency and flexibility and participants' responses (RoI) to different costume motifs and construction features. Row 1 illustrates the wedding dress costume with a needlepoint lace seam sample, 2-dimensional (2-D) illuminations and a constructed sample. Row 2 features the dot and crescent motif from the child's costume, a costume sample, and clay, cyanotype, and lino print explorations. Row 3 shows Mountmellick whitework embroidery costume samples and 2-D mixed-media work. Row 4 presents Carrickmacross lace interpretations, including 2-dimensional work with expanding foam, thread, crochet, clay and free machine embroidery.

Two workshop outputs were generated in a Finnish context (Figure 8), including tablet woven bands with yarns dyed with natural dyes made from velvet-roll-rim mushrooms, dried flowers, rhubarb, mugwort, rowanberries, onion skins and madder, to name a few and jewellery inspired by the traditional Karelian folk costumes. It was fascinating to observe how the details of Karelian folk costumes evolved during the students' creative process, transforming into new patterns and ways of using ribbons and ribbon ensembles. Tassels, embroidery, pearls, and other embellishments—rarely seen in traditional tablet weaving—were innovatively integrated. The interplay of varying warp and weft thicknesses and weaving techniques that merged traditional methods and contemporary rougher aesthetics added another layer of interest.

In Malta (Figure 9), participants created maquettes and samples. Time availability prohibited the advanced development of designs to the prototype and production stages. However, the samples show the acquisition of technical procedural knowledge and early ideation experimentation processes, including varied use of colour and fabric and mixing traditional with contemporary fashion design influences and styles. The two online workshops were held three days apart, giving participants time to respond to the activities. Figure 10 illustrates a variety of responses, including flexibility and some elaboration.

Figure 7. Fluency and flexibility of ideas, RoI (see acknowledgement section for contribution details)

Figure 8. Fluency and flexibility of ideas, Finland (see acknowledgement section for contribution details)

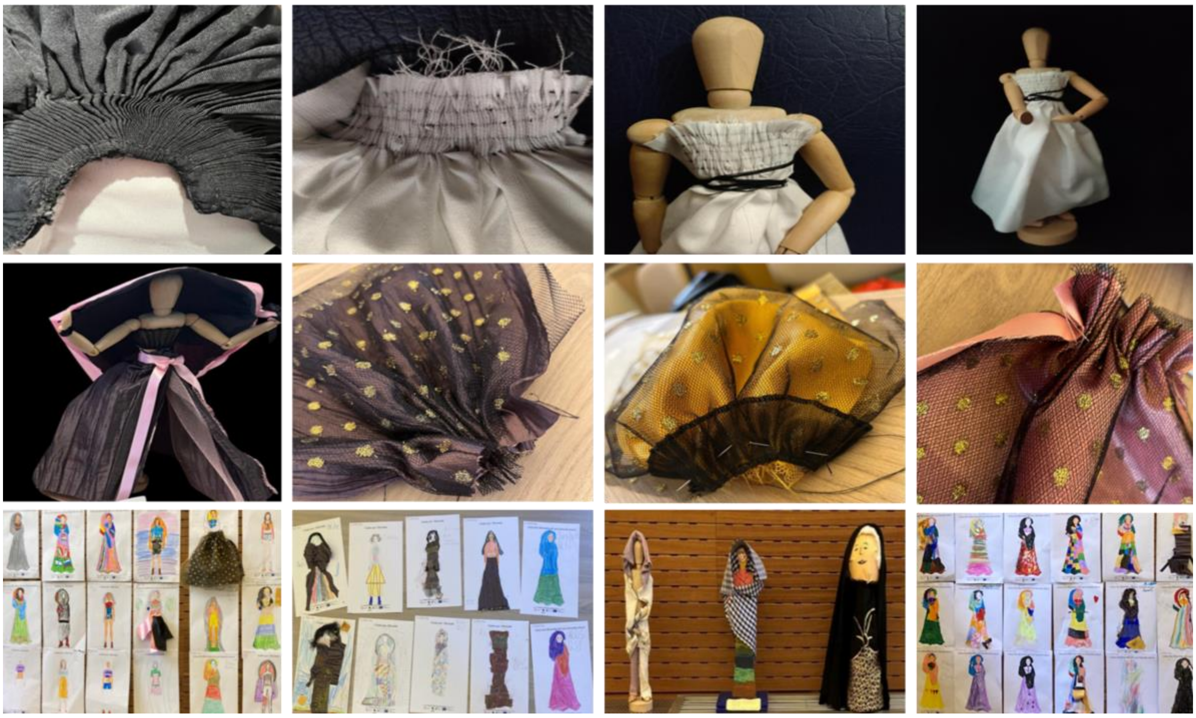


Figure 9. Fluency and flexibility of ideas, Malta (see acknowledgement section for contribution details)

Figure 10. Sample online workshop responses illustrating flexibility and elaboration

Elaboration

Some elaborate and embellished ideas emerged in the workshops. In the RoI, Alison focused on patterns and movement within the designs, and her work elaborated on these (Figure 11). She photographed the lace designs and concentrated on the lace spaces. “My pictures were quite blurry, but I liked that. There were spaces where I could see netting underneath, which was quite sharp. I like the idea of the layers and putting depth into it. It intrigued me.”

Figure 11. Development of lace design from paper to print using a stencil and lino print to the final exhibition piece, ‘Lace Spaces’ by Alison Hunter (RoI)

In a Maltese context, a group of workshop participants adopted a sustainable and contemporary approach by patchworking the base fabric used in creating a Ghonnella (Figure 12) and applying the symbolic Maltese cross to the rear of the costume.

Figure 12. Patchwork Ghonnella with Maltese Cross appliqué by Maltese university students

Originality

A few well-developed and considered designs were noted as unique or unusual. Figure 13 illustrates a lace rubbing to reveal different shapes. During workshops (RoI), costume border patterns were copied and recreated in new ways using a Truchet tile patterning technique (Lord & Ranganathan, 2006). The pattern that emerged from the lace rubbing was lifted from the drawing, and a new pattern was created by moving the tile shape around in different directions.

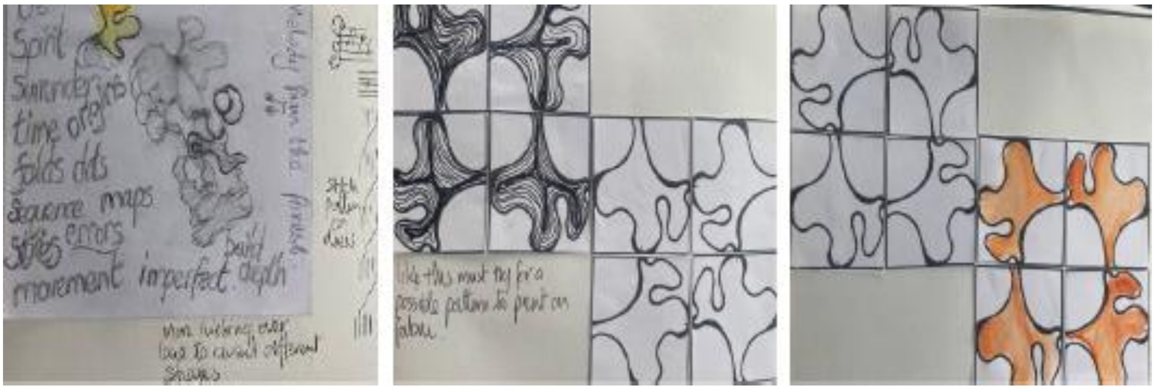


Figure 13. An original Carrickmacross lace rubbing and pattern creation by Linda Kerlin (RoI)

Another example of advanced design and crafting skills is evident in Figure 14. The student replicated the "metal raising" skill, an ancient jewellery technique. The earrings were deliberately textured and polished "to bring a sense of elegance" to the product (F, P13). What is unique in this design is that the earrings can be worn with or without the plates added behind the earlobe.

Figure 14. An original earring design by Riikka Räsänen (Finland)

Olli (F, P14), who previously referred to the importance of cultural heritage in his design process, designed a two-finger statement ring (Figure 15) "to serve both as an aesthetic and symbolic object….allowing the wearer to express their personal style and cultural heritage." The geometric shapes and colours of the Karelian costume embroideries inspired the design.

Figure 15. An original ring design by Olli Sutinen (Finland)

Another Finnish participant produced trendy "earrings different from each other because I wanted to highlight how every craft is one of a kind (F, P15)." Her endeavour involved merging tradition with modern design (Figure 16). "I aimed to challenge my aesthetic sense in a new way and expand my understanding of how tradition and modernity can coexist in design."

Figure 16. An original pendant and earring design by Veera Parsanen (Finland)

Similarly, the wedding dress tatted edge pattern (RoI) inspired a jewellery outcome (Figure 17). Molly studied the tatted edge pattern using the Perfect Magnifier Application [Perfect Magnifier mobile phone application, Netigen Tools, Kraków, Poland, 2014, version 5.0.36], recreated the pattern using different yarn and transformed the scale and outcome.

Figure 17. An original jewellery design by Molly Kerlin (RoI)

Discussion

Visual literacy involves understanding (Felten, 2008), analysing and generating images to communicate ideas and concepts (Stokes, 2002) and is viewed as an essential part of teaching and learning. Workshop participants developed visual literacy skills from costume analysis and related learning activities such as sketching and brainstorming strategies. They noticed (Vincent-Lancin et al., 2019), interpreted, and made meaning from the historical and culturally significant information afforded by the costume artefacts. The importance of craft culture (Ma, 2024) transpired in participants' responses. “Textiles are often highly emotional for their makers” (Dolan & Holloway, 2016, p. 155) as the making process can be experientially real (Pallasmaa, 2015). In this study, participants' tangible exploration of costumes and related experiential learning activities enabled the development of textile appreciation, empathy, and an emotional connection to textiles. For example, the design process allowed one participant to express his “artistic vision and cultural heritage” (F, P14). The designs that were created honoured traditions and costume patterns. Our project safeguarded and promoted cultural diversity (Ma, 2024; UNESCO, 2022) and intangible cultural heritage (UNESCO, 2022). The workshops promoted innovative practices while “nurturing and retaining craft” (Brown & Vacca, 2022, p. 590). Additionally, some workshop participants alluded to the significance of crafts in materialising experiences (Kouhia, 2016) and supporting well-being (F, P11, P13), confirming that the eudaimonic intrinsic needs of “doing, belonging, becoming and being” can be expressed in crafting (Pöllänen & Weissmann-Hanski, 2020, p. 348).

The SuoMu Design Learning Model (Finnish Association of Design Learning, 2023) was highly effective in supporting the development of creative thinking. Participants mentioned the experimental approach, freedom to explore, learning from mistakes and each other as positive features of their learning. Groupwork generated interaction, sharing of ideas and joy in the learning process. Brainstorming, which is a group or individual creativity technique, generated "a list of ideas spontaneously" and helped participants "find a conclusion" or solution "for a specific problem" or task (Litcanu et al., 2015, p. 387). The brainstorming activities involved the generation and sharing of many ideas without censorship. Working alone, together, and working alone strategies stimulated individuals and 'alone time' allowed for the shared ideas to be integrated and elaborated on by each individual, and it avoided "fixation on a particular solution very quickly" (Harms & van der Zee, 2013).

Studying creative behaviour and measuring idea generation was a daunting process, but guided by well-established frames and models (Johnson, 2010; Torrance, 2008). Workshops generated many similar ideas (fluent), but time constraints limited the production of many original ideas. Participants developed variations quickly owing to the availability of materials, resources and technical input from workshop facilitators. We used a guided instructional approach, which supported flexible responses. Some participants focused on elaboration, which led to further flexibility and originality in the details and implementation. For instance, Molly (RoI) studied and recreated a lace edging pattern using crochet and tatting (flexibility). She considered making the idea better or more elaborate by using different yarns to vary the scale (flexibility) and add more visual interest (elaboration). Following her explorations, she created new jewellery designs and products (originality).

Handayani et al. (2021) underscore the importance of the teacher's role in increasing creativity. Teaching for creativity involves more than creating an enjoyable learning environment; it involves intentionally promoting learners' creative behaviour and thinking (Jameel & Mohamood, 2017). In our workshops, we relied on brainstorming, a recognised strategy for developing fluency and flexibility (Jameel & Mohamood, 2017). The time available for elaborate and original designing was limited, and those who produced embellished and unique ideas invested personal time in their work. Another possible reason for the lower level of elaboration and originality may be limited knowledge about the materials provided (Trisnayanti et al., 2020) and technical textile procedural knowledge in this case.

Many participants developed contemporary responses to traditional textile artefacts. Classroom teaching ideas emerged in some pre-service teachers' responses and included using group project work to support cross-disciplinary learning and impact. Workshop discussions revealed geological, botanical, and ecological influences on costume design, and they nurtured awareness and appreciation of the artefacts' ecological, economic, and social value. We adopted a sustainable approach in the planning and implementation of the workshops. Waste cotton sheets from local hospitals were cut and used for process experiments and product development (RoI). Every effort was made to use available materials to realise creative designs. One participant noted that "limited materials or the reuse of materials gives a framework in which the material guides the work (F, P12)" which is an important frame for designers as materials are a significant guiding part of the design process (Atkas, 2018). The ecological and sustainable use of materials was achieved in all workshop contexts and manifested in the reuse of materials, sourcing organic dye materials and being mindful of environmentally conscious alternatives. Additionally, the connection with nature and environmental empathy can be enhanced when connections are made to nature.

Conclusion
Despite the various positive outcomes outlined so far, we acknowledge that the chosen frameworks present challenges in implementation and data interpretation. We used the frameworks as a guide rather than prescriptively. The descriptive analysis and interpretation of creative outputs can be highly subjective. However, the analyses provided an opportunity for rich learning about participants' engagement with heritage textiles and crafting processes and their perceptions of the creative process. The use of visual and feedback data in this study "lends weight" (Hamilton, 2011) to the validity of our findings. However, generalisation to the broader population was not a goal of the study. While this study has limitations, we developed a greater understanding and awareness of our approach to developing creative behaviour and thinking skills. Visual research methods have immense potential, and the possibility exists to extend this work further to include visual participatory research, where participants comment on their designs.

Acknowledgements
This research was funded by the EU CREA-CULT-2022-COOP funding, Grant Agreement 101099726.

We want to thank the workshop participants who contributed to this article. Included are: (RoI) Joan Brady, Cathyanne Raftery Brennan, Noreen Conway, Ana Faye, Jeanette Gilmartin, Sophia Hummel, Alison Hunter, Margaret Jackson, Linda Kerlin, Molly Kerlin and Silvana Zec; (Finland) students from the Craft Teacher Education Programme at the University of Helsinki who participated in the 'Natural Dyeing and Phenomenon-based Learning', 'Craft Culture and Wellbeing' and 'Jewellery' courses during 2023-2024, Elsi Hyttinen, Samppa Mäkelä, Outi Satuli, Susanna Lamminaho, Riikka Räsänen, Olli Sutinen, Veera Pasanen and funding from EU RIA Horizon-CL2-2022 Heritage-01-04 for the Colour4CRAFTS (Grant Agreement 101094809); and (Malta) secondary school students, secondary school teachers, primary school pupils and Fashion and Textiles University lecturers.

References
Anderson, L. W., Krathwohl, D., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). *A taxonomy for learning, teaching, and assessing A revision of Bloom's taxonomy of educational objectives*. Longman.

Arefi, M., & Jalali, N. (2016). *Comparation of Creativity Dimensions (Fluency, Flexibility, Elaboration, Originality) between Bilingual Elementary Students (Azari language-Kurdish language) in Urmia City—Iran*.

Atkas, B. (2018). Material as the Co-designer: Exploring a new practice in the nature and at the studio. *Research in Arts in Education*, *3*, 332–348. https://journal.fi/rae/article/view/118873

Azzopardi, L. (2022). *Għonnella – Deconstructing the garment.* Midsea Books Ltd.

Bloom, B. (1984). *Taxonomy of educational objectives Book 1: Cognitive domain* (2nd ed.). Addison Wesley.

Braun, V., & Clarke, V. (2022). *Thematic analysis A practical guide*. Sage.

Brown, S., & Vacca, F. (2022). Cultural sustainability in fashion: Reflections on craft and sustainable development models. *Sustainability: Science, Practice and Policy*, *18*(1), 590–600. https://www.tandfonline.com/doi/full/10.1080/15487733.2022.2100102

Coyne, I., Mallon, D., & Chubb, E. (2021). Research with young children: Exploring the methodological advantages and challenges of using hand puppets and draw and tell. *Children and Society*, *35*, 813–830.
DES. (2015). *Framework for junior cycle 2015*. Department of Education and Skills. https://ncca.ie/en/resources/framework-for-junior-cycle-2015-2/
Dolan, A., & Holloway, S. (2016). Emotional Textiles: An Introduction. *Textile Cloth and Culture*, *14*(2), 152–159. https://doi.org/10.1080/14759756.2016.1139369
Dufva, M., & Rekola, S. (2023). *Megatrends 2023 Understanding in times of surprises*. https://www.sitra.fi/wp/wp-content/uploads/2023/01/sitra_megatrendit-2023_ymmarrysta-yllatysten-aikaan.pdf
Felten, P. (2008). Visual Literacy. Change: The Magazine of Higher Learning. *Change: The Magazine of Higher Education*, *40*(6), 60–64.
Finnish Association of Design Learning. (2023). *Mutku Design Learning Methods Booklet.* Finnish Association of Design Learning in Cooperation with the Ministry of Education and Culture. https://muotoilukasvatus.info/eng-swe/
Finnish National Board of Education. (2016). *National Core Curriculum for Basic Education*. Finnish National Board of Education.
Fletcher, K. (2016). *Craft of Use: Post-Growth Fashion*. Routledge.
Fullan, M., Quinn, J., & McEachen, J. (2018). *Deep learning: Engage the world change the world*. Sage.
Hamilton, L. (2011). *Case study in educational research*. BERA. https://www.bera.ac.uk/publication/case-studies-in-educational-research
Handayani, S. A., Rahayu, Y. S., & Agustini, R. (2021). *Students' creative thinking skills in biology learning; fluency, flexibility, originality, and elaboration*. https://iopscience.iop.org/article/10.1088/1742-6596/1747/1/012040/pdf
Harms, R., & van der Zee, K. (2013). Interview: Paul Paulus on Group Creativity. *Creativity and Innovation Management*, *22*(1), 96–99.
Hollmén, R. (2009). *Juuret Karjalassa*. Facto.
Jameel, A. S., & Mohamood, D. F. (2017). The Effect of Flexibility and Fluency Strategies on Developing Creative Writing Skills in English Language Subject of the Fourth Preparatory Literary Students. *International Journal of Humanities and Applied Social Science*, *2*(1), 37–50.
Johnson, A. P. (2010). *Making Connections in Elementary and Middle School: Social Studies*. Sage.
Johnson, S. (2011). *Where Good Ideas Come From*. Penguin Books.
Kim, K. H. (2017). The Torrance Tests of Creative Thinking—Figural or Verbal: Which One Should We Use? *Creativity*, *4*(2), 1–20.
Koli, H. (2017). *Engaging to learn How to create learning opportunities to make learning inspiring*. House of Leading and Learning Ltd.
Konst, T., & Kairisto-Mertanen, L. (2020). Developing innovation pedagogy approach. *On the Horizon The International Journal of Learning Futures*, *28*(1), 45–54. https://doi.org/10.1108/OTH-08-2019-0060
Kouhia, A. (2016). *Unravelling the meanings of textile hobby crafts* (pp. 1–104) [Home Economics and Craft Studies Research Reports 42]. University of Helsinki. https://helda.helsinki.fi/server/api/core/bitstreams/dcefe4f8-4864-4f13-9b57-2e2f97103071/content

Litcanu, M., Prostean, O., Oros, C., & Mnerie, A. V. (2015). Brain-Writing Vs Brainstorming Case Study for Power Engineering Education. *Procedia - Social and Behavioural Sciences*, *191*, 387–390. https://doi.org/10.1016/j.sbspro.2015.04.452

Literat, I. (2013). 'A Pencil for your Thoughts': Participatory Drawing as a Visual Research Method with Children and Youth. *International Journal of Qualitative Methods*, *12*, 84–98.

Lord, E. A., & Ranganathan, S. (2006). Truchet tilings and their generalisations. *Resonance*, 42–50.

Ma, J. J. (2024). Re-Engineering Nubi: A Design-Driven Approach to Cultural Sustainability in Korean Fashion/Textile Practice. *Textile Cloth and Culture*, *22*(4), 647–665.

MATSEC. (2024). *SEC 44 Syllabus Fashion and Textiles.* MATSEC Examinations Board, University of Malta. https://www.um.edu.mt/media/um/docs/directorates/matsec/syllabi/2027/sec/SEC44FashionandTextilesSyllabus2027v3.pdf

Ministry of Education and Employment. (2012). *A National Curriculum Framework for All*. Salesian Press, Malta. https://curriculum.gov.mt/wp-content/uploads/2024/07/NCF.pdf

NCCA. (2023a). *Primary Curriculum Framework For Primary and Special Schools*. Department of Education. https://curriculumonline.ie/getmedia/84747851-0581-431b-b4d7-dc6ee850883e/2023-Primary-Framework-ENG-screen.pdf

NCCA. (2023b). *Key competencies in senior cycle (draft)*. Unpublished National Council for Curriculum and Assessment document.

NCCA. (2024). *Key Competencies in Senior Cycle*. National Council for Curriculum and Assessment. https://ncca.ie/media/mfhhagys/key-competencies-in-senior-cycle_en.pdf

OECD. (2024a). *Creative Thinking*. https://www.oecd.org/en/topics/creative-thinking.html

OECD. (2024b). *PISA 2022 Results (Volume III): Creative Minds, Creative Schools*. https://www.oecd.org/en/publications/pisa-2022-results-volume-iii_765ee8c2-en.html

O'Neill, M. (2023). *Irish lace and lacemakers*. Lettertec Publishing.

Pallasmaa, J. (2015). Empathic and Embodied Imagination: Intuiting Experience and Life in Architecture. In *Architecture and Empathy* (pp. 4–19). Tapio Wirkkala-Rut Bryk Foundation.

Pöllänen, S. H., & Weissmann-Hanski, M. (2020). Hand-made well-being: Textile crafts as a source of eudaimonic well-being. *Journal of Leisure Research*, *51*(3), 348–365. https://doi.org/10.1080/00222216.2019.1688738

Portelli, L., Arvanitidou, Z., Mc Sweeney, K., & Räisänen, R. (2024). Tradition in Action—Traditional Costume Innovations. *Heritage*, *7*, 5307–5318.

Ronkko, M.-L., Mommo, S., & Aerila, J.-A. (2016). The teachers' views on the significance of the design and craft teaching in Finland. *Design and Technology Education: An International Journal*, *21*(2), 49–58.

Runco, M. A., Millar, G., Acar, S., & Cramond, B. (2010). Torrance Tests of Creative Thinking as Predictors of Personal and Public Achievement: A Fifty-Year Follow-Up. *Creativity Research Journal*, *22*(4), 361–368.

Sahlberg, P. (2011). *Finnish Lessons*. The Teachers College Press.

Salemi, M. L. (2010). *Utilizing Fluency, Flexibility, Originality, and Elaboration to Enhance Creativity and Vocabulary Use for Improving Reading Comprehension in Third through Sixth Grade Students* [Union University]. https://www.researchgate.net/publication/320853217_Utilizing_Fluency_Flexibility_Ori

ginality_and_Elaboration_to_Enhance_Creativity_and_Vocabulary_Use_for_Improving_Reading_Comprehension_in_Third_through_Sixth_Grade_Students
Sawyer, K. R., & Henriksen, D. (2023). *Explaining Creativity: The Science of Human Innovation* (3rd ed.). Oxford University Press. https://doi.org/10.1093/oso/9780197747537.001.0001
Stanton, Y., & Scott, P. (2009). *Mountmellick Embroidery Inspired by Nature* (2nd ed.). Vetty Creations.
Stokes, S. (2002). Visual Literacy in Teaching and Learning: A Literature Perspective. *Electronic Journal for the Integration of Technology in Education*, *1*(1), 10–19.
Thuan, N. H., & Antunes, P. (2024). A conceptual model for educating design thinking dispositions. *International Journal of Technology and Design Education*, *34*, 1879–1902.
Torrance, E. P. (2008). *The Torrance tests of Creative Thinking norms-Technical Manual Figural Streamlined Forms A and B*. Scholastic Testing Service. https://www.ststesting.com/gift/TTCT_InterpMOD.2018.pdf
Treggiden, K. (2020). *Wasted When trash becomes treasure*. Ludion.
Trisnayanti, Y., Ashadi, Sunarno, W., & Masykuri, M. (2020). Creative thinking profile of junior high school students on learning science. *Journal of Physics: Conference Series*. https://iopscience.iop.org/article/10.1088/1742-6596/1511/1/012072/pdf
UNESCO. (2003). *Text of the Convention for the Safeguarding of the Intangible Cultural Heritage*. UNESCO Intangible Cultural Heritage. https://ich.unesco.org/en/convention
UNESCO. (2019). *Culture 2030 indicators*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000371562#:~:text=The%202030%20Agenda%20reflects%20a%20broad%20view%20of,local%20com-%20munities%2C%20local%20materials%2C%20and%20cultural%20divers
UNESCO. (2022). *Basic texts of the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage, 2022 edition*. United Nations Educational and Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000383762
Valkeapää, L. (2023). *Kansallispuvun kulttuurihistoria*. Vastapaino.
Van zanten, W. (2004). Constructing New Terminology for Intangible Cultural Heritage. *Museum International*, *56*(1–2), 36–44. https://doi.org/10.1111/j.1350-0775.2004.00456.x
Vincent-Lancin, S., Urgel, J., Kar, S., & Jacotin, G. (2019). *Fostering Students' Creativity and Critical Thinking: What it Means in School*. Educational Research and Innovation, OECD Publishing. https://www.oecd.org/en/publications/fostering-students-creativity-and-critical-thinking_62212c37-en.html
World Economic Forum. (2023). *Future of Jobs Report*. https://www.weforum.org/publications/the-future-of-jobs-report-2023/

Design students' views on future work at the stage of Industry 5.0 and Society 5.0: Dimensions and levels of resilience

Mari Silver, University of Lapland
Marianne Silén, University of Lapland
Heli Ruokamo, University of Lapland

Abstract
This study investigates design students' perspectives on future work environments shaped by the evolving paradigms of Industry 5.0 and Society 5.0, with a focus on their views of work communities, technological advancements and systemic problem-solving. The concept of resilience is used as an analytical lens. The study explores the relevance of Industry 5.0 and Society 5.0 frameworks in the context of the design profession and examines how design students anticipate and interpret future changes in their professional landscape. The study addresses the following research question: What are the dimensions and levels of resilience according to design students' views of future work? Data were collected in 2023 from 92 design students at various stages of their studies. Using principal component analysis, three dimensions of resilience were identified: resilience in work community, in technological development and in systemic problem solving. The findings suggest that students are aware of major shifts in their field and express varying degrees of readiness and adaptability across the identified dimensions. These results offer insights into how design education might better support students in navigating the uncertainties of future work.

Keywords
design students, resilience, future work, industry 5.0, society 5.0

Contextualising Change: Industry 5.0 and Society 5.0
Designers are increasingly faced with complex and changing challenges shaped by rapid technological developments and global sustainability requirements. In many areas of design, new solutions are shaped by data-driven tools, artificial intelligence and systems that adapt to user behavior based on their digital footprint. At the same time, societal changes and the sustainability crisis require a reassessment of the role of the designer in the future workplace. In this context, designers are expected to reflect on their responsibilities and competences in environments influenced by the visions of Industry 5.0 and Society 5.0 (Mortati, 2022). Understanding resilience among design students is especially important in the current context of rapidly evolving design challenges, shifting technologies, and increasing societal demands. While much attention has been given to future competences, less is known about how students perceive their ability to cope with these changes and shape their role within them.

Two influential frameworks describing transformations are Industry 5.0 and Society 5.0. Industry 5.0, developed primarily in Europe, envisions a human-centric, resilient, and sustainable industrial future where humans and machines collaborate to improve productivity and well-being (Breque et al., 2021; Adel, 2022). Society 5.0, originating in Japan, proposes a “super-smart” society that balances technological progress with individual well-being and social problem-solving. It emphasises a deeper integration of physical and digital spaces, supported by AI, robotics, and the Internet of Things (Hitachi-Utokyo Laboratory, 2018; Salgues, 2018).

Although these are policy-level visions rather than theoretical models, they offer useful insight into the kinds of futures designers may need to navigate. For design education, they highlight a growing demand for systemic thinking, ethical awareness, and the ability to work interdisciplinarily, often in close collaboration with both humans and intelligent systems (Mortati, 2022; Al-Emran & Al-Sharafi, 2022).

Industry 5.0 and Society 5.0 emphasise the ability to deal with constant change and rapid development. Working environments, and therefore expanding professional opportunities, provide a challenging and unique use of designers’ competence. Designers need open-mindedness and the confidence that their professional knowledge is adequate and will develop as the project progresses. Table 1 presents Industry 5.0 and Society 5.0 and their basic differences in a condensed form.

Table 1. Industry 5.0’s and Society 5.0’s frameworks summarised

	Industry 5.0	Society 5.0
Objectives and scope	A circular economy A focus on sustainability	A supersmart society Society as a whole
Key phrases	Industry supporting long-term service to humanity with planetary boundaries (Breque et al., 2021) From designing to people to designing with people (Schneorson et al., 2019)	The convergence of cyberspace and physical space A super-intelligent social services platform A human-centred society (Hitachi-UTokoy Laboratory, 2018)
Competences	Human centricity, sustainability and resilience (Breque et al., 2021) Communication, collaboration and systemic problem-solving (Schneorson et al., 2019)	An adaptive mindset Applied thinking Critical thinking (Mytra et al., 2021) Systemic problem-solving

According to recent literature, the core competences for future designers are the ability to have a holistic, ethical and interdisciplinary approach to design with a strong understanding of the United Nation’s Sustainable Development Goals (SDG) and their implications and the ability to integrate sustainability thinking into all company activities (Adel, 2022; Al-Emran & Al-Sharafi, 2022; Andres et al., 2022; Lutfi, 2023; Mortati, 2022). According to Silver and Ruokamo (2024), industry is expecting the designers entering to field to have systematic problem-solving competences and the ability to quickly adapt their competence, both technological and theoretical, to versatile business and client needs. Silver and Ruokamo (2024) also outlined new competences that should form the basis for design education. These competences most importantly include meta competences and the ability to solve systemic challenges. In this study, competence is understood through a holistic model that combines cognitive, social, functional and meta domains (Le Deist & Winterton, 2005). The holistic model of competence helps us to understand the combination of knowledge that is necessary for particular professions.

Although some recent studies have examined future competences or pedagogical reforms in design education (e.g. Choi & Song, 2022; Frascara, 2020; Wilde, 2020), only a few have focused on students' own perceptions or on how resilience may play a role in preparing for future work. Most existing research tends to emphasise curricular development from the educators' or institutional perspective, leaving a gap in understanding how students themselves experience and adapt to these systemic changes.

This study does not analyse Industry 5.0 or Society 5.0 in depth but refers to them as a contextual backdrop to explore how design students perceive the future of their work. While several publications have discussed the evolving competences required in design (e.g. Lahdenperä et al., 2022; Wilde, 2020; Noel et al., 2023), less is known about how students themselves anticipate these changes and what forms of resilience they feel are necessary. While this study approaches design education from a future- and industry-oriented perspectives, it is acknowledged that other framings such as critical, cultural, or socially driven perspectives also offer valuable insights into the role of design. The focus on resilience reflects one possible interpretation among many, and further research could explore how different conceptualisations of design education respond to broader societal, ethical, and environmental issues. This study contributes to addressing the gap by answering following research question: What are the dimensions and levels of resilience according to design students' views of future work?

Resilience and societal change in future work

Resilience, as a word, has its origins in the Latin verb resilire, which is defined as the ability to recover from difficult and harmful situations. Resilience also refers to the flexibility or elasticity of a material (Fletcher & Sarkar, 2013). While resilience can be viewed as a physical characteristic, it is also associated with the capacity of both organisations and individuals to respond to change. Resilience can be attached to meanings such as robustness, inner strength, competence, optimism, flexibility and the ability to cope effectively in challenging circumstances (Abiola & Udofia, 2011; Holling, 1973). Hamill (2003) referred to resilience as competence in the face of adversity, and Pooley and Cohen (2010) referred to resilience as resourcefulness, referring to using personal resources in different challenges. The European Commission defines resilience as one of the hallmark features of Industry 5.0 (Breque et al., 2021). Carmeli and Friedman noted that resilience is a two-dimensional construct, it refers to both coping with difficulty but also to the capacity to adapt (Carmeli et al., 2013). Adaptation, when it comes to the ability to work successfully in designers' future working environment, is an essential part of professional competence. As Fernandes and Varajão (2018, p. 816) noted 'Individuals play a very important role in organizations, by creating conditions that enable them to overcome difficulties, as well as to promote the organizational improvement and its overall performance'. Changes in the design industry are significant and rapid, and new entrants need to be adaptable, motivated and ready to update both their competences and their knowledge in line with current needs.

In this research context, resilience is described as both the ability to adapt to the renewal of systems, environments and ways of working and the ability to see opportunities for personal evolution and dynamic adaptation to change. For the purposes of this study, the most relevant aspects of design education have been highlighted. In this study resilience is further defined through Dweck's framework, which emphasises the tendency to maintain interest in change and open-mindedness towards continuous change.

Duckworth and Dweck talked about 'grit' and a 'flexible mindset' when they described individuals' tendency to sustain interest, passion and persistence in regard to long-term goals or navigating in a constantly changing working environment (Duckworth et al., 2007; Dweck, 2010). Students with a resilient mindset typically make faster and more determined progress in their studies. Folke (2006) emphasised the necessity to manage by change rather than just reacting. Designers need the ability to tolerate uncertainty and apply their competences in working environments and situations that have not been simulated or taught during education. Resilience towards the continuous application of competences and working in constantly evolving and changing working environments are perhaps the most important competences of future designers. Dweck's (2006) research on growth and a fixed mindset provides a valuable framework for understanding how design students perceive and respond to challenges. A growth mindset, characterised by the belief that abilities can be developed through effort, is closely tied to resilience, which is crucial in navigating the future working environment in the design business (Dweck, 2006).

Each societal change has required resilience from the workforce and the ability to adapt to new situations. Technological, economical and societal improvements have set new challenges during each industrial and societal phase (Rohne Till et al., 2024). Set in the 1960s, Industry 3.0 and Society 3.0 were characterised by the shift from mechanical and analogical processes to digital technology and automation (Schwab, 2016). Industry 4.0 and Society 4.0 were characterised by the dominance of information, digital technologies and automation, marking a shift towards smart factories and cyber-physical systems (Schwab, 2016). Industry 5.0 and Society 5.0 emphasise human creativity, problem-solving and customisation in production process. Society 5.0 addresses human-centred society that, 'through the high degree of merging between cyberspace and physical space, will be able to balance economic advancement with the resolution of social problems' (Hitachi-UTokoy Laboratory, 2018, p. xii). At the same time, Society 5.0 emphasises lifelong learning and people's ability to adapt their competences to the circumstances at hand and modify and develop knowledge (Carter et al., 2019).

Methodology and data

Data was collected by questionnaire in 2023. The questionnaire was developed collaboratively with participants of a doctoral seminar at University of Lapland, ensuring that both academic and practical perspectives were considered. The structure and content of the questionnaire were formed by previous surveys conducted in similar contexts within design education. Prior to distribution, the questionnaire was pilot tested with a small group of design students at the university of applied sciences. Based on their feedback, minor adjustments were made to improve the clarity and order of the questions.

A total of 92 design students from two Finnish higher education institutions - one university and one university of applied sciences - participated in the study. These institutions were selected because they both offer cross-cutting higher design education. Participation in the study was voluntary. As this is a small-scale study conducted in Finland, the findings do not aim for generalisability but offer insight into how students perceive future challenges in design within a specific national and educational context.

The design students were at various stages of their bachelor or master level studies, with specialisations in digital design, service design, visual communication design, AR/VR/XR design, and industrial design. The data collection was divided into three parts and the questions were related to the work community, technological development and systemic problem-solving. Gender, age and credit accumulation were asked about to gather background information. Credit accumulation was indicated according to the European Credit Transfer and Accumulation System (ECTS), where one academic year corresponds to 60 ECTS credits. In this study, the students were grouped as follows: first year (10–60 ECTS), second year (60–120 ECTS), third year (120–180 ECTS), and fourth year (>180 ECTS). This categorisation reflects the typical European degree structure, where students may take longer than three years to complete a bachelor's degree due to individual study paths or participation in internships, exchange studies, or part-time study. The responses were given using a five-point Likert scale ranging from 1 ('Strongly disagree') to 5 ('Strongly agree'). The statements were designed to assess students' beliefs and attitudes regarding the future of design work and their own role as designers. The prompts included statements such as "In the future, designers will increasingly work in multidisciplinary teams" and "At a personal level, I want to contribute to solving systemic problems (e.g. the climate crisis, natural catastrophes, inequality, ageing population).

Data were analysed using IBM SPSS Statistics 28. First a principal component analysis (PCA) with varimax rotation and KMO and Bartlett's test of sphericity was performed. The Kaiser criterion was used to determine the number of principal components. The aim of the analysis was to identify variables indicating resilience and its sub-areas. Reliability analysis was then conducted on the key variables (loading>.5) of the principal components to assess their reliability and measurement capability. Based on the results of PCA three composite variables were computed representing different dimensions of resilience and they were analysed using descriptive methods.

Results

What are the dimensions and levels of resilience according to design students' views of future work?

PCA resulted three components. KMO value .723. was higher than .50 and hence the analysis met the criteria of sampling adequacy. The Bartlett's test of sphericity was significant (<.001).

The first component was named 'Resilience in the work community', which reflects the ability of designers to adapt and thrive in different collaborative environments. The component title highlights the designer's ability to adapt to teamwork development, engagement with diverse stakeholders and the ability to navigate complex social dynamics in multidisciplinary and inclusive design contexts.

The second component was named 'Resilience in technological development' in order to describe the evolving role of designers in navigating and shaping technology-driven interactions. This component title highlights the ability to adapt to technology-mediated communication, the enthusiasm to take on human–machine interaction expertise and the open-mindedness to work in new areas, such as augmented reality and virtual reality (AR/VR) design.

The third component was named 'Resilience in systemic problem-solving', reflecting the crucial role of designers in solving complex global challenges. The component title refers to the readiness to move from product and service design towards solving systemic problems (such as the climate crisis, inequality and population ageing) and the personal and professional commitment required to adapt to the changing nature and content of design work in response to these challenges. Table 2 shows the results of the principal component analysis and reliability analysis.

Table 2. The results of the principal component analysis and reliability analysis: Dimensions of resilience

Claim	Resilience in the work community	Resilience in technological development	Resilience in systemic problem-solving
In the future, the designer will increasingly work with a wide range of stakeholders.	**.802**	.064	.309
In the future, designers will increasingly work in multidisciplinary teams.	**.870**	.060	.060
In the future, designers will increasingly work with the public in a non-technological way (e.g. citizen participation in design projects).	**.575**	.097	.097
In the future, a designer's work will be based more on technology-mediated interaction than on face-to-face interaction.	-.234	**.726**	-.036
In the future, designers will increasingly be needed to design human–machine interaction.	.358	**.730**	.094
In the future, designers will increasingly be needed for augmented reality and virtual reality design.	.077	**.724**	.261
In the future, designers will be needed more to solve systemic problems (e.g. the climate crisis, inequality, an ageing population) than to design concrete products or services.	.155	.282	**.668**

At a personal level, I want to contribute to solving systemic problems (e.g. the climate crisis, natural catastrophes, inequality, ageing population).	.018	.089	**.612**
The climate crisis affects the way designers work (e.g. teleworking, the use of equipment and materials).	.467	-.033	**.659**
The climate crisis affects the content of the designer's work (e.g. the designer addresses the challenges posed by the climate crisis).	.107	.016	.797
Cronbach's alpha	.724	.631	.685

Resilience in the work community
'Resilience in the work community' consists of questions that highlight the ability of designers to work in multidisciplinary teams and with multiple stakeholders. Loadings indicate that items related to collaboration with stakeholders and multidisciplinary teams are strongly associated with one another, suggesting that these aspects form a coherent underlying dimension within the data structure. Multidisciplinary and working alongside people with a different professional background have been a tradition in Higher Education Institutions (HEI) for a long time, but now, with Industry 5.0 and Society 5.0, the ability to work in a multidisciplinary team is becoming a standard rather than a curiosity. During their studies, students become accustomed to working in client-based projects involving an increasingly wide range of representatives from different departments on the employer side. On the other hand, multidisciplinary cannot be emphasised enough and even though the students seem to be familiar and comfortable working with versatile team settings, this should be kept as standard practice and not as an exception during the studies. Collaboration with the public was not well identified among students. This may indicate, among other things, that work-life projects in HEIs are largely carried out in cooperation with companies and not with social actors.

Industry 5.0 and Society 5.0 are about human-centric design, and this, in turn, requires authentic collaboration with the public (Lahdenperä et al., 2022). Working with the public in a non-technological way was less prominently identified among the students. This may be because the students do not fully comprehend what this concept means in practice. The current pedagogical paradigm of design education in HEIs does not allow, in most cases, for genuine and wide-ranging collaboration with the public. Society 5.0 and the Internet of Humans (IoH) demand active citizen participation in the form of providing data in different purposes for data gathering and design. User-centred design and its methods are familiar frameworks to designers, but the way in which cooperation and planning itself is carried out with civil society in a Society 5.0 environment seems to still be a bit unstructured. However, the results reveal that the students recognise the change in design protocol. One interpretation of the results is that they show that the students already recognise the importance of collaboration with the public and that it is actualising in workplaces, even if it is not possible in HEIs.

Resilience in technological development
Based on the research, the design of virtual spaces and human–machine interaction are

identified as a part of design students' future work. With technological advances, the work of designers might eventually shift also in designing for virtual spaces and experiences. Individual breakthroughs in working in virtual spaces have already been seen, such as concept of remote surgery and a virtual-training surgical theatre in Stanford (Erickson, 2017).

AR/VR experiences and spaces, which are increasingly adopted in various industries, were not considered more important than other types of design projects by the students in this study. This finding may be related to visibility or integration of AR/VR technologies in students' current educational design environments, which could make it more difficult to anticipate their future relevance. The lack of resources for virtual spaces in higher education institutions and a shortage of skilled labour in HEIs might influence students' ability to recognise and take advantage of new technologies. The high level of investment and the rapid development of technology contribute to making it more difficult for universities to deepen their knowledge in this area.

The design students' views toward technological development correspond well with the European Commission's characterisation of digital resilience (European Commission, 2020). Curiously, 'Resilience in technological development' appears at a slightly lower level than other two components. This may be influenced by the perceived lack of new technologies in learning environments and also by the technological utopianism that is sometimes associated with AR/VR technologies in public debate (Coenen, 2007; Dai & Hao, 2018; Dickel & Schrape, 2017).

Based on the results, the 'supersmart society' that will be brought about by Industry 5.0 and Society 5.0 has not yet penetrated higher education (Hitachi-UTokoy Laboratory, 2018). 'Super-smart society' refers, among other things, to design work that combines physical space with cyberspace. This in turn brings in a new kind of design work that takes place at the interface between the real and virtual worlds and how they are combined, for example, in the development of smart homes and similar environments. Students should be familiar with and prepared to take ownership of the constant development of AR/VR realities and those environments' possibilities and realities in future society; they should also be familiar with virtual working spaces. Face-to-face interaction remains, but there is a significant increase in media-mediated project work.

Resilience in systemic problem-solving

In Industry 5.0 and Society 5.0, designers are increasingly needed to solve systemic problems due to their ability to bring and combine multiple design methods and their collaboration competences (Frascara, 2020; Noel et al., 2023; Redström, 2020; Wilde, 2020). 'Resilience in systemic problem-solving' describes the students' ability and motivation to face and solve large-scale global challenges such as the climate crisis, inequality, aging populations and dwindling natural resources.

The difference between the impact of systemic problems and climate change on future jobs can be partly explained by the visibility of the themes in public debate and in the commissioning of projects by educational institutions (Ávila et al., 2017; Friman et al., 2018; Hess & Collins, 2018). Acknowledgement that Industry 5.0 and Society 5.0 support the development of a sustainable world and underpin the efforts to achieve it is discussed, for example, by Kasinathan et al. (2022). External funding, including for higher education institutions, has at times included climate change issues and mitigation mandates. However, the availability and prioritisations of such funding has varied significantly across regions and political contexts and is often influenced by changes in government agendas and broader policy shifts. The integration of these projects into teaching has made the work and research projects related to climate change familiar to students in the field and thus revealed the presence of climate change in their everyday work. A similar thematic upsurge has not been seen, at least so far, in the case of the mainstreaming of systemic problems. The responses reveal that design students have not fully grasped the scale of social change. Projects on systemic problems, for example, involve work across local and national boundaries. Designers are increasingly involved in projects where expertise and possible consultancy comes from international actors or collaborative partners.

The concept of Industry 5.0 and Society 5.0 are regarded as a development trend that is conducive to environmental sustainability, with a focus on sustainability and human-centric concerns. Prior to the implementation of these changes, climate issues assume a substantial role in the realm of sustainable design. However, the research did not reflect the level of recognition and awareness of the impact of environmental change. As Wang et al. (2024) astutely pointed out, designers' role in the sustainability discourse is not just designing for products and services with a lower carbon footprint. Instead, it has to do with making sustainability more accessible and comprehensible to a wider audience (Wang et al., 2024). Calvo and De Rosa (2017) also pointed out that designers are enhancing well-being, addressing issues of justice and acknowledging cultural diversity. These aspects of design are seldom addressed in design education, leaving students with no comprehension of a major part of design responsibilities in working life.

Working with systemic challenges requires the ability to tolerate one's ignorance and the willingness to abandon old ways of working and develop new ones. Resilience in this aspect could refer to processes that limit stress-related negative behaviour. Resilience is particularly important in situations where complicated challenges are encountered so that one is not paralysed by challenges but faces adversity with motivation and perseverance (Bandura et al., 2001; Cassidy, 2015).

Levels of design students' resilience

Table 3 provides an interpretative overview of how different levels of resilience may manifest in various dimensions. The levels are based on Likert scale groupings (1–2 = low, 3 = moderate, 4–5 = high) and are intended to support a deeper understanding of how resilience might present itself in each dimension. The descriptions of each level aim to contextualise how differing levels of agreement may reflect varying degrees of adaptability, motivation, and readiness in relation to future design work.

Table 3. Interpretative overview of different levels of resilience

Levels	Resilience in the work community	Resilience in technological development	Resilience in systemic problem-solving
4–5	Enjoys working in a variety of working environments and adapts easily to different configurations in the work community	Is enthusiastic about new technologies and willing to try them out without reservations	Enjoys new challenges and tolerates feelings of uncertainty well
3	Adapts to different work communities and working	Prefers familiar technologies; has some	Prefers to work on clearly defined challenges; adapts to

	environments but does not seek them out for himself/herself	reservations about adopting new technological environments/devices	feelings of discomfort in work projects
1–2	Avoids changes in the working environment and working teams; works independently as far as possible	Avoids new technologies and sticks to the old ways of thinking for as long as possible	Avoids complicated projects and feelings of discomfort in work projects

A boxplot (see Figure 1) shows the levels of different resilience dimensions among design students. Figure 1 presents the dimensions and levels of resilience according to the design students' views on resilience in regard to the work community, technological development and systemic problem-solving.

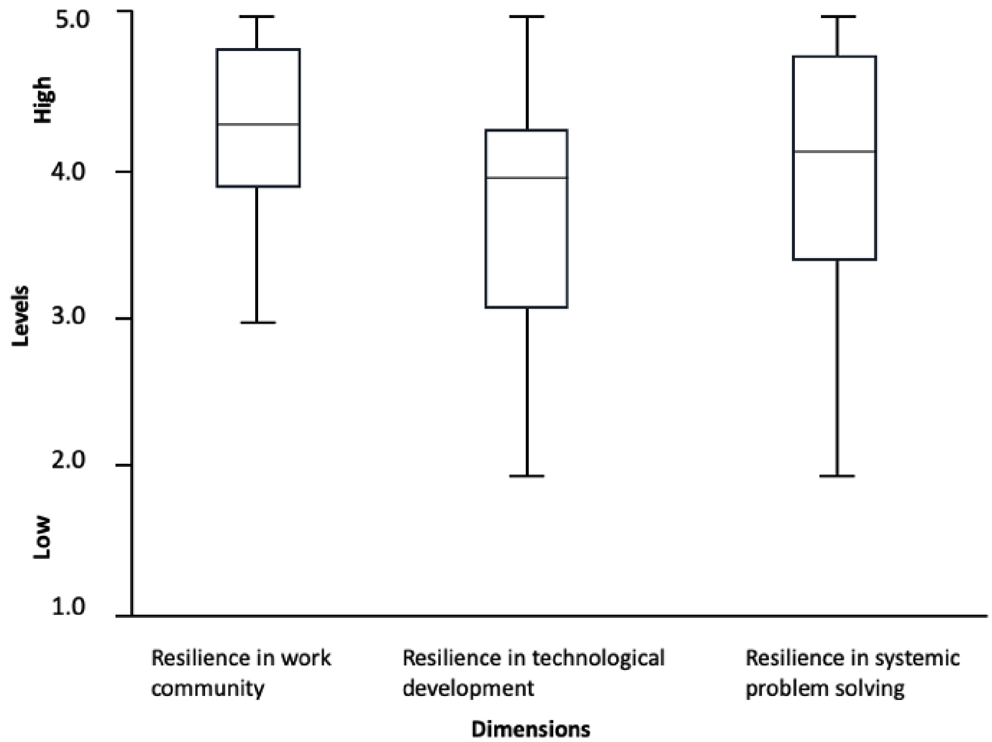


Figure 1. The dimensions and levels of resilience according to the design students' views on resilience

The horizontal axis represents the different dimensions of resilience, while the vertical axis illustrates student responses. The boxplot visualises the spread and central tendency of responses across the three resilience dimensions. The results show that the median score for 'Resilience in the work community' is high, with a relatively narrow interquartile range and values clustered between 4 and 5 for the majority of students. However, a proportion of responses also fall below this range, indicating that not all students share the same level of confidence in this area. Rather than full consensus, the results suggest that many students feel confident in their collaborative abilities, but there is still some diversity in how these experiences are perceived.

The boxplot also reveals broader variation in the dimensions of ‘Resilience in technological development’ and ‘Resilience in systemic problem-solving’. In particular, ‘Resilience in technological development’ shows the widest range of responses—from 2 to 5—which may reflect significant variation in students' familiarity and comfort with emerging technologies. This indicates that technological confidence is not yet evenly distributed among design students.

In ‘Resilience in systemic problem-solving’, the median response is also relatively high, but with noticeable variability. This suggests that students recognise the importance of systemic challenges such as the climate crisis or inequality yet differ in their own perceived readiness to engage with these issues.

The component data provides insight into overall trends, but it is important to note that individual items within each component may vary in response patterns. Therefore, while the components help highlight key areas of resilience, variation at the item level should be considered in future studies to explore the nuances of student perspectives more deeply.

Overall, the results suggest that while many design students demonstrate strong readiness in collaborative contexts, their views regarding technological change and complex societal problems are more heterogeneous. These findings offer a useful basis for considering how design education can better support different types of resilience in response to future challenges.

Discussion

The Industry 5.0 and Society 5.0 frameworks provide topical reference points in relation to the future competences of design students. Industry 5.0 and Society 5.0 rely on three core elements: new types of work communities, technological development and systemic problems (Carayannis & Morawska-Jancelewicz, 2022). As stated by European Union publications, the new society attempts to balance economic development with the resolution of societal and environmental problems (Breque et al., 2021). Dguchi and Karasawa (2018) discussed about the new industrial and social era being more than the smart city; it is not just smart but ‘supersmart’ (Hitachi-UTokoy Laboratory, 2018). The development of cutting-edge technology, big data, AI and the deepening of systematic problems demand for collaboration and communication at all levels and between disciplines (Carayannis & Morawska-Jancelewicz, 2022; Hitachi-UTokoy Laboratory, 2018; Lubis & Lubis, 2024; Mytra et al., 2021; Suganya et al., 2024). Multidisciplinarity and the ability and readiness to work with multiple stakeholders are therefore the core competences for future designers.

The new operating environment emphasises the importance of citizens as the end users of technological solutions and as the data providers of new product and service innovations. As Hitachi-UTokoy Laboratory (2018, 165) put it ‘Society 5.0 is a society that facilitates innovation by citizens and for citizens and that is itself the product of the aggregate of such innovation’. Therefore, designers’ ability to work alongside with citizens, carefully reviewing the needs and translating them into products and services that are feasible, is a vital role for future designers. Industry 5.0 and Society 5.0 force societal actors to increasingly consider global climate change challenges in all their activities. The SDGs framework and stakeholders’ willingness to take sustainability into account at all levels will also influence designers' job descriptions and project briefs.

In addition to the quantitative results of the survey, the open-ended responses provided valuable information about how students see their future work. Responses reveal that students' resilience involves reflection, uncertainty and ethical considerations. Many students described how their understanding of the work of a designer had evolved during their studies. Some reported increased clarity and confidence in their future tasks, while others became more aware of the complexity and ethical dimensions of the field. Technological developments, the impact of artificial intelligence and sustainability challenges were seen as new challenges. Several respondents saw the potential of new tools, while others expressed concerns about their ability to keep up with technological developments or the impact of automation on creative work. A recurring theme in the responses was the desire to work in a way that reflects personal values and to be involved in solving broader societal challenges. Several students emphasized the importance of designing with social challenges and environmental impacts in mind. Many also emphasized the emotional and cognitive work required to cope in a rapidly changing and uncertain world.

The students' reflections suggest that resilience is not only about coping with change, but also about forming a professional identity, reassessing personal values, and finding meaning in their future careers. In addition to technical skills, students crave opportunities for critical thinking, discussion, and the ambiguous role of a designer in the future of work.

Based on the results of this study, the challenge in reforming design education is therefore not related to the students' ability and willingness to undergo change in design education development but relates to the HEIs' ability and willingness to undergo this change. The change in working life is so significant that it requires a change and update in teaching content and pedagogical solutions; this, in turn, may be seen as resistance from the teaching staff.

Limitations and future research

The design students who participated in this study have a versatile design background, which may affect their interpretation of how changes in the design field relate to their future working environment. To gain more detailed and generalisable insights into design students' understanding and views toward change, a larger and more diverse sample would be necessary. This study was conducted in Finland and provides an overview of the situation in Finnish design education. The results are a starting point for building a broader understanding of students' capabilities in adapting to change.

The research did not examine how current curricula or educational content in higher education reflect changes in working life and society within the content and framework of design projects. As a result, the participants did not need to reflect directly on how their current education and training support the competences needed for their future careers.

In addition, there are some limitations related to the validity of the questionnaire itself, even within the Finnish context. The instrument was developed specifically for this study and, although it was pilot tested and informed by previous reserach, it has not been validated through broader empirical or cross-institutional testing. The interpretation of the identified dimensions is based on the researcher's conceptual framing of resilience, which may influence how student responses are grouped and understood. Future research could benefit from further development and validation of the instrument across different educational and national contexts.

Conclusion

The research answered the following research question: What are the dimensions and levels of resilience according to design students' views of future work? The research findings were based on 92 answers gathered with a questionnaire from design students in 2023. Industrial and societal change reshape what is expected of the future workforce, including designers. The overarching theme for the change is the concept of a supersmart society which combines technology, data and human-centric design. Among technological know-how, the emphasis lies in soft skills and understanding of how to combine, for example, worldwide systemic change, climate change and worldwide ageing with multiple stakeholders' needs and cross-cutting teamwork. Resilience plays significant role in coping with change. According to the study, the design students' levels of resilience are good in relation to the three dimensions of future work: 'Resilience in the work community', 'Resilience in technological development' and 'Resilience in systemic problem-solving'.

The responsibility of equipping the future designers with the modern know-how lies with higher education institutions. The results of the research propose that HEIs should seize the moment and critically examine their design curricula to better meet the needs of new industrial and societal demands. As Carayannis and Morawska-Jancelewicz (2022, 3445) put it: 'Universities are created to tackle the unknown. While their future cannot be planned, the tools they have at their disposal to meet the future can be improved.'

Acknowledgements

The corresponding author wishes to thank Professor Jonna Häkkilä and Doctoral researcher Mari Karhu from the Faculty of Art and Design at the University of Lapland for their valuable support in the design and distribution of the questionnaire used in this study.

References

Abiola, T., & Udofia, O. (2011). Psychometric assessment of the Wagnild and Young's resilience scale in Kano, Nigeria. *BMC Research Notes, 4(1):509*. https://doi.org/10.1186/1756-0500-4-509

Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. *Journal of Cloud Computing, 11(1*). https://doi.org/10.1186/s13677-022-00314-5

Al-Emran, M., & Al-Sharafi, M. A. (2022). Revolutionizing education with Industry 5.0: Challenges and future research agendas. *International Journal of Information Technology and Language Studies (IJITLS), 6(3), 1–5*. http://journals.sfu.ca/ijitls

Andres, B., Sempere-Ripoll, F., Esteso, A., & Alemany, M. M. E. (2022, July 4–6, 2921–2926). *Mapping between Industry 5.0 and Education 5.0*. 14th International Conference on education and Learning Technologies, Palma, Spain. https://doi.org/10.21125/edulearn.2022.0739

Ávila, L. V., Leal Filho, W., Brandli, L., Macgregor, C. J., Molthan-Hill, P., Özuyar, P. G., & Moreira, R. M. (2017). Barriers to innovation and sustainability at universities around the world.

Journal of Cleaner Production, 164, 1268–1278. https://doi.org/10.1016/j.jclepro.2017.07.025
Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations can career trajectories. *Child Development, 72(1), 187–206*. https://doi.org/https://doi.org/10.1111/1467-8624.00273
Bhulakshmi, D., Bhattacharya, S., Reddy Gadekallu, T., Vyas, P., Kaluri, R., Koppu, S., Brown, D. J., & Mahmud, M. (2024). Industry 5.0 in smart education: Concepts, applications, challenges, opportunities, and future directions. *IEEE Access*. https://doi.org/10.1109/ACCESS.2017.DOI
Breque, M., De Nul, L., Petridis, A., & European Commission, Directorate-General for Research and Innovation. (2021). Industry 5.0: *Towards a sustainable, human-centric and resilient European industry*. European Commission. https://op.europa.eu/en/publication-detail/-/publication/468a892a-5097-11eb-b59f-01aa75ed71a1/
Calvo, M., & De Rosa, A. (2017). Design for social sustainability: A reflection on the role of the physical realm in facilitating community co-design. *Design Journal, 20(1),* S1705–S1724. https://doi.org/10.1080/14606925.2017.1352694
Carayannis, E. G., & Morawska-Jancelewicz, J. (2022). The futures of Europe: Society 5.0 and Industry 5.0 as driving forces of future universities. *Journal of the Knowledge Economy, 13(4),* 3445–3471. https://doi.org/10.1007/s13132-021-00854-2
Carter, M. A., Lundberg, A., Geerlings, L. R. C., & Bhati, A. (2019). Shifting landscapes in higher education: A case study of transferable skills and a networked classroom in South-East Asia. Asia *Pacific Journal of Education, 39(4),* 436–450. https://doi.org/10.1080/02188791.2019.1671801
Cassidy, S. (2015). Resilience building in students: The role of academic self-efficacy. *Frontiers in Psychology, 6(Nov.)*. https://doi.org/10.3389/fpsyg.2015.01781
Cezzar, J. (2020). Teaching the designer of now: A new basis for graphic and communication design education. *She Ji, 6(2),* 213–227. https://doi.org/10.1016/j.sheji.2020.05.002
Choi, E., & Song, M. J. (2022). Designing sustainable craft curricula: Balancing academic and practical training. *International Journal of Art and Design Education, 41(3)*, 446–463. https://doi.org/10.1111/JADE.12416
Coenen, C. (2007). Utopian aspects of the debate on converging technologies. In *Assessing Societal Implications of Converging Technological Development* (pp. 141–174). Nomos Verlagsgesellschaft mbH & Co KG. https://doi.org/10.5771/9783845271118-141
Dai, Y. X., & Hao, S. T. (2018). Transcending the opposition between techno-utopianism and techno-dystopianism. *Technology in Society, 53*, 9–13. https://doi.org/10.1016/j.techsoc.2017.11.001
Dickel, S., & Schrape, J. F. (2017). The renaissance of techno-utopianism as a challenge for responsible innovation. *Journal of Responsible Innovation, 4(2),* 289–294. https://doi.org/10.1080/23299460.2017.1310523
Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology, 92(6)*, 1087–1101. https://doi.org/10.1037/0022-3514.92.6.1087
Dweck, C. (2010). Mindsets and equitable education. *Principal Leadership, 10(5)*, 26–29.
Erickson, M. (2017, July 11). Virtual reality system helps surgeons, reassures patients. *Stanford Medicine*. https://med.stanford.edu/news/all-news/2017/07/virtual-reality-system-helps-surgeons-reassures-patients.html

European Commission. (2020). *Resilience Dashboards*. https://commission.europa. eu/strategy-and-policy/strategic-planning/strategic-foresight/2020-strategic-fo resight-report/resilience-dashboards_en

Fernández-Arias, P., Antón-Sancho, Á., Vergara, D., & Barrientos, A. (2021). Soft skills of American university teachers: Self-concept. *Sustainability (Switzerland), 13(22*), 1–25. https://doi.org/10.3390/su132212397

Fletcher, D., & Sarkar, M. (2013). Psychological resilience. *European Psychologist, 18(1),* 12–23.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change, 16(3),* 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Frascara, J. (2020). Design education, training, and the broad picture: Eight experts respond to a few questions. *She Ji: The Journal of Design, Economics, and Innovation, 6(1)*, 106–117. https://doi.org/10.1016/J.SHEJI.2019.12.003

Friedman, K. (2019). Design education today: Challenges, opportunities, failures. In *Chatterjee Global Lecture Series.* Tongji University College of Design. https://www.academia.edu/40519668

Friman, M., Schreiber, D., Syrjänen, R., Kokkonen, E., Mutanen, A., & Salminen, J. (2018). Steering sustainable development in higher education — Outcomes from Brazil and Finland. *Journal of Cleaner Production, 186*, 364–372. https://doi.org/10.1016/j.jclepro.2018.03.090

Groumpos, P. P. (2021). A critical historical and scientific overview of all industrial revolutions. *IFAC-PapersOnLine, 54(13)*, 464–471. https://doi.org/10.1016/j.ifacol.2021.10.492

Hess, D. J., & Collins, B. M. (2018). Climate change and higher education: Assessing factors that affect curriculum requirements. *Journal of Cleaner Production, 170,* 1451–1458. https://doi.org/10.1016/j.jclepro.2017.09.215

Hitachi-UTokoy Laboratory. (2018). Society 5.0: *A People-centric Super-smart Society*. The University of Tokyo. https://doi.org.10.1007/978-981-15-2989-4

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4,* 1–23. http://www.jstor.org/stable/2096802

Kasinathan, P., Pugazhendhi, R., Elavarasan, R. M., Ramachandaramurthy, V. K., Ramanathan, V., Subramanian, S., Kumar, S., Nandhagopal, K., Raghavan, R. R. V., Rangasamy, S., Devendiran, R., & Alsharif, M. H. (2022). Realization of Sustainable Development Goals with disruptive technologies by integrating Industry 5.0, Society 5.0, smart cities and villages. *Sustainability (Switzerland), 14(22)* 1-31. https://doi.org/10.3390/su142215258

Kolko, J. (2018). The divisiveness of design thinking. *Interactions, 25(3)*, 28–34.

Lahdenperä, J., Jussila, J., Järvenpää, A. M., & Postareff, L. (2022). Design factory - Supporting technology students' learning of general competences through university–industry collaboration. *LUMAT, 10(1*), 127–150. https://doi.org/10.31129/LUMAT.10.1.1672

Lubis, A. S., & Lubis, A. R. (2024). Proposed human resource competency for Society 5.0. *Mimbar Ilmu, 29(1)*, 46–55. https://doi.org/10.23887/mi.v29i1.71535

Lutfi, D. (2023). The design problem revisited. *Design Issues, 39(3)*, 60–71. https://doi.org/10.1162/desi_a_00726

Manzini, E. (2009). New design knowledge. *Design Studies, 30(1*), 4–12. https://doi.org/10.1016/J.DESTUD.2008.10.001

Mavri, A., Ioannou, A., & Loizides, F. (2020). Design students meet industry players: Feedback and creativity in communities of practice. *Thinking Skills and Creativity, 37*, Article 100684. https://doi.org/10.1016/j.tsc.2020.100684

Meyer, M. W., & Norman, D. (2020). Changing design education for the 21st century. *She Ji, 6(1)*, 13–49. https://doi.org/10.1016/j.sheji.2019.12.002

Mortati, M. (2022). New design knowledge and the fifth order of design. *Design Issues, 38(4)*, 21–34. https://doi.org/10.1162/desi_a_00695

Mytra, P., Wardawaty, W., Akmal, A., Kusnadi, K., & Rahmatullah, R. (2021, October 7). *Society 5.0 in Education: Higher Order Thinking Skills*. 2nd Borobudur International Symposium on Humanities and Social Sciences, BIS-HSS 2020, 18, Magelang, Central Java, Indonesia. https://doi.org/10.4108/eai.18-11-2020.2311812

Noel, L. A., Ruiz, A., van Amstel, F. M. C., Udoewa, V., Verma, N., Botchway, N. K., Lodaya, A., & Agrawal, S. (2023). Pluriversal futures for design education. *She Ji, 9(2)*, 179–196. https://doi.org/10.1016/j.sheji.2023.04.002

Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., & Miranda, J. (2022). Complex thinking in the framework of Education 4.0 and open innovation — A systematic literature review. Journal of Open Innovation: *Technology, Market, and Complexity, 8(1*). 1–15. https://doi.org/10.3390/joitmc8010004

Redström, J. (2020). Certain uncertainties and the design of design education. *She Ji, 6(1)*, 83–100. https://doi.org/10.1016/j.sheji.2020.02.001

Rohne Till, E., Schwaag Serger, S., Axelsson, T., & Andersson, M. (2024). Transformation and resilience in times of change: A historical perspective. *Technological Forecasting and Social Change, 206,* 1-11. https://doi.org/10.1016/j.techfore.2024.123558

Sá, M. J., & Serpa, S. (2022). Higher education as a promoter of soft skills in a sustainable Society 5.0. *Journal of Curriculum and Teaching, 11(4)*, 1–12. https://doi.org/10.5430/JCT.V11N4P1

Schneorson, D., Persov, E., & Bigger, R. (2019). Designing your future - 21st century skill-set for industrial designers: The case study of Israel Design Field. *Design Journal, 22(sup1)*, 243–259. https://doi.org/10.1080/14606925.2019.1595862.

Schwab, K. (2016). The Fourth Industrial Revolution. *World Economic Forum*. https://www.docdroid.net/DNG1NMW/klaus-schwab-the-fourth-industrial-revolution-2016-pdf#page=3

Siddiq, F., Røkenes, F. M., Lund, A., & Scherer, R. (2023). New kid on the block? A conceptual systematic review of digital agency. *Education and Information Technologies, 29(1*), 1–32. https://doi.org/10.1007/s10639-023-12038-3

Silver, M., & Ruokamo, H. (2024). Competencies of modern designers: A systematic literature review [Unpublished manuscript]. Faculty of Education, University of Lapland. https://doi.org/10.30191/ETS

Suganya, G., Selvakumar, J. J., Varadharajan, P., & Pachiyappan, S. (2024). Skill sets required to meet a human-centered Industry 5.0: A systematic literature review and bibliometric analysis. In Infrastructure Possibilities and Human-Centered Approaches With Industry 5.0 (pp. 231–252*). IGI Global*. https://doi.org/10.4018/979-8-3693-0782-3.ch014

Wang, C. Z., Wu, Y., & Gutierrez, L. (2024). Repositioning design as the new attractor in sustainability. *Design Research Society Boston, 23–28 June*, Boston, USA. https://doi.org/10.21606/drs.2024.693

Wilde, D. (2020). Design research education and global concerns. *She Ji, 6(2),* 170–212. https://doi.org/10.1016/j.sheji.2020.05.003

Design and Technology Education: An International Journal

30.1

Roadmap to Early-Stage Medical Device Design through Experiential Learning and Role-Play

Steven C. Koenig, University of Louisville, United States
Gretel Monreal, University of Louisville, United States

Abstract

Purpose: Biomedical engineers that have the ability and skill sets to comprehend and retain basic anatomy and physiology (A&P) knowledge, apply fundamental engineering principles, use critical thinking, and communicate effectively across multiple disciplines to facilitate successful development and clinical translation of medical devices. The authors created an undergraduate medical device design course that follows a roadmap for developing novel devices and/or innovative technology from concept to clinical product with the course focusing on the early-stage of the development process.
Methods: A holistic approach is taught from the unique perspective of inventors, investors, and surgeons (IIS) by integrating interactive presentations, guest lectures, labs, field trips, and role-playing activities into a 15-week curriculum and meets ABET student learning objectives. Individual assignments require oral presentations and written reports that mimic project leaders on design teams, and group assignments are completed through IIS role-playing. These activities culminate with individual student design projects that help build self-confidence in their ability to successfully jump into and navigate the medical device development process. This is accomplished by identifying a clinical need, formulating an innovative concept, defining design criteria, fabricating a prototype to demonstrate proof-of-concept, bench testing to demonstrate feasibility, completing an invention disclosure, making an elevator pitch with constructive classroom critique, and writing an executive summary and detailed report emulating a NIH SBIR Phase I grant.
Results: Course effectiveness was demonstrated by: (1) 204% improvement in A&P knowledge, (2) positive role-playing evaluations (98.7% of students reporting that it was a useful educational experience, written feedback), and (3) favorable course evaluations.
Conclusions: A roadmap for early-stage development of medical devices using a holistic, experiential learning approach is presented to prepare undergraduate bioengineering students for future healthcare careers as engineers, scientists, clinicians, and/or entrepreneurs.

Keywords

biomedical engineering, experiential learning, undergraduate, device, design

Introduction

Role of the Biomedical Engineer

The history of engineering education in the United States dates back to the separation from England during the American Revolution, when Congressman John Adams recognized the need for a school of engineering to support military efforts, manufacturing, and civil infrastructure (Grayson, 1980, Hazarika et al., 2019), the latter of which was being accomplished either by Americans with no formal training or foreign-educated engineers (Mann, 19; Reynolds, 1992; Lee, 1963). Adams wrote a letter to General William Heath in 1776 that read in part:

> *Engineers are very scarce, rare and dear. We want many, and Seem to have none. I think it high Time We should have an Academy for their Education. (Klosky & Klosky, 2013; Smith 1976).*

General George Washington himself was a talented surveyor but similarly with no formal engineering training and recognized this need, thus leading Congress to establishing the Military Academy at West Point in 1802, where the cadets would provide military support while also assisting with public works (Grayson, 1980). The Academy's educational structure was modelled after the French Ecole Polytechnique's curriculum which emphasized civil engineering and design through didactic instruction (Grayson, 1980, Reynolds, 1992). Advances in transportation, communication, agriculture, and civil infrastructure facilitated westward expansion and, as machinery increased in complexity, led to engineers specializing in areas including mining, dynamics, metallurgy, and mechanics (Mann, 1918). From 1860 to 1880, the number of engineering schools in the United States increased from 4 to 85 (Mann, 1918), and by 1890 nearly ten thousand engineering students were enrolled (Grayson, 1980).

At the start of the 20th Century, more than 30,000 students were enrolled in engineering schools (Grayson, 1980). Instruction shifted from didactics to laboratory-based learning, as design-based work was replaced by electrical, mechanical, and transportation technologies that focused on production and which required hands-on instruction and generated graduates who could be immediately useful to their field (Grayson, 1980; Hazarika et al., 2019; Groumpos, 2021). As a result of the rapidly diversifying engineering subspecialties, The Society for the Promotion of Engineering Education recommended the Joint Committee on Engineering Education be assembled to evaluate all engineering education in the United States. Their report, released in 1918, recommended a unification of curricula and a return to engineering fundamentals (Mann, 1918). Following completion of WWII, technologies previously used to advance military goals became repurposed for the domestic front (ex. radar, which went on to become standard tools of meteorology, medical ultrasound, air traffic control monitoring, and numerous other uses (Sarkar et al., 2016). The 1960s led to a pivot in engineering education away from the prior focus on national defense to now tackling domestic and social challenges by developing "engineers of tomorrow" that required collaboration with scientists, economists, lawyers, politicians, and physicians to expand the human aspect of engineering (Grayson, 1980). It was physician concerns over the electrical safety of hospital equipment that resulted in engineers entering the biomedical arena for the first time (Bronzino, 2005).

Medical Device Design Course Considerations

Today's biomedical engineers need to be lifelong learners (Lucky, 1990; Broo et al., 2022; Singh et al., 2018) with both transdisciplinary (Baturalp et al., 2024; Montesinos et al., 2023) and interdisciplinary (Singh et al., 2018; Van den Breent et al., 2020) literacy to facilitate effective communication with clinicians, patients, scientists, entrepreneurs, legal and regulatory agents, clients, and stakeholders in order to advance medical devices. An applicable and conceptual approach to the medical device design process consists of Design, Conduct, Evaluation, and Feedback (Wolfe & Byrne, 1975). Core elements of medical device design include the ability to:

- Identify clinical need, define patient population, and communicate with clients and stakeholders.
- Identify current knowledge gaps and technology limitations.

- Evaluate competitors and analyze market opportunity, assess benefit vs risk, and explore funding opportunities.
- Estimate costs and forecast project timelines.
- Convey novel concepts and confirm intellectual property with broad claims with freedom to operate.
- Define design criteria and advance development via multiple design iterations to achieve a design freeze.
- Carefully evaluate human factors, ethical, and legal considerations.

This strategy emulates, in part, the medical device design process funded by the National Institutes of Health (NIH) Small Business Innovation Research (SBIR) program Phase I (proof-of-concept, feasibility), Phase II (design freeze, commercial plan), and Phase IIB (final preparations for clinical trial, including Validation and Verification or V&V, Good Manufacturing Practices or GMP, Good Laboratory Practices or GLP) studies (Figure 1). In this undergraduate Medical Device Design course, the authors focus on the early-stage development process and considerations (Phase 0 and Phase I).

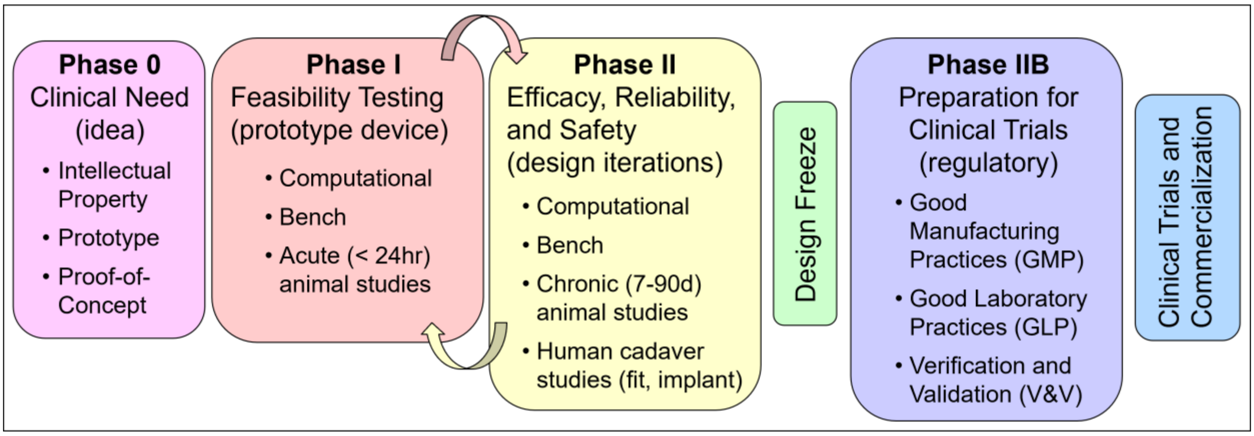


Figure 1. Illustration of the medical device development process emulating National Institutes of Health (NIH) Small Business Innovative Research (SBIR) program: idea, proof-of-concept, prototype, feasibility, multiple design iterations, pre-clinical testing, design freeze, and good laboratory practices (GLP), good manufacturing practices (GMP), and/or other federal regulatory requirements to demonstrate device efficacy, reliability, and safety in preparation for clinical trials approved by the Food and Drug Administration (FDA).

In this article, we present an innovative approach to actively engage students and spark their creativity, practice critical thinking, and learn early-stage medical device design through a variety of fun, hands-on, and practical experiential activities. Our teaching paradigm emphasizes active learning through pre-class preparation (recent journal articles, real-world assignments), in-class student presentations and discussion as individuals and teams, guest speakers and off-site field trips (Foo & Foo, 2022; Scarce, 1997), organ dissection (Elizondo-Omaña et al., 2005; Kaiser et al., 2023) and medical device labs, role-playing (McSharry & Jones, 2000; Brown & Chidume, 2023) and improvisation (Wendland & Worthington, 2024), and a device design project. Ultimately, the primary objective is to successfully train students to understand and apply a holistic approach to medical device design and gain self-confidence in their ability to apply their engineering knowledge and skills. The course didactic content and experiential learning activities (Staehle et al., 2023), student comprehension and evaluation results, and lessons learned and future considerations from our own experiences as researchers and instructors are presented.

Methods

Course Structure

The Medical Device Design elective course (BE 480, 3 credits) was first created and taught by the authors in 2008 and has been offered annually in the Spring semester to third-year undergraduate bioengineering students for the past seventeen years (Table 1). The course meets three times per week (50 min per class) in a forty-seat lecture room equipped with digital projector and whiteboards. The primary goal is for students to have a comprehensive and holistic understanding of the medical device design process development from the unique perspective of an inventor, investor, and surgeon as well as other important clients and stakeholders. This is accomplished through active participation in experiential learning lectures, labs, field trips, and individual and paired student assignments (Table 2). The course culminates with individual student device design projects due at the end of the semester to demonstrate their clear understanding and ability to apply the medical device design process from idea to proof-of-concept and feasibility (Phases 0 and 1).

Table 1. Bioengineering student (n=234) demographics completing the BE 480 undergraduate medical device design course from 2008-2023 (n=17 courses).

Gender	139 female, 190 male
Race	10 African-American, 34 Asian, 8 Hispanic, 256 White, 11 two or more, 3 non-resident alien, 2 unknown
1st Generation to Attend College	28 yes, 296 no
Residency	268 in-state, 56 out-of-state
Graduates	136 BEng, 167 BEng and MEng, 21 no degree

Table 2. Medical Device Design course content and associated assignments.

Class Activity	Assignment (graded)
Lecture 1 – Introduction Medical Device Design	
Lecture 2 – Real-World Examples and Opportunities (guest)	
Lecture 3 - Creativity and Innovation	Individual written summary and presentation
Lecture 4 - Failure	Individual written summary and presentation
Lecture 5 – Ethics (guest conflict of interest)	
Lecture 6 - Intellectual Property (guest patent attorney)	Individual Invention Disclosure (2 iterations)
Lecture 7 – Design of Experiments (DOE – guest)	Team experiment, analysis report, presentation

Lecture 8 – Design, Reliability, Manufacturability (DRM - guest)	Team experiment, analysis report, presentation
Lecture 9 – mini-Design Project (human factors)	Team written summary and presentation
Lecture 10 - Artificial Ear	
Lecture 12 - Artificial Heart	
Lecture 12 - Artificial Kidney	
Lecture 13 - Artificial Lung	
Lecture 14 - Artificial Pancreas	
Lecture 15 - Breast and Prostate Cancer	
Lecture 16 – Neurosurgery (guest)	
Lecture 17 - Prosthetics	
Lecture 18 – Surgical Tools	
Lecture 19 – Wearable Health Monitoring Devices	
Lecture 20 – Mobile Apps, Artificial Learning, Machine Learning	
Lab 1 – Organ Dissection	Team Project
Lab 2 – "Inventor, Investor, Surgeon" role-play lab	Team Project (role play)
Field Trip 1 – Heart Hospital	
Field Trip 2 – Neurosurgery Hospital	
Field Trip 3 – Pre-clinical Testing Facility	
Field Trip 4 – Local Medical Device Industry	
Field Trip 5 – Observe Clinical Case (office, surgery)	Individual Volunteer(s)
Device Design Project ('elevator pitch' – in class)	prototype demonstration (2 iterations) invention disclosure (2 iterations) elevator pitch (final presentation) written summary (2 iterations) written report (final submission)

Medical Device Design Course Roadmap

The authors developed a curriculum modelled from their own expertise and experiences based in part upon their collaborations with over one-hundred industry partners ranging from early-stage start-ups (< 500 employees) to well-established companies (> 10,000 employees), including their own small businesses. For start-ups, the primary funding paths were through NIH SBIR grants, angel investors, and/or venture capital, and industry contracts with large medical device companies. For Class III medical devices, it may take up to 10-15 years and over $500M to successfully develop a novel medical device from concept to FDA-approved clinical-grade commercial product(s). The complete roadmap for medical device is presented at the start of the semester with focus throughout the course on early-stage development (Phases 0-1) that typically takes 6-12 months to achieve.

We assume students have no prior knowledge and experience with medical device design at the start of the semester with the goal of achieving basic knowledge and self-confidence in their ability to understand the process and to acquire and apply critical thinking and communication skills. Our objective is to realistically simulate the medical device development process within the constraints of a 15-week course using individual student semester-long design projects as the primary learning vehicle. The roadmap for navigating the medical device design course (Figure 2) starts with introduction to biomedical engineers and the device development process followed by didactic instruction, experiential learning, and real-world experiences designed to actively engage and instruct undergraduate bioengineering students. Collectively, these learning modalities throughout the semester provide the vehicle to acquire knowledge, develop and practice communication and engineering skills, appreciate risk-reward, feel empathy, and build self-confidence. By the end of the semester, students should be well-prepared to confidently, passionately, and successfully complete and share their device design projects.

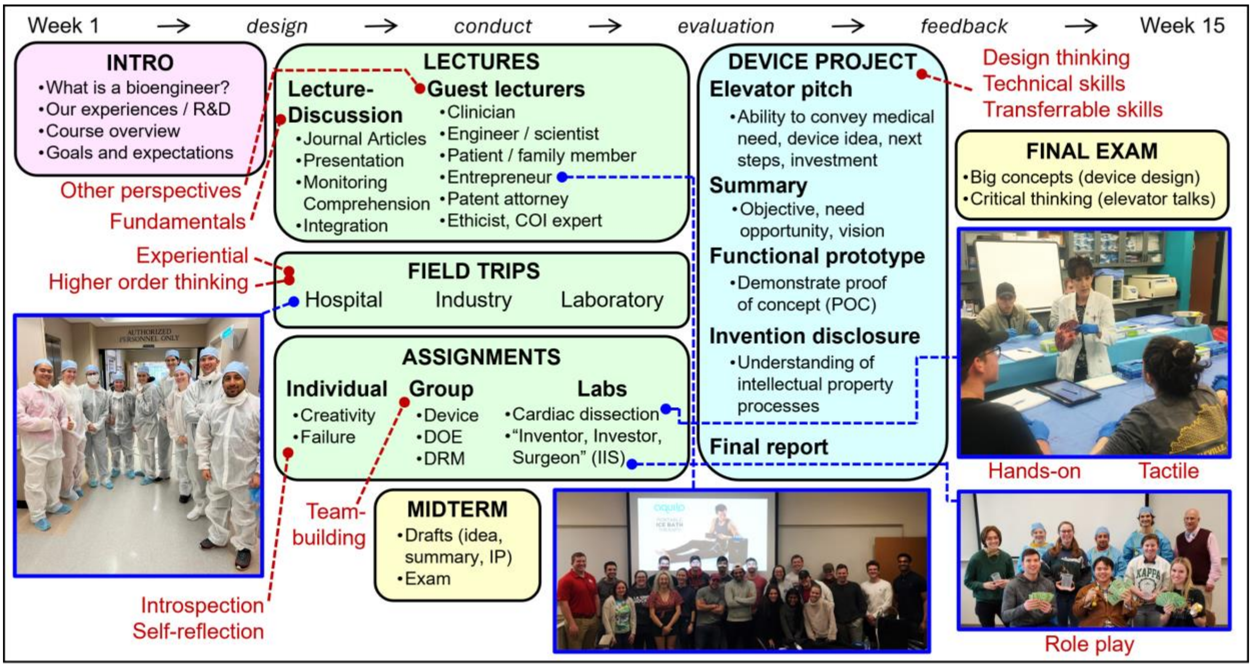


Figure 2. Medical Device Design course roadmap. R&D, research and development; DOE, design of experiments; DRM, design, reliability, manufacturability; COI, conflict of interest; IP, intellectual property.

Start of Learning Adventure

During the first week (week 1) of the semester: (1) students are asked to introduce themselves, share their interest in taking the course, what they hope to learn, and their future career goals; (2) the role of biomedical engineers, career opportunities, and an overview to the medical device development process is presented; and (3) authors share examples of the medical device development process from concept to design freeze, and highlight the successes, failures, and lessons learned from our own experiences. Administratively, the week concludes by presenting course goals, objectives, and expectations while emphasizing the extraordinary experiential learning opportunities scheduled throughout the semester to generate excitement and interest.

Didactic Lectures

A series of didactic lectures presenting an overview of 12-15 assorted technologies (Table 2) is designed for students to learn how to apply critical thinking skills to the medical device design process and evaluation criteria from a holistic perspective. Each presentation follows the same general outline for medical device design to encourage design thinking (Davies et al., 2023) and careful consideration of the following factors:

- Review anatomy, physiology, and targeted disease
- Identify knowledge gaps and clinical need
- Identify current technology with limitations and opportunities
- Define design criteria and engineering requirements
- Understand targeted patient population and potential markets
- Research existing intellectual property, define new claims (broad vs narrow), and defend freedom to operate
- Evaluate human factors and design with empathy
- Review legal and ethical considerations

At the start of class lectures, each student is required to present to the class one of these key consideration points, which then segues into the lecture presentation and student discussion. The selection of topics varies based upon student interest with emphasis on broad understanding of process rather than rigorous in-depth analyses of the medical device. To help ease students into this format, well-established devices (e.g. hearing aids, limb prosthetics, mechanical circulatory support devices) are presented first and then extended in complexity to current emerging technologies (e.g. wearable sensors, mobile apps, artificial intelligence / machine learning) later in the semester. Course content and structure has evolved annually through iterative cycles of student evaluations, guest lectures, field trips, external advisory board feedback, and instructor self-analysis and reflection for continuous improvements.

Guest Lectures

Guest lectures are integrated into the curriculum with experts in their respective fields sharing their experiences, feedback, and guidance providing their unique perspective of medical devices. The lecturers are provided in an open format ranging from informal storytelling and question/answer (ex. fireside chat) to formal presentation (PowerPoint slides) and focused discussion. Guest lecturers have included:

- Surgeons that share current unmet clinical device needs for their patients, risk vs benefit, and their future predictions for emerging technologies and potential applications.
- Patients (and their family members) who have received lifesaving Class III medical devices (ex. left ventricular assist devices, total artificial hearts, stimulation leads) that talk about their disease condition, share their stories and needs, discuss human factors and challenges related to their device, and provide valuable insights into the importance of designing with introspection, reflection, and empathy (Davies, et al., 2023; Radović et al., 2023).
- Entrepreneurs (Ita et al., 2023; Jaworski & Cho, 2023) that share insights and tips on how to transform ideas into practice cost-effectively and efficiently, and to secure

funding to support early-stage proof-of-concept prototypes to late-stage clinical-grade products.

- Business and community leaders (Jaworski & Cho, 2023) that showcase opportunity and impact.
- Scientists involved with the hands-on development and testing of medical devices, including experts in pre-clinical animal testing to discuss FDA requirements including GLP, the challenges and realities of in vivo research, oversight of humane care (OLAW), and the concepts of Reduce, Refine, Replace as the principles for best practice (Hubrecht & Carter, 2019).
- Patent attorneys that present intellectual property (IP) concepts and how-to steps, demonstrate the importance of protecting IP with case studies of past failures and successes, identify potential legal risk factors and their unintended consequences, role of IP and academic research in medical device development (Heus et al., 2017), and lead discussions by asking/answering student questions (Garris & Garris, 2017).
- Experts on ethics and conflict of interest that present important concepts, cases studies, and discuss the Biomedical Engineering Society's (BMES) Code of Ethics with focus on the diverse group of people potentially impacted by medical devices (Martin et al., 2021)
- Former students practicing medicine, working in industry or government agencies, and/or running their own companies share their experience with students and ask/answer their questions.

Field Trips

To reinforce concepts presented and discussed in the classroom didactic and guest lectures, the authors incorporate several field trips into the curriculum to create unique experiential learning opportunities and enhance students' higher order thinking skills (Foo & Foo, 2022; Scarce, 1997; Billiar et al., 2022). Field trips include visits to:

1. Hospitals, where students dress in medical scrubs and visit diagnostic imaging facilities, surgical operating rooms, and intensive care units (ICU) while also meeting with teams of clinicians (surgeon, anaesthesiologist, nurses, perfusionists), patients and their families and caregivers, and/or hospital administrators.

2. Medical device companies (local), where students meet with senior leaders (entrepreneurs, chief executive officers, chief technology officers), engineers (R&D inventors, manufacturing, quality control, regulatory and safety), and business and commercialization associates (finance, sales, marketing).

3. Development and testing facilities (ex. research laboratories, imaging, human cadaver, and animal facilities).

Experiential Activities (Lab-Based)

The authors incorporate two practical, interactive hands-on labs during the course:

1. Organ dissection lab, designed to improve anatomy and physiology knowledge retention through hands-on experiences (Abeyratne, 2008) and realistically simulate a medical device study to identify design criteria, assess fit, and evaluate surgical technique. In preparation for

the dissection lab, students are given a pre-lab 'surprise quiz' to test their knowledge of organ features and function (Supplemental Resource 1). Students are handed back their graded pre-lab quiz and a medical device design assignment with detailed instructions and deliverables to complete prior to the scheduled lab (Supplemental Resource 2). During the lab, the instructors lead gross organ (e.g. heart) dissection while engaging with the students by asking them to identify key features, structure, and function (covering the material in the pre-lab quiz) while students touch, hold, probe, and/or photograph the organ (Figure 3). Next, paired student teams are each assigned a medical device (e.g. cardiac) to define design criteria, assess fit, and evaluate surgical approach, which they document and write-up in a summary report. An identical post-quiz (again unannounced) is administered to the students approximately one week after the dissection lab to assess their knowledge retention. At the end of the organ dissection lab, students complete course evaluations (1-5 Likert scale, 1=poor, 5=excellent) with qualitative open-ended written feedback, Supplemental Resource 3).

Figure 3. Photo of student team during the organ dissection lab (heart). Here, students are examining a Perceval stented aortic valve (Corcym, Milan, Italy). The valve is visible on its own on the table and also implanted in situ in an explanted pig heart.

2. "Inventor, Investor, Surgeon" (IIS) lab. Here, students are encouraged to evaluate clinically approved and/or emerging pre-clinical medical devices from the view of an inventor, investor, and a surgeon (IIS) through the use of role-play. Role-play and improvisation (McSharry & Jones, 2000; Brown & Chidume, 2023; Wendland & Worthington, 2024) are simple, adaptable, interactive, and cost-effective means of enhancing student engagement and injecting light-hearted fun into often quite technical topics. We designed our IIS lab (1.5hrs) to be engaging, interactive, and presented in multiple modalities to encompass auditory, visual, and tactile forms of learning (Monreal et al., 2014; Monreal & Koenig, 2025). Students were first provided

a review of cardiovascular anatomy/function, heart failure (HF) pathophysiology, and a discussion of mechanical circulatory support device (MCS) therapy for HF. Next, they held and assessed MCS devices including the AbioCor total artificial heart (Abiomed, Danvers, MA), Impella 2.5 (Abiomed), HeartMate XVE (Thoratec, Pleasanton CA), HeartMate II (Thoratec), HeartMate 3 (Abbott, Abbott Park IL), HVAD (Medtronic, Minneapolis MN), and SynCardia total artificial heart (SynCardia Systems LLC, Tucson AZ). Students were then split into teams of three with each person assuming one of the following roles (Figure 4):

- The Inventor (props included bowties, beakers) selects an MCS device, articulates their rationale, and makes a convincing elevator pitch to the Investor.
- The Investor (toy money and toy sports cars) evaluates whether to fund and champion the device and then convinces the Surgeon to adopt its use.
- The Surgeon (surgical caps, stethoscopes) weighs device efficacy, clinical applications, and assesses risk-benefits for their patients.

Students remain in the above roles as each team is given ~15 minutes to present their rationale for why they selected their device and make a compelling case to the instructors and rest of the class for their device's superiority. After all IIS teams have presented, the instructors and fellow classmates ask challenging questions (while still in their roles) that spark provocative debates that require critical thinking, analysis, and improvisation. At the end of the IIS lab, students complete course evaluations (1-5 Likert scale, 1=poor, 5=excellent) and the opportunity to also provide qualitative open-ended written feedback (Supplemental Resource 3).

Figure 4. Group photo of three student teams still in character during participation in the "Inventor, Investor, Surgeon" (IIS) role-play lab. During the activity, the Inventors (wearing bowties and holding beakers) had to select an MCS device, articulate their rationale, and make a convincing elevator pitch to the Investor. The Investors (holding toy money and pirate coins) had to evaluate whether to fund and champion the device and then convince the Surgeon to adopt its use. The Surgeon (wearing surgical caps, gowns, and stethoscopes) then had to weigh device efficacy, clinical applications, and assess risk-benefits for their patients.

Assignments

Lecture, lab, and device design project assignments provide multiple opportunities for students to integrate lecture, lab, and engineering knowledge, apply critical thinking, continue development of communication skills, and actively practice design development exercises using a real-world approach. For example, instructor lectures, journal articles, and student discussion have included:

Individual Exercises:

1. Creativity. What is creativity and why is it important (Egan et al., 2017)? How does one come up with creative and innovative ideas (ex. using biomimicry, toys, etc as inspiration)? The creativity assignment requires each student to independently identify their own example of something creative in the medical device world and its global impact, write a 1-page summary, and make a 5-min presentation to the class. The creativity exercise also helps students identify potential topics for their medical device design projects.

2. Failure. What is failure and why is it important (Laksov & McGrath, 2023)? The failure assignment requires each student to independently identify their own example of a past medical device failure and its global impact (ex. catastrophic adverse events, FDA recall notification, negative publicity, etc), write a 1-page summary and make a 5-min presentation to the class. The failure exercise shows students how often failure occurs, the importance of learning from and overcoming failure, and builds self-confidence, which encourages students to start, stay committed, and overcome many of the unanticipated challenges and failures they will experience with their own device design projects.

Team Exercises:

1. To encourage team-building and communication skills (Billiar et al., 2022; John, 2022; Marasi, 2019), paired student teams are assigned to a mini-project where each team is tasked to propose device/technology solution to help patients overcome disease symptoms in everyday life. Paired student design teams write a 1-page summary and make a 5-min presentation.

2. Paired student teams complete Design of Experiments (DOE) and Design, Reliability, and Manufacturability (DRM) assignments using industry standard software (Minitab, State College PA). These engineering development tools help students define medical device design criteria for simple medical devices and help build self-confidence.

End of the Journey (Device Design Projects)

Students work on their individual medical device design projects over the course of the semester, where they learn and practice early-stage device design process from conceptual idea to demonstrating proof-of-concept and feasibility. The expectations are that:

1. Students identify a clinical need of interest to them, reflecting on their own personal experiences (through their own or a loved one's health condition, through something they may have seen or experienced during a co-op, etc). The expectation is for students to identify area of interest and clinical need within first few weeks of the course.

2. By mid-semester, students complete a patent search, their first draft of an invention disclosure form (using university template) and write a draft summary (one page) of their

proposed medical device which the instructor assigns an initial grade with written feedback. Students have the opportunity to then revise both their initial invention disclosure forms and project summary documents with submission of their final device design written reports.

3. At the end of the semester (week 15), students are randomly selected for an "elevator pitch" to present their idea and device prototypes with the goal of convincing the instructors and fellow students to invest a requested amount of funding (e.g. $100k) in their start-up company along with rationale and projected milestones, deliverables, and timeline. The students then have one week to use the in-class critiques following their "elevator pitch" to make last-minute improvements to their final project reports.

4. The final written report is a comprehensive presentation of student medical device design from idea to proof-of-concept prototype. In addition to the project summary and invention disclosure forms, the written report includes the key elements in the early-stage of medical device development presented and learned over the entire semester, including clinical need, disease, critique of current diagnostic/therapeutic modalities, devices, and technologies, patient population and market, prototype design and testing, and human factors, ethical, and legal considerations (Online Resource 4). Supporting references from rigorous literature review and patent searches are also required.

All assignments are graded numerically (0-5 scale oral, 0-5 scale written) along with instructor written comments identifying strengths and weaknesses designed to offer consistent, constructive feedback and guidance.

Exams

Midterm and final exams are designed as new learning experiences for students to integrate and apply multiple concepts with open-ended questions that they may answer using equations, illustrations, models, and/or written responses to demonstrate their understanding and ability to apply critical thinking. An example mid-term exam question may ask students to identify key challenges and propose solutions for gaining widespread clinical approval of a medical device that may not have been presented in previous lectures (ex. automated insulin delivery). A final exam question may ask students to select student design project (other than their own) they would not invest funds in, while providing rationale from the perspective of multiple stakeholders and clients, and then clearly and concisely state what they may potentially do to address the clinical need and/or improve upon the proposed technology.

Results

Course Effectiveness and Student Satisfaction

As others have shown (Montesinos et al., 2023; Tembrevilla et al., 2024), we hypothesized that retention and comprehension of anatomy and physiology knowledge taught in previous course(s) would greatly improve with experiential learning. Data demonstrated a mean 204% improvement in students' pre- and post-test scores following hands-on participation in the cardiac dissection lab (pre 27.9 ± 19.6% vs post 84.7 ± 17.4%, $p<0.0001$ via paired t test) (Figure 5a). Lab evaluations were extremely positive (Figure 5b). Participants self-reported that it was a fun educational experience (98.7% responded to this question with a 5-excellent or 4-very good) and that they learned new things (98.7% responded to this question with a 5-excellent or 4-very good).

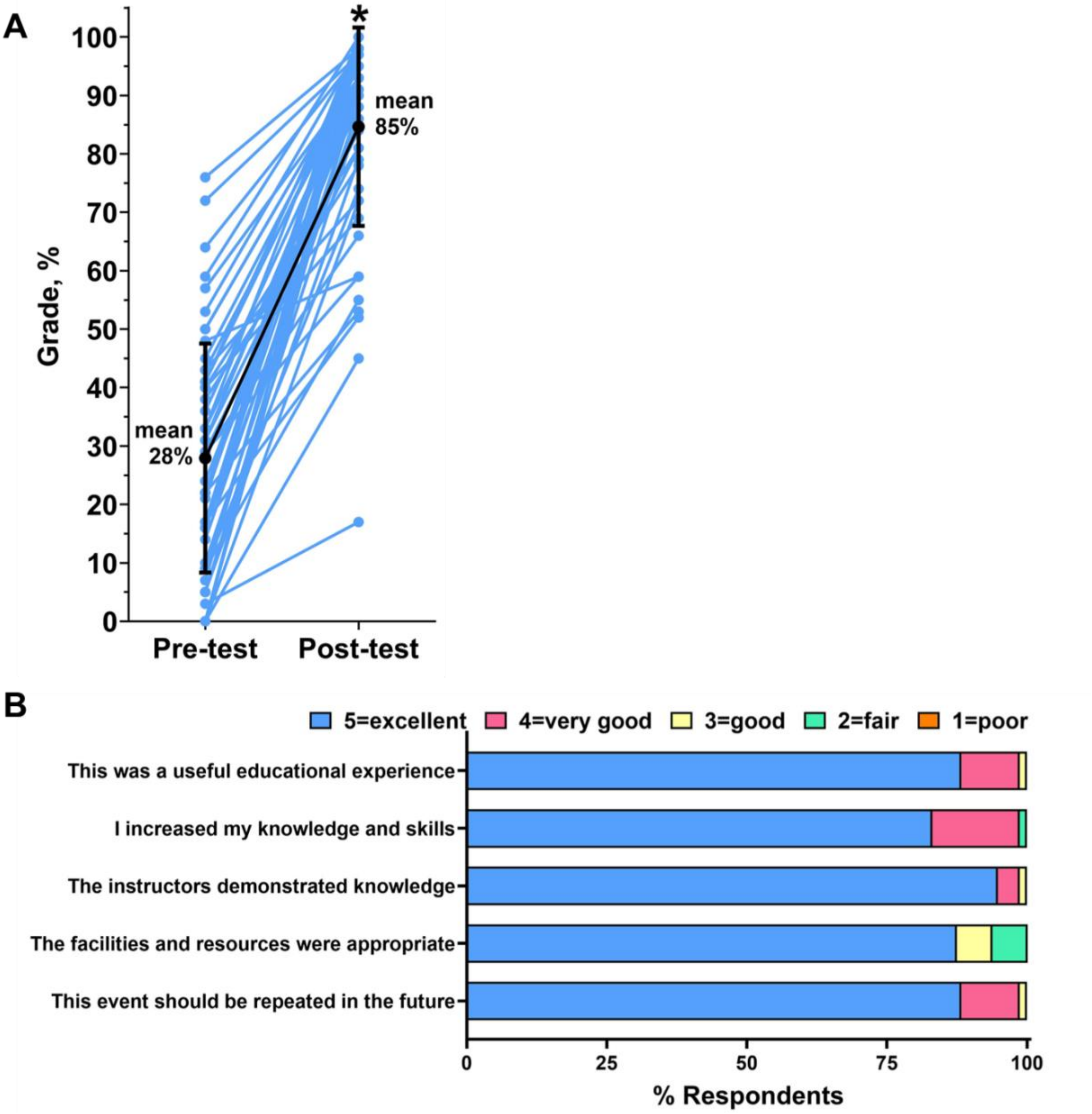


Figure 5. A, Pre- and post-organ dissection lab quiz (Online Resource 1) scores (2020 and 2022 students only; no lab in 2021 due to the COVID pandemic; no pre- or post-quiz in 2023). Results demonstrated significant improvement in knowledge and understanding of heart anatomical features and function. Data are presented as individual students' paired results (gray lines) and as the mean ± SD (black line). *p<0.0001 via paired t test. B, Results of the lab evaluations (n=79 participants, n=77 responses), with questions rated on a scale of 1 (poor) to 5 (excellent). Data are presented as stacked percentages of respondents.

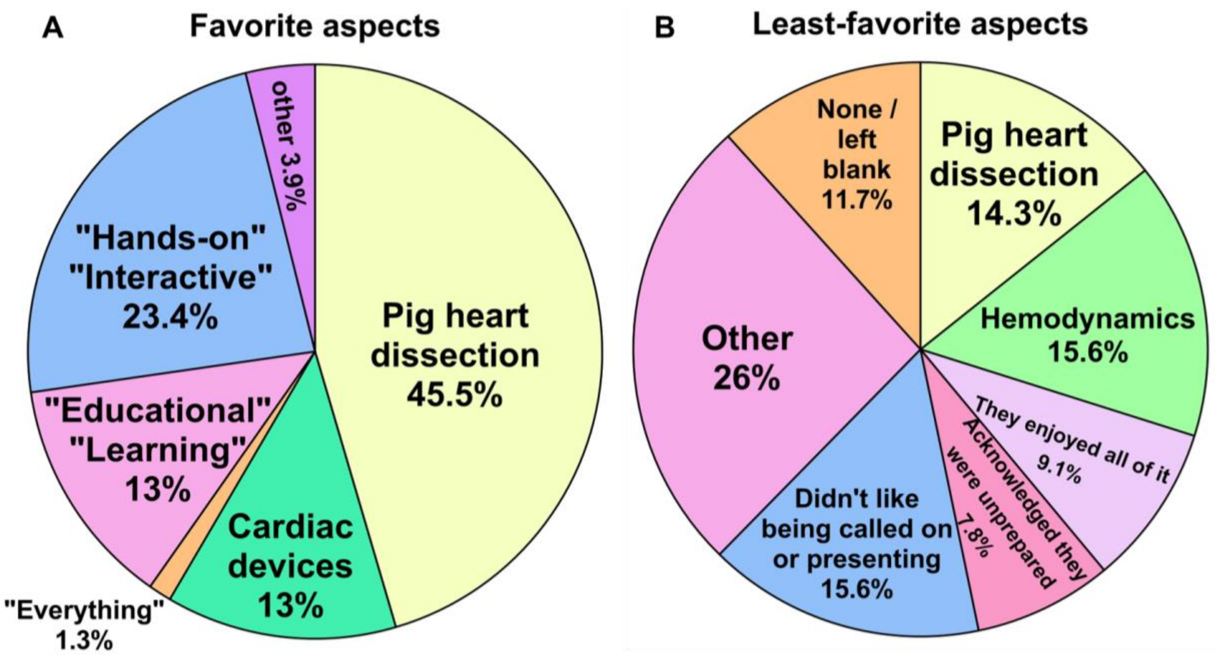


Figure 6. Students' favorite (A) and least-favorite (B) aspects of the cardiac dissection and "Inventor, Investor, and Surgeon" (IIS) labs as self-reported on their evaluations. Data presented as percent breakdowns of responses (Prism v10.3.0 (507), GraphPad Software, Boston MA).

Space was provided within the evaluation forms for students to describe their favorite and least-favorite aspects of the labs. As shown in Figure 6a, students really enjoyed the pig heart dissection (45.5% enjoyed this part the most), as well as the hands-on (23.4%) and educational (13%) aspects of the labs. Least-favorite aspects (Figure 6b) included the pig heart dissection (14.3% reported this was their least-favorite part) and learning about hemodynamics. Space was also provided on the evaluation forms for open-ended written comments (Figure 7). Students self-reported that they really enjoyed the lab events, including the heart dissection and role-playing experience in the IIS lab. Particularly in the IIS labs, students were interactive, had fun wearing/using the props for their respective roles, and engaged in highly animated discussions defending the device they chose, critiquing the others, and considering alternate viewpoints. The labs were light-hearted and filled with laughter, which was also observed during role-play activities by Brown & Chidume (2023). Open-ended comments were extremely positive, with written comments that emphasized "fun", "hands-on", "educational", and "awesome."

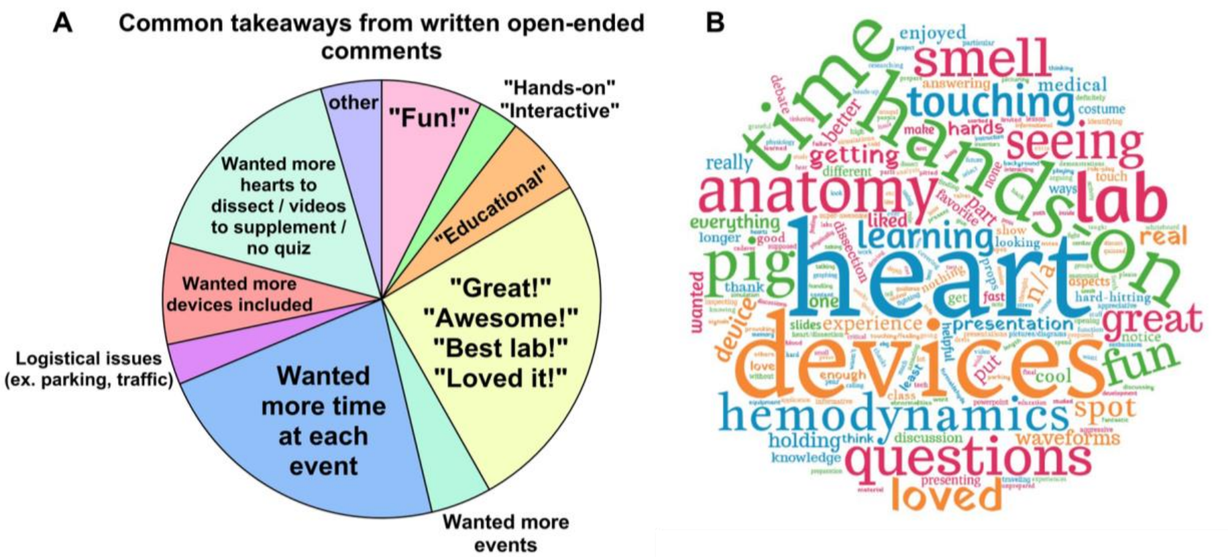


Figure 7. Common themes in the open-ended written comments of lab evaluations. A, Data are presented as percent breakdowns of responses (Prism v10.3.0 (507), GraphPad Software, Boston MA). B, The same data presented as a wordcloud visual representation of the participants' open-ended written comments on their evaluation forms. The larger the size of the words, the higher the frequency of the repeated comments. Participant open-ended comments were transcribed by the authors and the wordcloud was generated using www.wordclouds.com (Zygomatic, The Netherlands).

Students benefited from multiple opportunities to continue to develop their critical thinking, engineering, and communication skills through multiple learning modalities, which align with the Accreditation Board for Engineering and Technology (ABET) Student Outcomes: (1) identify, formulate, and solve complex engineering problems, (2) apply engineering design, (3) effective communication, (4) ethical and professional responsibilities, (5) function on teams (and independent), (6) conduct experiments and analyze data, and (7) acquire and apply new knowledge (Table 3).

Table 3. Student assignments, deliverables, and associated Accreditation Board for Engineering and Technology (ABET) student learning outcomes: 1 - identify, formulate, and solve complex engineering problems, 2 - apply engineering design, 3 - effective communication, 4 - ethical and professional responsibilities, 5 - function on teams, 6 - conduct experiments and analyze data, and 7 - acquire and apply new knowledge.

Assignment	Description	ABET Criteria
Creativity	Identify, summarize, and present example of medical device idea from biomimicry, toys, and/or other sources	2, 3, 4, 7
Failure	Identify, summarize, and present example of past medical device failure, lessons learned, and propose solution(s)	2, 3, 4, 7
Design of Experiments (DOE)	Conduct computational experiments and analysis to aid in defining design criteria	1, 2, 3, 4, 5, 6, 7

Design, Reliability, Manufacturability (DRM)	Develop function model, boundary diagram, interface dictionary, and P-diagram for medical device component	1, 2, 3, 4, 5, 6, 7
Mini-Design Project (human factors)	Design a device to improve patient quality of life, write summary, and present to class	2, 3, 4, 5
Prototype Device (proof-of-concept)	Design, fabricate, and bench test project device that conveys concept and demonstrates potential	1, 2, 3, 4, 6, 7
Intellectual Property	Complete University Invention Disclosure form	3, 7
Device Project Presentation	Present Device Project via 'Elevator Pitch' to investors	3
Device Project Summary Report	Written report (one-page) succinctly summarizing proposed device development project targeting potential investors	3
Device Project Development Report	Written report presenting medical device design project using holistic approach and development process	1, 2, 3, 4, 6, 7

The course evaluation data spans the pre- and COVID pandemic era. The pandemic's lockdown and subsequent reduction of in-person activities left its mark on students and their exposure to innovative hands-on educational opportunities (Asgari et al., 2021). We were curious if the cohort of students who had taken the brunt of the pandemic (freshmen and sophomore bioengineering students during COVID, 2022 course) would place greater emphasize or value on educational aspects that perhaps the pre-pandemic students (2020 course) took for granted. Indeed, 34% of the pandemic students emphasized the appeal of "hands-on" in their course evaluations, compared to 11% of the pre-pandemic cohort ($p<0.0292$ via a Fisher's Exact test, data analyzed using Prism v10.3.0 (507), GraphPad Software, Boston MA).

Cumulatively, this course demands significant student commitment, effort, and time management. The authors continuously solicited student feedback over the entire semester. On the 1st day of class, each student was asked why they signed up for class, area of interest in bioengineering, and post-graduate plans, which enabled us to tailor lectures accordingly (e.g. devices/technologies presented in lectures). Students had the opportunity to voluntarily complete mid-semester course evaluations (Supplemental Resource 5) to evaluate course content, instructors, and self-assessment of their performance by providing anonymous Likert score and written responses. Mid-semester evaluations (2023) demonstrated the course was a useful, educational experience (4.6 of 5.0 scale) and increased student knowledge and skills (4.4 of 5.0); the instructors demonstrated knowledge (5.0 of 5.0), provided valuable feedback (4.9 of 5.0), acted professionally (4.9 of 5.0), and were accessible (5.0 of 5.0); and students reported their own class preparation (3.6 of 5.0), class participation (4.4 of 5.0), and time completing assignments (4.5 of 5.0). This information enabled the authors to address any potential concerns to improve their educational experience over the second half of the semester rather than waiting until final end-of-semester evaluations, which are helpful for future classes but have no impact for the current class of students. Averaged final course evaluations (2019-2023) demonstrated favorable review of the instructors (4.4 of 5.0 scale), content and value (4.5 of 5.0), and meeting seven ABET criteria (4.6 of 5.0).

Lessons learned and future considerations

A holistic critical thinking approach to medical device development from early-stage prototypes through design freeze is needed to successfully translate effective, reliable, and safe clinical-grade commercial products into clinical practice to improve patient outcomes and quality of life. Biomedical engineering graduates may continue to pursue their interest in medical device development via one of many distinct, yet interconnected pathways. They may choose to develop medical devices as engineers and scientists, entrepreneurs and/or small business owners, clinicians that identify unmet need(s) in practice (or active lifestyle) and formulate innovative solution(s), patent attorneys or litigators filing and protecting intellectual property, or hospital administrators stratifying projected risk and associated costs. The value of a multidisciplinary approach to medical device design by grouping teams of engineering, medical, and business students was demonstrated by the high percentage of biomedical engineering students that pursue productive and impactful healthcare careers (Denend et al., 2021). Specifically, long-term follow-up with post-graduate surveys of Stanford students that completed their Biodesign course (Yock et al., 2015) was shown to be influential in choosing their career direction and impactful in their career (Denend et al., 2021).

Knowledge retention, comprehension, and the ability to apply fundamental engineering concepts in combination with basic human anatomy and physiology and introductory engineering courses from completed pre-requisite courses is required to enroll in our Medical Device Design course. In a traditional engineering didactic lecture-based approach, focus may be placed on engineering-driven course content with a structured curriculum that follows a medical device design textbook. There are a number of informative medical device design textbooks that the authors carefully considered (Yock et al., 2015; Chan, 2023; King et al., 2018); however, the authors chose to create content by developing their own lectures, choosing recently published journal articles, and experiential activities as the primary learning vehicle to follow as the medical device design roadmap (Figure 2). Diagnostic and therapeutic medical devices, emerging technologies, and clinical paradigms change rapidly in a highly competitive, fast-paced industry. Thus, using recently published journal articles (review, emerging technologies) allows course content to be flexible and updated annually.

Since creating and first offering the course in 2008, content, format, presentation, style, and structure have been critically evaluated and modified for continuous improvement annually. The instructors actively solicit and review feedback and guidance to identify strengths and weaknesses from multiple stakeholders, including authors contacts with clinicians and patients, industry partners, government officials (e.g. FDA, NIH), guest lecturers, student and ABET course evaluations, and our university ABET external advisory board comprised of five education and industry leaders. Initially, the course followed traditional a textbook format supplemented with didactic lecture (e.g. slides) and interactive classroom discussions. Guest lectures by invited experts and field trips were later integrated into the course curriculum to provide multidisciplinary and multi-institutional perspectives in response to student feedback for more hands-on experiential learning opportunities with added benefits of networking (coop, employment) and evaluating their future career path. Course content evolved with advances in technology and clinical practices along with changes in ABET guidelines and improvements in defining student learning outcomes by identifying emerging areas of emphasis and need (e.g. ethics, societal perspectives). In 2019, the authors observed a concerning pattern of declining student retention of prerequisite (e.g. anatomy and physiology) and fundamental engineering knowledge (e.g. critical thinking) required to successfully apply to medical device design and development. Subsequently, an organ dissection lab was added, which students overwhelmingly valued. They also requested additional hands-on labs be integrated into the course. Based upon this student feedback, the IIS lab was added in 2021, which built upon the authors industry and SBIR experiences and expertise and featured new learning modality (role-play). Student course (mid- and end-semester) and lab evaluation data have shown strong student interest and demonstrated their ability to learn, retain, and apply knowledge.

Challenges identified have included: (1) time constraints with classes often running long; (2) travel requiring extra time and resources needed for off-site labs and tours; (3) time and effort to complete the large number of assignments and labs. To address these concerns, we have considered extending one of the weekly classes to 120 min and/or reduce number of weekly classes to two 90-min meeting times to accommodate off-site labs and field trips. We are also considering development of a follow-on graduate course with students having the opportunity not only develop prototypes, but to extend the process further by demonstrating feasibility. The roadmap for the graduate course may focus on Phase II and provide a learning vehicle for students to write an abstract and/or manuscript and prepare a NIH SBIR Phase II grant application in support of their independent graduate research.

Declarations

Steven C. Koenig and Gretel Monreal are investigators on a National Institutes of Health (NIH) grant R44HL144214 (Inspired Therapeutics) unrelated to this article. Steven C. Koenig and Gretel Monreal are investigators on a Kentucky Academy of Science Athey Science Education and Outreach Grant unrelated to this article. Gretel Monreal is the recipient of a grant from Abiomed unrelated to this article. Steven C. Koenig is an investigator on a NIH grant (R01HL150346) unrelated to this project. Gretel Monreal is supported in part by a gift from Robert M. Prizant to the Legacy Foundation of Kentuckiana.

References

Abeyratne, U. R. (2008) “Balancing hands-on vs. theory in biomedical engineering and informatics education.” *Int. J. Medical Engineering and Informatics* 1 (1). https://doi.org/10.1504/IJMEI.2008.019467

Asgari, S., Trajkovic J., Rahmani, M., Zhang, W., Lo, R.C., Sciortino, A. (2021) “An observational study of engineering online education during the COVID-19 pandemic.” *PLoS One* 16:e0250041. https://doi.org/10.1371/journal.pone.0250041

Baturalp, T.B., Bozkurt, S., Baldock, C. (2024) “The future of biomedical engineering education is transdisciplinary.” *Phys Eng Sci Med* May 30. https://doi.org/10.1007/s13246-024-01442-9

Billiar, K., Gaver III, D.P., Kenneth, B., et al. (2022) “Learning Environments and Evidence-Based Practices in Bioengineering and Biomedical Engineering.” *Biomedical Engineering Education* 2: 1-16. https://doi.org/10.1007/s43683-021-00062-z

Bronzino, J. (2005) “1 – Biomedical Engineering: A Historical Perspective.” In Introduction to Biomedical Engineering (Second Edition), edited by Enderle, J.D., Blanchard, S.M., Bronzino, J.D. Academic Press. pp. 1-29. https://doi.org/10.1016/B978-0-12-238662-6.50003-3

Broo, D.G., Kaynak, O., Sait, S.M. (2022) "Rethinking engineering education at the age of industry 5.0." *Journal of Industrial Information Integration* 25: 100311. https://doi.org/10.1016/j.jii.2021.100311

Brown, L.G., Chidume, T. (2023) "Don't forget about role play: An enduring active teaching strategy." *Teaching and Learning in Nursing* 18:238-241. https://doi.org/10.1016/j.teln.2022.09.002

Chan, A.Y.K. (2023) "Biomedical Device Technology: Principles and Design (3rd Edition)." Charles C Thomas Publisher Ltd.

Davies, T.C., Manzin, J., Meraw, M., Munro, D.S. 2023. "Understanding the Development of a Design Thinking Mindset During a Biomedical Engineering Third-Year Course." *Biomedical Engineering Education* 3: 123-132. https://doi.org/10.1007/s43683-022-00093-0

Denend, L., Xu, S., Yock, P., Venook, R. (2021) "Biomedical Technology Innovation Education and Its Effect on Graduate Student Careers Over 17 Years." *Biomedical Engineering Education* 1 (2): 291-300. https://doi.org/10.1007/s43683-021-00050-3

Egan, A., Maguire, R., Christophers, L., Rooney, B. (2017) "Developing creativity in higher education for 21st century learners: A protocol for a scoping review." *Int J Educational Research* 82: 21-27. https://doi.org/10.1016/j.ijer.2016.12.004

Elizondo-Omaña, R.E., Guzmán-López, S., de los Angeles García-Rodríguez, M. (2005) "Dissection as a teaching tool: Past, Present, and Future." *Anat Rec B New Anat* 285 (1): 11-5. https://doi.org/10.1002/ar.b.20070

Foo, S.C., Foo, K.K. (2022) "Purposeful Field Trip: Impact on Experiential Learning Opportunities and Critical Thinking Skills." *Pertanika Journal of Social Sciences and Humanities* 30: 1-30. https://doi.org/10.47836/pjssh.30.1.01

Garris, C. A. Jr., Garris III, C.A. (2017) "The United States patent system and engineering education: an alliance for innovation." *Technology and Innovation* 19: 509-524. http://dx.doi.org/10.21300/19.2.2017.509

Grayson, L.P. (1980) "A Brief History of Engineering Education in the United States." *IEEE Transactions on Aerospace and Electronic Systems* AES-16:373-392. https://doi.org/10.1109/TAES.1980.308907

Groumpos, P.P. (2021) "A Critical Historical and Scientific Overview of all Industrial Revolutions." *IFAC-PapersOnLine* 54 (13): 464-471. https://doi.org/10.1016/j.ifacol.2021.10.492

Hazarika, M., Dixit, U.S., Davim, J.P. (2019) "Chapter 1 - History of Production and Industrial Engineering Through Contributions of Stalwarts." In *Manufacturing Engineering Education*, edited by J. Paulo Davim JP. Chandos Publishing; pp. 1-29. https://doi.org/10.1016/B978-0-08-101247-5.00001-0

Heus, J.J., de Pauw, E.S., Leloux, M., Morpurgo, M., Hamblin, M.R., Heger, M. (2017) "Importance of intellectual property generated by biomedical research at universities and academic hospitals." *J Clin Transl Res* 3 (2): 250-259. https://doi.org/10.18053/jctres.03.201702.005

Hubrecht, R.C., Carter, E. (2019) "The 3Rs and Humane Experimental Technique: Implementing Change." *Animals* 9: 754. https://doi.org/10.3390/ani9100754

Ita, M.E., Kaletunç, G.Z., Swindle-Reilly, K.E. (2023) "Designing a Biomedical Engineering Course to Develop Entrepreneurial Mindset in Students." *Biomedical Engineering Education* 3 (2): 179-191. https://doi.org/10.1007/s43683-022-00101-3

Jaworski, J., Cho, M. (2023) "Implementation of an Experiential Service-Learning Course in Biomedical Engineering Design for Undergraduate Students." *Biomedical Engineering Education* 3 (2): 243-251. https://doi.org/10.1007/s43683-022-00103-1

John, D. (2022) "A Life-skills Course for Engineers to Acquire Communication Skills and Team Skills." *IEEE International Professional Communication Conference (ProComm)* 36-41. https://doi.org/10.1109/ProComm53155.2022.00010

Kaiser, L.-M., Polte, S., Kirchhoff, T., Großmann, N., Wilde, M. (2023) "Dissection in biology education compared to alternative methods in terms of their influence on students' emotional experience." *Front. Psychol* 14: 1138273. https://doi.org/10.3389/fpsyg.2023.1138273

King, P.H., Fries, R.C., Johnson, A.T. (2018) *Design of Biomedical Devices and Systems,* 4th edition. Taylor & Francis Group. https://doi.org/10.1201/9780429434792

Klosky, J.L., Klosky, W.E. (2013) "Men of action: French influence and the founding of American civil and military engineering." *Construction History* 28 (3): 69-87. http://www.jstor.org/stable/43856053

Laksov, K.B., McGrath, C. (2023) "Failure as a catalyst for learning: towards deliberate reflection in academic development work." *Int J Academic Development* 25 (1): 1-4. https://doi.org/10.1080/1360144X.2020.1717783

Lee, G.C. (1963) "The Morrill Act and Education." *British Journal of Educational Studies* 12 (1): 19-40. https://doi.org/10.2307/3118919

Lucky, R.W. (1990) "Engineering Education and Industrial Research and Development - The Promise and the Reality." *IEEE Communications Magazine* 28 (12): 16-22. https://doi.org/10.1109/35.61716

Mann, C.R. (1918) "A Study of Engineering Education." In Bulletin number 11, Carnegie Foundation for the Advancement of Teaching. The Merrymount Press.

Marasi, S. (2019) "Team-building: Developing Teamwork Skills in College Students Using Experiential Activities in a Classroom Setting." *Organization Management Journal* 16: 324-337. https://doi.org/10.1080/15416518.2019.1662761

Martin, D.A., Conlon, E., Bowe, B. (2021) "A Multi-level Review of Engineering Ethics Education: Towards a Socio-technical Orientation of Engineering Education for Ethics." *Science and Engineering Ethics* 27: 60. https://doi.org/10.1007/s11948-021-00333-6

McSharry, G., Jones, S. (2000) "Role-play in science teaching and learning." *School Science Review* 82 (298): 73-82.

Monreal, G., Moran, K.R., and Gerhardt, M.A. (2014) "The In Vivo Skills Laboratory in Anesthesiology Residency Training." *J Educ Perioper Med* 16: E075.

Monreal, G., Koenig, S.C. (2025) "Heartwheels! STEM Mobile Outreach." *Advances in Physiology Education* 49: 128-135.

Montesinos, L., Salinas-Navarro, D.E., Santos-Diaz, A. (2023) "Transdisciplinary experiential learning in biomedical engineering education for healthcare systems improvement." *BMC Medical Education* 23 (1): 207. https://doi.org/10.1186/s12909-023-04171-x

Radović, S., Firssova, O., Hummel, H.G.K., Vermeulen, M. (2023) "Improving academic performance: Strengthening the relation between theory and practice through prompted reflection." *Active Learning in Higher Education* 24 (2): 139-154. https://doi.org/10.1177/14697874211014411

Reynolds, T.S. (1992) "The Education of Engineers in America before the Morrill Act of 1862." *History of Education Quarterly* 32 (4): 459–82. https://doi.org/10.2307/368959

Sarkar, T.K., Palma, M.S., Mokole, E.L. (2016) "Echoing across the years: A history of early radar evolution." *IEEE Microwave Magazine* 17 (10): 46-60. https://doi.org/10.1109/MMM.2016.2589200

Scarce, R. (1997) "Field trips as short-term experiential education." *Teaching Sociology* 25: 219-226. https://doi.org/10.2307/1319398

Singh, A., Ferry, D. Mills, S. (2018) "Improving Biomedical Engineering Education Through Continuity in Adaptive, Experiential, and Interdisciplinary Learning Environments." *J Biomechanical Engineering* 140:0810091–8. https://doi.org/10.1115/1.4040359

Smith, P. H. "Letters of Delegates to Congress, 1774-1789." 1976. Washington, DC: Library of Congress, 3, p.275.

Staehle, M. M., Childers, R.C., Guilford, W.H. (2023) "From Theory to Practice: Unraveling the Impact of Experiential Learning in Biomedical Engineering Education." *Biomedical Engineering Education* 3: 111-112. https://doi.org/10.1007/s43683-023-00122-6

Tembrevilla, G., Phillion, A., Zeadin, M. (2024) "Experiential learning in engineering education: A systematic literature review." *J Eng Educ* 113: 195–218. https://doi.org/10.1002/jee.20575

Van den Breent, A., MacLeod, M., Van der Veen, J., et al. (2020) "Interdisciplinary engineering education: A review of vision, teaching, and support." *J Eng Educ* 109:508-555. https://doi.org/10.1002/jee.20347

Wendland, R.J., Worthington, K.S. (2024) "Improv Activities in an Engineering Classroom Increase Student Self-Perceptions of Engagement, Adaptability, and Communication." *Biomedical Engineering Education* 4: 97-107. https://doi.org/10.1007/s43683-023-00129-z

Wolfe, D.E., Byrne, E.T. (1975) "Research on experiential learning: enhancing the process." *Business Games and Experiential Learning in Action* 2: 325-336.

Yock, P.G., Zenios, S., Makower, J. et al. (2015) "Biodesign: The Process of Innovating Medical Technologies." Cambridge University Press; 2015.

Design and Technology Education: An International Journal

30.1

SUPPLEMENTAL MATERIAL

Supplemental Resource 1. Example quiz requiring students to identify heart anatomy and function. Students were given a surprise quiz before and one week after heart dissection lab to assess their ability to retain and apply basic anatomy and physiology in preparation for medical device design assignment.

Name____________________ Date_____________

Question 1: Please label the waveforms and key points to the best of your ability.

A____________

B____________

C____________

D____________

E____________

F____________

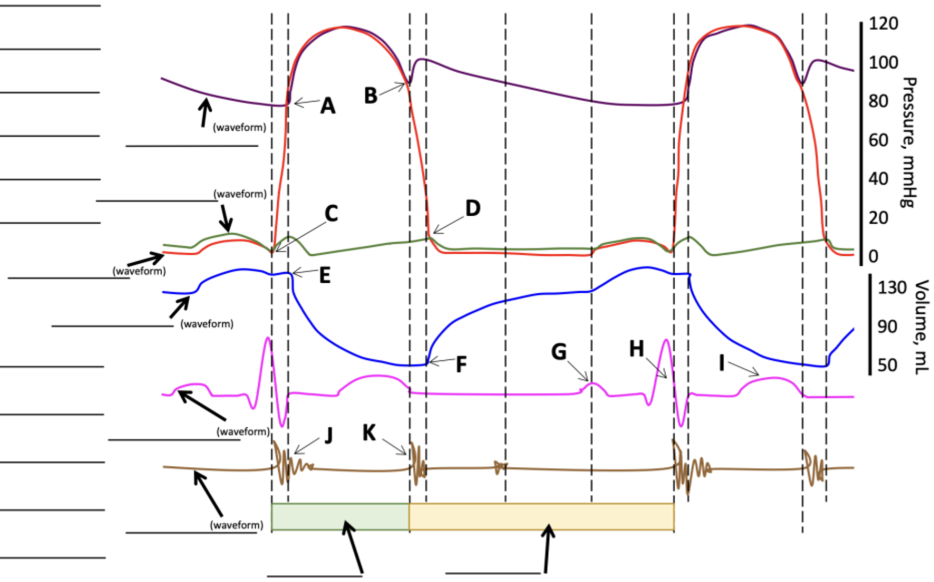
G____________

H____________

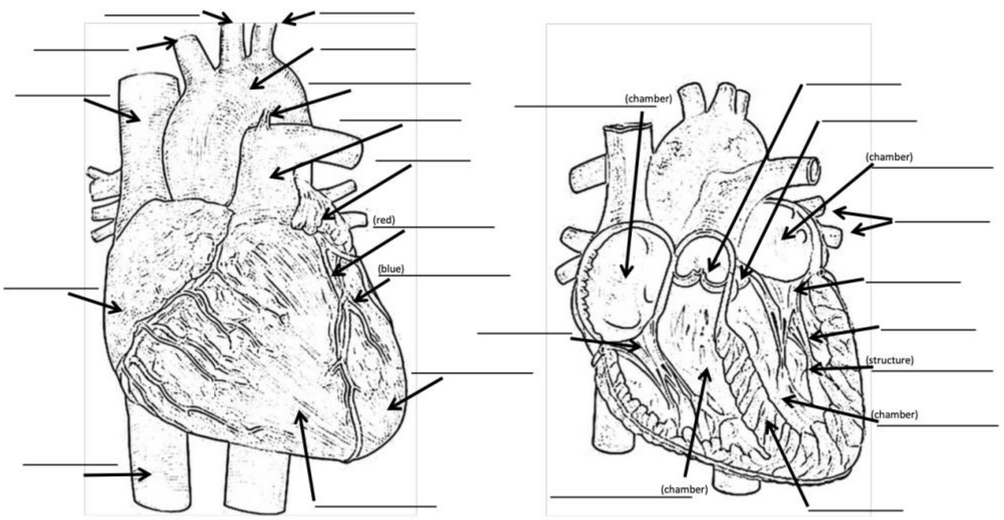
I____________

J____________

K____________



Question #2: Please label the anatomy / structures to the best of your ability:



Question #3: Please write the pathway of the blood through the heart and structures below:

vena cava → ________ (chamber) → ________ (valve) → ________ (chamber) → ________ (valve) → ________ (vessel) → ________ (organ) →

→ ________ (vessels) → ________ (chamber) → ________ (valve) → ________ (chamber) → ________ (valve) → ________ (vessel) → ________ (organs)

Supplemental Resource 2. Example assignment with detailed instructions for preparation, execution, and completion of group device design lab. Each team was comprised of three students who were then randomly assigned the role of Investor, Inventor, and Surgeon (IIS) for interactive role-play and written summary.

Lab Assignment (Heart Anatomy, Physiology, and Devices)
BE 480 Medical Device Design (Spring 2023)

Learning Objectives:

1. Basic knowledge, understanding and application of cardiac *anatomy*, *physiology*, and *hemodynamics*
2. Practical 'hands on' experience with dissection of porcine heart for visualization of cardiac *anatomy*, *tissues*, and *structures*
3. Application of porcine heart model for development of cardiac medical devices, including defining device *design criteria* and *anatomic fit* as well as anatomy, hemodynamics, physiology, structure and tissues (objectives 1, 2)
4. Careful consideration and understanding of device development from the prospective of the *clinician-patient*, *inventor*, and *investor* (deliverables - summary document, oral panel presentation).

Assignment:

As starting level biomedical engineers at Medtronic (Minneapolis MN) working in the Heart Failure Cardiac Devices Division, you've been assigned to travel to pre-clinical medical device development facility to engage with and learn from cardiac surgeon(s), cardiologist(s), engineer(s), and scientist(s) to evaluate the potential development of next generation cardiovascular medical devices. Course instructors will provide an orientation using an explanted porcine heart model and presentation of three current cardiac devices (HM III, Impella, Valve). You are expected to achieve each of the 4 learning objectives listed above. In addition, three teams (3 students per team) will be randomly assigned a specific cardiac device to study and apply your new knowledge. Each team member will be randomly assigned the role of (1) inventor, (2) investor, and (3) surgeon. As a team, you'll need to carefully define the following: (1) clinical need, (2) patient population, (3) anatomic fit, (4) interventional and/or surgical delivery-retrieval, and (5) design criteria (e.g. dimensions, diameter, length, thickness, sizes, weights, materials; and hemodynamic requirements – e.g. pressures, flows, volumes). You're expected to (1) record presented information and observations during lab, (2) submit a 2-page summary report for review (due by 4pm Wednesday, March 8, 2023), and (3) present your device as a panel and answer questions from the audience (instructors, students) during class (Wednesday, March 8, 2023) while playing each of your assigned roles (inventor, investor, surgeon)

Pre-Lab Procedures:

1 – Review Cardiac Anatomy, Physiology, Hemodynamics, Function, and Structure (complete worksheet)

2 – Bring Notebook, Pencil/Pen, Camera, Ruler, Caliper, other?

3 – Prepare List of Questions

In-Lab Procedures:

1 – Please DRESS appropriately (*long pants – no shorts; sleeves – no tank tops; *closed toe shoes – no sandals)

2 – Listen, Observe, and Record information critical to completing your travel assignment

3 – Consider taking any photo(s) that may be of assistance in defining design criteria and assessing anatomic fit for your randomly assigned medical device

4 – When provided opportunity, actively participate in 'hands on' evaluation of porcine heart

5 – Ask prepared and/or unanticipated questions

6 – Complete brief post-lab survey (one page)

7 – Clean Up and Wash your hands

Post-Lab Procedures:

1 – Research your assigned medical device, carefully consider device development from the prospective of your assigned role, and meet as a 3-member team to review, discuss, and prepare your deliverables (item 2 below).

2 – Complete Summary Report (e-mail PDF by 4pm on March 8, 2023), including background, methods, medical device and design criteria, and key findings and observations (*Lab Notes may be attached as an appendix to your summary report) and Panel Presentation (e-mail PPT talk and present in class on March 8, 2023).

Supplemental Resource 3. Example of student evaluation completed after in class lab assignment. Questions are graded on Likert scale (1-5) with opportunity for students to provide written feedback. The student evaluations demonstrated positive experiential learning experiences.

Bioengineering 480
Inventor, Investor, Surgeon lab

Evaluation of event and instructors

	Poor				Excellent
1. This was a useful educational experience	1	2	3	4	5
2. I increased my knowledge and skills	1	2	3	4	5
3. The instructor(s) demonstrated knowledge	1	2	3	4	5
4. The facilities and resources were appropriate	1	2	3	4	5
5. This event should be repeated in the future	1	2	3	4	5

What was your favorite part?

What was your least favorite part?

Ways to improve this event:

Additional comments:

Please place in the envelope provided when finished

Supplemental Resource 4. Example of independent student design project to be completed over the entire semester. Students are required to select their own clinical need, formulate concept for, design, and fabricate medical device to demonstrate proof-of-concept, complete invention disclosure form, present elevator pitch to class, and write summary and project report.

Medical Device Design (BE 480)

Project Instructions

Assignment - Identify a clinical need for a novel medical device design (or improvement of existing device) and design/develop/test 'proof-of-concept' prototype. Propose your solution in a 'white paper' that may be presented to your project manager, investors, and/or Small Business Investigator Research (SBIR) grant. Additionally, you will have the opportunity to demonstrate your prototype and 'pitch' your idea in a 5-minute oral presentation. Please use the following template as a guide toward completing this project. **Grade** (40% = 5% aims, 5% IP, 5% prototype, 5% talk, 20% written report)

A. Specific Aims (1 pg) – executive summary of overall project
- Clinical Need and Significance
- Current diagnostics/therapy(s) and their limitations
- Design or Approach – what makes it novel/innovative?
- Description of your concept/medical device, including advantages/benefits and weaknesses
- Project Development short-term goal(s)/aim(s) and long-term objective/vision
  consider embedding/including CAD, illustration, and/or photo of device

B. Background and Significance (~2 pgs)
- Describe disease process and target patient population
- Clinical Need
- How is clinical need currently being addressed? What are the limitations?
- Market Analysis (opportunity, competition) and potential Economic Impact
- How much will your device cost to make? How much could you sell it for? What are your anticipated development challenges? How many patients/physicians may benefit?
  **consider using illustrations, figures, tables, graphs, flow charts, etc*

C. Innovation (~1-2 pgs)
- How will this change clinical practice? New clinical paradigm?
- What is the potential clinical impact?
- Describe improvements to existing and/or advantages of your technology. What is novel?
  **consider using photos, illustrations, figures, etc as well as Tables and/or bullet key items*

D. Preliminary Data and Design (~4-5 pgs)
- Proposed prototype design (CAD, illustrations, schematics, photos, etc)
- Detailed description of your proposed design, including function, design specifications, benchmarks, metrics (Tables, Bullet items)
- Propose how you may test device to demonstrate proof-of-concept and/or feasibility
- Intellectual Property (IP) review, Freedom to Operate (Appendix – UofL invention disclosure)
- Description of human factors, safety, and ethical considerations with your design
  **consider using photos, illustrations, tables, graphs, figures, etc*

E. References
- Minimum of 20 citations (peer-reviewed journals) and 5 related technology (patent search, patent numbers, key claims)

1 – UofL Invention Disclosure (IP) due by 5pm EDT on Friday, February 17, 2023 (e-mail PDF)

2 – Specific Aims due by 5pm EDT on Friday, March 10, 2023 (e-mail PDF)

3 – Prototype Demonstrations April 10/12, 2023 (e-mail PDF)

4 - Elevator Pitch April 19/21, 2023 (e-mail talk PDF)

5 - Written Reports due by 5pm EDT on Monday, April 25, 2023 (e-mail PDF)

Name: ____________________ Date: ________________

Criteria	Comments	Grade
Oral Presentation (in class)		
Intellectual Property (patent search, claims, freedom-to-operate)		
Specific Aims (summary)		
Concept (innovative idea)		
Device Prototype (proof-of-concept, in class)		
Design Criteria (specifications)		
Clinical Application (need, application, impact)		
Cost & Market Analysis (expenses, sales, patient populations		
Human Factors (end-users, design issues)		
References (journal articles, patents)		

<u>Overall Grade</u>:
UofL IP Disclosure (5%) =
Aims/Summary (5%) =
Device Prototype (5%) =
Oral Presentation (5%) =
Written Report (20%) =

Supplemental Resource 5. Example of student course evaluation completed at mid-semester to evaluate course content, instructor performance, and self-assessment of student performance. Questions are graded on Likert scale (1-5) with opportunity for students to provide written feedback. These data enable instructors and students to improve course content and performance over the second half of course semester.

BE 480 Medical Device Design

Mid-Semester Course Evaluation (Spring 2023)

Q1 – How would you rate <u>Course Content and Assignments</u>?

	Poor				Excellent
1. Course has been a useful educational experience	1	2	3	4	5
2. I have increased my knowledge and skills	1	2	3	4	5

What has been your favorite part?

What has been your least favorite part?

What improvement(s) to course would you recommend?

Q3 – How would you rate <u>Instructor</u>?

	Poor				Excellent
1. The instructor has demonstrated knowledge	1	2	3	4	5
2. The instructor has provided valuable feedback	1	2	3	4	5
3. The instructor has acted professionally (prepared, on-time)	1	2	3	4	5
4. This instructor has been accessible (e-mail, office hours)	1	2	3	4	5

What has Instructor done well?

What has Instructor done poorly?

What improvement(s) would you recommend for Instructor?

Q3 – How would you rate <u>Student</u> (your) performance?

	Poor				Excellent
1. Have you been prepared for each class	1	2	3	4	5
2. Have you actively participated in class	1	2	3	4	5
3. Time spent completing assignments	1	2	3	4	5

What have you as student done well?

What have you as student done poorly?

What area(s) as student can you improve?

Additional comments:

Please place in the envelope provided when finished