Challenging creativity constraints

Three design studios in craft teacher education

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In this design and development research, we revisit the term affordance and explore its contribution to understanding and facilitating collaborative designing in educational settings. Collaborative designing requires students to frame the design task and generate their design ideas by constructing the problem and solution together. We focused on various design challenges – that is to say, creativity constraints – during collaborative designing. Our research entailed three design studios focusing on authentic design tasks with supplied resources. The design tasks were a part of the compulsory first-year courses in Craft Studies at a university. The first design studio consisted of workshops in which student teams constructed toys based on children's drawings. In the second design studio, the teams designed functional three-dimensional textile puzzles for visually impaired children, and in the third design studio, they produced wearable sea creatures for groups visiting the SEA LIFE aquarium. The study revealed how the creativity constraints and particular sources of inspiration facilitated students' progressive design processes. The outcomes of the design tasks varied from simply reproducing the elements of the inspiration sources to more complex approaches through which ideas were further developed. We concluded that a balance between openness and the constraints of collaborative design tasks needs careful consideration.

Keywords: affordance, collaborative design, constraints, creativity, design task, learning environment

Introduction

Design researchers have characterised collaborative designing through a range of activities such as problem framing, idea generation, and evaluation (e.g. Stempfle & Badke-Schaub, 2002; Valkenburg & Dorst, 1998) and others have identified the ways that artefacts and representations support the collaborative design process (e.g. Binder et al., 2011; Brereton, 2004; Henderson, 1999; Perry & Sanderson, 1998). The present study combines these approaches by understanding collaborative designing in such a way that artefacts become mediating artefacts that facilitate design thinking within a design community. In the collaborative design process, the mediating artefacts can be divided into procedural artefacts and design artefacts (Perry & Sanderson, 1998). Procedural artefacts are related to structuring and organising the collaborative design process whereas design artefacts are related to designing the product itself. Thus, artefacts can be seen as 'mediators' as well as 'products' of collaborative design (Vyas et al., 2013).

Teaching creative practices in the design disciplines is generally based on a studio model that usually emphasises project-based learning (Cocchiarella & Booth, 2015; Lee, 2009; Sawyer, 2017; 2018). Students are introduced to the collaborative process to solve open-ended and authentic design problems that include external design constraints given in the form of design brief. Biskjaer and Halskov (2014) has proposed the generic term 'creativity constraints' to help draw together a wide selection of existing work investigating various aspects of constraints in relation to creativity. Creativity constraints can be either explicit or tacit factors that work both as a resource and a limitation of creative agency. In the collaborative design studio, the teacher is needed to structure and orchestrate the collaborative efforts and provide guidance for design learning (e.g., Lee, 2009). Thus, explicit creativity constraints can

govern what the creative output must, should, can, and cannot be (cf. Biskjaer & Halskov, 2014). In the studio model, students must take responsibility for their learning and determine how to proceed with the design task, and gradually improve their capacity to deal with uncertainty and produce increasingly creative solutions (Cocchiarella & Booth, 2015).

From the very beginning, product designing is focused on creating and developing design ideas that are given a material form (Ramduny-Ellis et al., 2010). Thus, ideation with visualisation or materialisation of design ideas plays the crucial role and it is critical aspect in collaborative designing. An important aspect of collaborative designing is working with various forms of representations (e.g., sketches, mind maps, material collages, mock-ups and prototypes). Cardella et al. (2006; see also Chamorro-Koc et al., 2015) suggest that student designers should be encouraged to develop their representation skills and to use more representational activities. Taking this as the starting point, design educators need to have skills and knowledge to support collaborative designing: how the given design tasks, tools and materials and social structures facilitate the student teams' collaborative designing in the design studio context.

Affordances in design can be understood as the action options of a user interacting with a designed object (Norman, 1988). However, designers themselves are not just passive users of affordances; they actively create their own world of representations, tailored to the design task and the situation at hand. Therefore, Gero and Kannengiesser (2012) have developed the notion of 'representational affordances' to denote affordances provided by design representations to the designer as the 'user' of these representations. A major characteristic of representational affordances is that they can drive the construction of new representations and may then afford different design actions. Thus, physical affordances are much more limited than representational affordances.

An understanding of affordances as a part of design process is useful for the development of better design environments and for the improvement of design education. The aim of this study is to facilitate collaborative ideation and designing by means of affordances and creativity constraints. The research questions are as follows:

1. What creativity constraints are appropriate in design studio contexts?
2. How do the specified creativity constraints stimulate collaborative ideation?

In the following section, we revisit the concept of affordance and explore its contribution to idea generation. After that, we focus on design tasks and different types of affordances in three design studio settings in order to analyse both opportunities for and constraints of ideation. Design ideation and processes have been studied intensively for more than 40 years (Cross, 2004). However, there has been little research on the effects of creativity constraints on the design process.

Affordances as a pathway to creative solutions

Creative design appears to be a matter of developing and refining both the formulation of a problem and ideas for its solution, with constant iteration of analysis, synthesis and evaluation processes between the problem space and the solution space. In other words, design process is seen as the co-evolution of problem and solution spaces (Dorst & Cross, 2001). A design space refers to the constraints and all logical solution alternatives of a certain design task. Ill-structured design problems have wider problem spaces and therefore more logical solution alternatives than well-structured problems. The design space forms the external frame to designing, but the set of possible acts is usually so wide that the designer can study only a part of the design space at a realistic time. However, knowledge related to the creativity constraints may work as an affordance to a creative solution.

The term affordance was introduced by Gibson (1979) to refer a resource that the environment offers to any animal or person with the capabilities to perceive and use it. As such, affordances are meaningful,

and they provide an opportunity for particular kinds of behaviour. To Gibson, an affordance exists whether anyone ever notices it or not. However, the designer is primarily concerned with perceived affordances, and with respect to this, Norman (1988) has offered a modified view of affordance focusing on the world of design. In his words, 'the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used' (p.9). Thus, an affordance is a relationship between a user and an object with the object perceived in relation to the needs of the user. For example, the door handle provides a signal to be grasped by the hand and pulled and the aim of the design is to let the user of the product know beforehand what range of operation is possible, what operation needs to be performed and how to do it.

In our study, instead of focusing on how to put an affordance on a product, we examined how design tasks and materials work as affordances for collaborating students. Users of designed objects commonly need to rely on the physical affordances that exist. While in designing, design materials and artefacts can stimulate the generation of new design ideas or facilitate the elaboration of these ideas and work as dynamic affordances (Binder et al., 2011; Glăveanu, 2012). Dynamic affordances arise as a consequence of real physical and symbolic properties of artefacts. Different affordances can be produced even if they are associated with the same artefact. This is because actors may have different experiences and goals leading to different interactions with the artefact. For example, simple design techniques (e.g., forming a paper) can be used both in early childhood educational settings (Carr, 2000) and in higher education settings (Seevinck & Lenigas, 2013) for ideation, experimentation and exploration.

At the beginning of the design process, designers deliberately collect and use sources of inspiration to formulate their plan (Keller et al., 2006). The range of sources of inspiration utilised varies from domain-specific images and materials to natural phenomena and abstract concepts (Petre et al., 2006). Designers are known for preferring visual stimuli such as images and objects (e.g., Eckert & Stacey, 2003; Henderson, 1999; Gonçalves et al., 2014). Besides preference, it is important to investigate how the different types of stimuli are retrieved and transformed during idea generation phases. For example, analogy making is based on identifying and transferring knowledge from the source representation to the target design (Gero & Kannengiesser, 2012). As stated before, creativity constraints have a two-way role in ideation: they may trigger ideation, but they may also limit the production of a variety of ideas (Biskjaer & Halskov, 2014). For example, there is evidence that an early commitment to a certain source of inspiration prevents rather than affords new insights, and thus constrains transformation of the problem space (Ward et al., 2004).

Design ideation is learned through open-ended design tasks that provide a prolonged ideation process for novices so that they can understand the dynamics of ideation in practice (Laamanen & Seitamaa-Hakkarainen, 2014). A design idea is not necessarily well detailed or articulated in the early stages of the design process. Externalisation helps intangible ideas to become concrete and allows them to be reworked and renegotiated. Working with various design representations affords a greater degree of flexibility than working with the details mentally: resources can be brought to the problem that are not dependent on the cognitive structures present in an individual's mind. It appears important that the externalisation method provides a designer with a relatively quick way to express ideas, deal with the ambiguity of the process, and constructively utilise unexpected emerging elements or novel interpretations and insights. According to Pinski et al. (2018), craft-based approaches can facilitate decision-making through holistic awareness of the problem or design situation, and further have a positive impact on novelty and the quality of the design.

Design activity can be characterised by materials and representations that facilitate sense-making and communication. Flach et al. (2017) claim that sense-making requires the combination of product-centric, experience-centric and human-centric thinking. At a practical level, this means affording (what options are afforded), specifying (how can these options be made apparent to a potential user) and satisfying

(why would one option be more desirable than another). Affordances are always relative to something and in the context of design education, they are relative to desirable goals or strategies for design teaching and learning. Our previous studies (Lahti & Seitamaa-Hakkarainen, 2014; Lahti, Seitamaa-Hakkarainen et al., 2016) have brought out problem-driven and solution-driven strategies in design teaching and learning. Both strategies were extensively built around the mediating artefacts, and further, progressive design processes were based on the movements between problem and solution spaces. Therefore, the teacher can facilitate a progressive design process by setting appropriate tasks and materials for problem-solution discussions.

Design and development research approach

Design-based research, characterized by iterative design in real settings, can be called design and development research (Richey & Klein, 2007). It is a suitable approach for developing tools, practices, and theories in design studio contexts. In our case, the iterative process consisted of collaborative design assignments, which were a part of the 10-week course called Basics of Craft and Design Studies. These three design studios were compulsory first-year courses in a program for Craft Teacher Education. The aim of the courses was to learn to collaborate and to carry out an entire design project for the first time in their Craft Studies. These courses consisted of lectures about the nature of design problems, the theories of design processes and the role of visualisation. The students met each other during the weekly lectures followed by face-to-face teamwork sessions. Teamwork following the lectures was organized as a collaborative design session constructed around an open-ended and authentic design assignments. The design assignments and organisation for each session was carefully planned and varied slightly between the three design studios. The authentic design tasks were divided into subtasks that focused on the specific design aspects such as creativity constraints, visualisation and building a mock-up model. In this way, the student teams were able to progress during their face-to-face collaborative design sessions. Later, during the sewing technology course, the student teams produced their products from textiles.

Three-Dimensional Textile Toys

The first-year craft teacher students were asked to design three-dimensional toys based on a child's drawing. Thirty-four students attended the courses, from which four teams (three students per team) volunteered to participate in the data collection. This design studio was our pilot study and represented the first cycle of the three design studios. These design assignments comprised several phases: 1) collecting a child's drawing, 2) making a mind map and a material collage, 3) building a mock-up model and making patterns for the toy, 4) making a prototype, and 5) sewing a toy. Later, most of the toys were donated to the children who did the drawings.

Three-Dimensional Textile Puzzles

The design assignment was to design a functional 3D textile puzzle for visually impaired children. Twelve voluntary participants (i.e., four teams: Team Truck, Team Ball, Team Landscape, and Team Robot) were selected for the study from 36 course participants. The 3D textile puzzle design assignment comprised the following sessions: 1) defining design constraints and making a mind map, 2) visualisation, 3) building a mock-up, 4) making a prototype, and 5) sewing a puzzle. After the sewing technology course, the puzzles were donated to a library for visually impaired people and those with other print disabilities.

Wearable Textile Sea Creatures

The assignment took 38 first-year craft teacher students to meet a client, the SEA LIFE acquarium, which requested custom-made accessories, wearable sea creatures, for visiting kindergarten groups to use. Twelve students (i.e., four teams: Team Sea Star, Team Epaulette Shark, Team Octopus, and Team Coral) volunteered to participate in the data collection. The structure of this design studio varied slightly

compared with the previous ones including 1) visiting SEA LIFE and making quick sketches and taking photos using tablets, 2) making a mind map, 3) visualisation, 4) building a mock-up, 5) creating a material collage, 6) obtaining feedback from the client, 7) making a prototype, and 8) making an accessory. In addition to sewing, the teams were able to decide whether they wanted to produce parts of their accessories during a knitting and crocheting course.

The present study focused on the creativity constraints and creative turning points in the three design studios mentioned above. We were interested in how the creativity constraints and representational affordances facilitated collaborative ideation and designing. We have collected video data of all teams' design processes, but in this study, the research data consisted of the design assignments, various inspiration sources and design ideas presented in visual or material form. The data set made it possible to analyse how the creativity constraints stimulated ideation. Thus, we conducted a qualitative effect analysis for all creativity constraints. In all three design studios, challenging creativity constraints related to the design task or to the available design tools emerged (see Table 1).

Table 1. The variation of the creativity constraints.

Design studio setting	**Test teams**	**Design task challenge**	**Design tool challenge**
Three-Dimensional Textile Toys	4 teams	• a child's drawing	lottery: • pen and paper • masking tape and thin cardboard • wire and non-woven interfacing fabric • modelling clay
Three-Dimensional Textile Puzzles	4 teams	lottery: • variety of the shapes (1–15) • a theme (e.g., plant, song, building)	lottery: • masking tape and thin cardboard • wire and non-woven interfacing fabric • modelling clay
Wearable Textile Sea Creatures	4 teams	lottery: • a name of a body part where the sea-creature accessories should be worn (e.g., arm, back, waist)	collection of design materials: • cardboard • masking tape • wire • non-woven interfacing fabric • net

Surprising design tasks

In our design studios, the design teams had a challenge to take a specific representation or object as a source of inspiration. Representational affordances can be categorised according to various levels of tangibility, abstraction and ownership (cf. Brereton, 2004, p. 85). According to these dimensions, representations vary from transient to durable, from abstract to concrete, and from self-generated to ready-made. In the first design studio, the students asked for a 3–6-year-olds children's drawing as a starting point for the collaborative design process. Therefore, the main source of inspiration was a ready-made representation. In the third design studio, the students themselves generated appropriate source representations by sketching and taking photos of sea creatures during the SEA LIFE visit.

In order to prevent fixation on the first design ideas, we created an opportunity for creative turning point with creativity constraints in the early part of the design process. In the second design studio, the students made one classical creative problem-solving task (adapted from Sawyer, 2013, p. 33). Each student picked three random numbers from 1 to 15, and further, from 1 to 8. The previous numbers corresponded to the shapes presented in Figure 1, the later ones to the theme of the puzzle. The themes were 1) a piece of furniture, 2) a bridge, 3) a plant, 4) a song/fairy-tale, 5) a building, 6) a vehicle, 7) an animal, and 8)

a tool. After individual collections of available shapes and themes, each design team selected a common theme and the forms they wanted to use in their puzzle (see the coloured sectors in Figure 1). For example, Team Ball got eight shapes (numbers 2, 3, 4, 7, 8, 9, 11, 12) for designing, but they selected just one (number 4; a cone) for use. Team Truck got seven shapes for designing and they used them all with the exception of number 13.

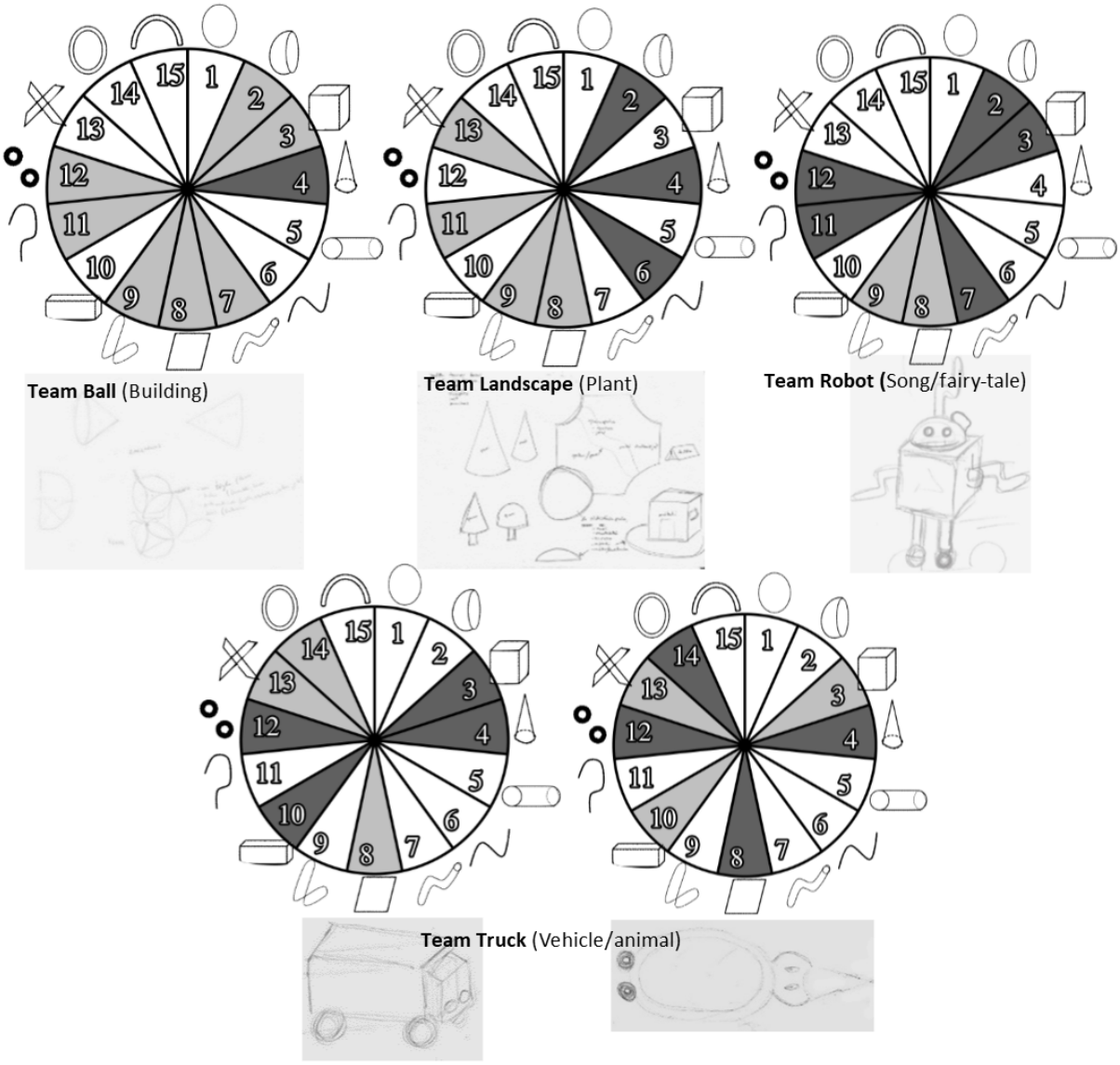


Figure 1. The decision-making disks related to the creative problem-solving task in the second design studio.

We developed a tool to illustrate constrained design spaces in each design team. These 'decision-making disks' indicate a set of possible combinations that enabled the generation of different ideas for a textile puzzle (see Figure 1). Without the creative problem-solving task, the students had probably relied on conventional design solutions. To be precise, Gero and Kannengiesser (2012) have distinguished three types of representational affordances resulting from the different design processes: 1) reflexive representational affordance is based on existing action that is available without processing, 2) reactive representational affordance is an action option that is selected from among a set of action options, and 3) reflective representational affordance is a constructed action option that applies to situations in which a new action needs to be generated. During the creative problem-solving task, the design teams also

generated reactive and reflective representational affordances that afforded novel design ideas for textile puzzles. This subtask helped students to avoid habituated responses (i.e., reflexive representations) at the beginning of the design process.

One way in which a novel design could be produced is by expanding the range of creativity constraints that then give rise to different affordances. In the first design studio, children's drawings worked as creativity constraints, whereas in the third design studio, the design teams decided on their constraints (i.e., parts of the body related to accessories) by drawing lots. Laamanen and Seitamaa-Hakkarainen (2014) have argued that a primary generator of this kind would either help to constrain certain lines of ideas (i.e., anchor the idea to the source of inspiration) or generate different ideas that are not traceable to the original idea (as a key idea to produce a variety of reinterpretations). In general, both ways are useful, but when the anchoring effect of a primary generator becomes too strong, fixation may occur. Team Ball had a strong anchoring effect with the one selected shape, whereas two teams (i.e., Team Robot and Team Landscape) produced the variation of details through recombination of the selected shapes. Only Team Truck produced two separate design solutions based on the alternative themes of a vehicle or an animal.

Design tool challenges

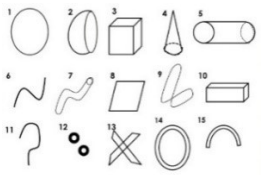
Design researchers (e.g., Ramduny-Ellis et al., 2010) have emphasised that designing is often material-centric, that interacting with and through physical materials is an intrinsic part of the design process. The designed solution may take the form of sketches or models, but it may also be a prototype. Material artefacts (also called intermediary objects) have three main features in design activity: 1) mediation, 2) transformation, and 3) representation (Boujut & Blanco, 2003). Alternatively, Heimdal and Rosenqvist (2012) stated that different kinds of tangible working materials seem to stimulate different kinds of exploration in co-design situations of textile products: 1) representative materials (e.g., pictures) for inspiration, 2) real materials (e.g., material collages) for showing the special attributes of textiles, and 3) mediating materials (e.g., modelling clay) for creating mock-ups and playing with materials.

It seems that simple material tools support students' design processes and could be applied to different design settings (Alesina & Lupton, 2010; Ramduny-Ellis et al., 2010). Seevinck and Lenigas (2013) have paid attention to a design setting that develops novices' design process with opportunities for experimentation and exploration. Their design exercises required little domain or design expertise to support the development of conceptual thinking and a design rationale. For example, a simple design technique – forming a paper – facilitated students' reflective practice methods, such as problem framing and skills in abstraction. Respectively, we afforded simple mediating materials and tools for collaborative designing.

We encouraged students to experience physical interaction with materials, which allowed ideas to develop and mature. Design tool challenges varied between the design studios and design teams. In two design studios (i.e., toy and sea creature), design teams were asked to make a material collage in order to get direction for making decision for the material selection. The tasks of material collages invited students to consider the importance of tactile senses, qualities of the texture of surfaces, and functional properties of material selection. This kind of material collage made preliminary ideas tangible and enabled material selection, even if the final materials for the actual product might have changed.

In the first design studio, each team received materials for 3D modelling: either 1) pen and paper, 2) masking tape and thin cardboard, 3) wire and non-woven interfacing fabric, or 4) modelling clay. The outcomes of the project indicated that differences in children's drawings influenced the nature of the design process. More abstract drawings required more interpretation by the students, and thus they fed association type of adaptation (cf. Eckert & Stacey, 2003).

Table 2. The examples of adaptation with different design tools

Inspiration sources	**3D modelling and final crafts**	**Types of adaptation**
Three-Dimensional Textile Toys 	 	Association with other elements or ideas which are visually similar, or which originate in a similar context
Three-Dimensional Textile Puzzles 		Modification or variation through re-arrangement, replacement, or recombination of elements
Wearable Textile Sea Creatures 	 	Simplification, i.e., selection of some details and omission of others

In the second design studio, the teams received similar materials as those in the previous setting. Only the use of pen and paper was rethought, because our experiences indicated that drawing solely was an insufficient medium for stimulating and developing 3D design ideas compared with other modelling tools (see Lahti, Kangas et al., 2016). The classical creative problem-solving task (adapted from Sawyer, 2013) afforded modification or variation of design elements. The design teams rearranged, replaced and recombined the given elements in order to create their own entity. Representational affordances (i.e., sketches and mock-up) made by Team Landscape are presented in Figure 1 and Table 2. In the first phase, they sketched preliminary ideas of the separate elements and later, they worked expressively by moulding the clay into the desired shapes. Because different styles and levels of fidelity of a representation yielded different perspectives, meanings and experiences, externalising ideas through a variety of mediating artefacts afforded a richer understanding of a design. All teams in the second design studio had to discover elements or ideas which were visually and spatially similar to the available abstract shapes.

In the third design studio, the teams constructed mock-ups by using cardboard and masking tape, or wire and non-woven interfacing fabric. They were able to select which materials they wanted to use for form-giving the 3D model. The emergence of new and improved design ideas was connected closely with the

3D modelling techniques. Different kinds of adaption occurred when design teams generated and transformed mediating artefacts during their collaborative design process. The source of inspiration (i.e., sea creatures at the SEA LIFE aquarium) required simplification in order to produce accessories by sewing, knitting and crocheting. The source of inspiration remained recognisable but the shape was simpler in a paper model and the final crafted model (an example of a coral in Table 2).

Discussion

In this study, we explored the concept of affordance as an intrinsic part of craft and design learning with specific focus on the nature of design tasks and the role of design materials. The open-ended features of the design tasks are characterised through multiple opportunities for manipulation of design. According to Petre et al. (2006), designers incorporate elements or ideas from sources of inspiration into detailed designs by making three design decisions: 1) selection (choosing elements for use), 2) adaptation (interpreting selected elements), and 3) transformation (manipulating the selected and interpreted elements spatially within the composition). Our study indicated that creativity constraints affected both the process and the outcomes of design activity, constraining and inspiring the work of design teams. The students transformed (i.e., manipulated design elements spatially) representations by means of mediating materials. Various types of adaptation were found from the data which indicate the wealth of expressions. However, it is not possible to identify a direct relationship between the type of mediating material used and the approach each team adopted. But then, each type of adaption has the potential to provide valuable lessons to be learnt.

According to Carr (2000), one kind of affordance is whether tasks are challenging or not, and further tasks may have optimum levels of open-endedness. The mind maps created at the beginning of the design process indicate that the design context was challenging and unique for the students. In the choice of any design task and materials, it is also important to ensure that they are meaningful for the students. Pöllänen (2020) has stated that multi-material craft solutions can be achieved through open, complex real-life design challenges, in which the students are helped to connect diverse tools, materials, artefacts and people around a shared tangible object of activity.

In the design studios, the students collaborated with the users and clients; they got information about the design context and feedback on their design ideas. The constrained design tasks with sources of inspiration (such as drawings, photographs and natural objects) formed the core of ideation. Children's drawings and sea creatures anchored ideation to the source of inspiration, whereas the creative problem-solving task worked as a generator to produce a variety of reinterpretations. The outcomes of the design tasks varied from simply reproducing the elements of the inspiration sources to more complex approaches through which ideas were developed further.

In our design studios, modelling materials —i.e., masking tape and thin cardboard, wire and non-woven interfacing fabric, or modelling clay—facilitated exploratory and explanatory design activities. On one hand, these materials helped in specifying and evaluating ideas and solutions within the design teams, and on the other hand, they helped in describing and communicating the ideas to the other team members (see also Lahti, Seitamaa-Hakkarainen et al., 2016). In other words, mediating artefacts (mind maps, sketches, material collages and mock-ups) created in three design studios afforded access to collaborative construction of the design object. Overall, the students benefited from the different working materials in prompting and developing new design ideas. Representational affordances captured the interplay between design representations and student designers producing new design representations. However, there are limitations to these findings. Since the study involved a small number of participants and design studios, the data do not support the drawing of comparative conclusions.

Conclusion

Students' design activities can be supported by design tasks that differ with respect to creativity constraints and design affordances. To help students engage in collaborative design processes, various instructional strategies, supports, and scaffolds have been developed as an alternative to unstructured teamwork, and continue to be so (see Lee, 2009). Collaboration, by definition, means that actors work towards a shared goal and co-construct something new (Lahti et al., 2004). In this process, design representations have two dimensions: they are both the product of and resources for collaborative designing. Externalising ideas through a variety of verbal, visual and material representations afford a richer understanding of a design. Different design representations can afford and trigger different collaborative actions in the team.

In craft and design education, there is a need to find a balance for providing both opportunities and constraints for designing. Too much openness or too few constraints may lead to traditional ways of making. Sawyer (2018) argued that tasks that have constraints in balance allow students freedom, but also limit options so that reaching learning outcomes desirable at that point in the learning trajectory becomes possible. He continues that constraints lead to early failure, break students' misconceptions and guide them to more advanced conceptions. In addition, constraints prevent students from following patterns with which they are already familiar (Sawyer, 2018). Thus, the most effective learning environments are highly constrained while still allowing the students to engage in authentic practices.

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