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Craft education: authentic design constraints, embodied thinking, and craft making

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Abstract: *Craft education, as a form of design learning, has a special significance in inspiring human creativity, particularly when conceptual and material aspects of the process reciprocally support one another. This article underlines the relevance of craft and design education; 1) the importance of dealing with various constraints and professional design knowledge, 2) the role of the embodied thinking in design and making activities, and 3) the ability to foster students' awareness and competence in exploring, evaluating and improving their local environment and design culture. Two longitudinal elementary students' design projects will be described as examples of integrative and thematic school projects. In addition, implications and possible future for craft education will be described.*

Keywords*: Craft education, design constraints, embodied thinking, making, collaborative designing.*

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Introduction

The creation and production of design ideas in concrete end products is considered to be the essence of craft education. The holistic craft process, i.e., ideation, testing and making, as well as reflective and evaluative aspects of craft education are strongly underlined in the Finnish National Curriculum for Basic Education (FNBE 2004, 242). Designing is essentially included into craft processes, and craft is seen as the way to materialize design thinking. However, in Finland, there is on-going debate related to what is the main role of craft education in the modern society, and how craft education can be better integrated with other school subjects. It is argued that the contemporary society does not need traditional craft education, and that it should shift towards technology education which more closely relates to students' everyday life. Further, Karppinen (2008) has criticized that school craft over emphasizes technical skills as compared with self-expression. Accordingly, in basic education, the construction of craft products is often perceived as the primary focus of learning activities, rather than as a way of supporting the rationale directing the design and making practices. In this article, we argue that craft education, as a form of design learning, has a lot of potential for promoting creativity and innovation in modern society.

Craft and design have a special significance in stimulating human creativity, particularly when conceptual and material aspects of the process reciprocally support one another. Design and making activities develop the ability to enhance and transform ideas through visualization; they involve testing the practicality of multiple solutions through sketching and prototyping. The goal of craft education has long been to create critical understanding of design practice both through action and reflection upon it (Schön 1983; Pöllänen 2009). These practices include production of design artefacts, such as sketches, models and final products, which provide mediating entry into design and craft discourse (Rowell 2004). The core curriculum for craft education highlights values and aims that relate to creativity and problem solving, technical and aesthetic skills, independent working skills and promotion of self-expression (FNBE 2004, p. 242). The understanding of everyday technological phenomena, critical thinking, and responsibilities related to selection of materials are also seen very important. The appreciation of quality of materials and end products is considered to educate students towards becoming critical consumers. Furthermore, the curriculum of the craft education emphasizes the integrated projects and thematic entities (FNBE 2004). However, the curriculum does not give any detailed guidelines how the craft education should be taught, or detailed content to be covered, or materials and techniques to be used in school craft.

Craft designing and making is a complex process, including extensive visual or artistic and technical skills, as well as intensive domain specific knowledge (Goel 1995; Cross 2004). Production of visual and material artefacts is a crucial element of success in the design field, which depends on the management of the whole design process in all its components, from idea generation to the mastery of techniques (Murphy and Hennessy 2001; Rowell 2004). Thus, in design learning the unique qualities of holistic craft process relays on the ability to solve complex problems. Students need to manage the procedures of planning and making, integrating representations of mind to surrounding material/physical and societal conditions, reflecting possibilities, and testing the boundaries of self-fulfilment. Learning through designing and making arguably has an essential role in human development by facilitating the development of cognitive, spatial, motor, social, and aesthetic skills. However, the students should be provided opportunities to recognize, create, and reflect on their own ways of participating in the design culture. The design tasks or projects should be centred in the problems of our daily lives and the places in which we live. Conversely, the challenge for the craft education is that the origins of the design problem too often come only from the student's personal context (Seitamaa-Hakkarainen 2010).

In the following, we will first highlight the value of design and making activities by focusing on the nature of authentic design problems, as well as embodied and material aspects of designing and craft making. The central idea of this article is to introduce two longitudinal elementary students' design projects, collaborative lamp designing and architectural designing, as examples of integrative school projects. Through describing these projects, we underline the relevance of design learning; 1) the importance of dealing with various constraints and design knowledge, 2) the meaning of embodied dimensions of design thinking and making activities, and 3) the capacities to foster children's awareness and competence in exploring, evaluating, and improving their local environment and design culture. In the end of the article, we will discuss implications and possible future for craft education.

Challenging problems and collaboration

Bereiter (2002) argued that innovation society creates novel challenges for education; it requires competencies that develop through participation in the practices of working with knowledge and solving authentic problems. Further, Bereiter and Scardamalia (2003) emphasized the importance of design mode in student learning. In design mode, students are concerned with the usefulness, adequacy, improvability, and developmental potential of ideas. According to Pöllänen (2009), the teaching of craft should attempt towards a holistic craft process from the very beginning. Further, according to Carroll et al. (2010) designing and making provides a powerful method by challenging students to find answers to complex and difficult design problems by promoting students' capacity to act as change agents. For that reason, young students need both the experiences and the tools to participate and solve design challenges. Likewise, students' experiences of collaborative working promote practices of collective elaboration of design ideas as well as the implementation of these ideas in the actual design of artefacts (Drain 2011; Murphy and Hennessy 2001).

Designing puts emphasis on conceiving something new and clarifying as yet unknown details. This requires active knowledge creation and meaning making -- aspects which make craft education and D&T settings potentially rich environments for successful learning. Design thinking has the potential to promote, for example, constructive thinking, creative problem-solving, collaboration, and multimodality (Cross 2006). Designing and making has been characterized as problem solving oriented towards the construction of an artefact for specific purposes (Hennessy and Murphy 1999). Designing is a complex process, including intensive visual or artistic and technical skills, as well as extensive domain specific knowledge (Goel 1995; Cross 2004). As an inherently interdisciplinary activity, design addresses the social, economic, cultural, cognitive, physical, and technological dimensions of a design situation. The cyclical design processes begins with the identification of a problem, and it might engage exploring and the ranking of design priorities that might appear to be in competition within each other. The design context, design problems and design constraints guide the way how these aspects are relevant for problem solving and how they are dealt with. The complexity of the design process emerges from its cyclical and iterative nature and thus the possible solutions arise from a complex interaction between parallel refinement of the design challenge and the design ideas (Lawson 2006).

The use of collaborative learning settings in the areas of Design and Technology education has increased recently (Murphy and Hennessy 2001). The Learning by Collaborative Designing model (LCD) emphasizes collaborative interaction within and between peers or teams; between students and teacher and/or external domain experts of the design field (see Seitamaa-Hakkarainen et al. 2010). Collaboration refers to the situation where students actively communicate and work together in order to create a shared view of their design ideas, make joint design decisions, construct and modify their design solutions as well as evaluate their outcomes through discourse (Hennessy and Murphy 1999). In collaborative settings, the design context and the design task are defined through joint analysis; all participants have to learn to understand the external and internal constraints related to the problem or solution. During the outlining of the design constraints and sometimes conflicting issues that have an effect on the design process and its requirements need to be taken into consideration. Through collaborative design projects, students learn to view the same information from many viewpoints, and to represent various solutions and alternative forms of presentation. This entails evaluation of the solutions as well as reflection of the design process itself.

The basic requirement for collaborative construction of the design object is that students' solve the authentic and challenging design tasks. The successful collaboration is based on authentic design tasks that allow students to confront the multidisciplinary or user-centred characters of design practice (Murphy and Hennessy 2001). Moreover, in collaborative design activity, students share a task around an actual, concrete artefact, which becomes an object of their shared cognition (Medway 1996). Design discourse, including sketching, modelling, and interactions with objects, has the unique potential to support shared thinking processes (Murphy and Hennessy 2001).

Embodied thinking and development of awareness

In recent years, the embodied dimension of designers' and artisans' work has gained increasing attention (Keller and Keller 1996; Patel 2008). Research on embodied cognition questions the traditional dualism of body and mind, and emphasizes the role of the body, handling of tools and materials, use of space, and interaction with others in the thinking processes (for review, see Hall and Nemirowsky 2011). The designing and making of the product highlight the inter-relationship of conceptual and procedural knowledge. Designing cannot be reduced to mere play with ideas; in order to understand and improve the ideas in question, they have to be given a material form by means of practical exploration, prototyping, and making.

The role of materials and artefacts in the design process is crucial (Keller and Keller 1996; Murphy and Hennessy 2001). Consequently, in craft education the physical context, interaction with tools, concrete objects and materials mediate the learning processes (Hennessy and Murphy 1999; Johansson, 2006). Students think with different materials during the design activity, they formulate thoughts with the help of tools and machines, which mediate the meaning (Johansson 2006; Johansson and Illum 2009). In the design process, the interaction with two- and three-dimensional models (sketches, prototypes) allows students direct possibilities to explore and evaluate a proposed solution's form and function directly (Hennessy and Murphy 1999). The various representations (graphical and physical) provide different kinds of prompts to test the design ideas (Henderson, 1999; Hope 2005). Through the externalization ideas become visible and improvable and support the development of ideas by adding the material aspect to the conceptual ideas, enabling their collaborative advancement.

As stated earlier, the curriculum of craft education in Finland, emphasize that the understanding the daily technological phenomena as well as the appreciation and responsibilities of selection quality of materials and end products, foster students towards competent consumers and critical thinkers. The competence has been seen to consist of three main aspects; 1) personal awareness and attitudes, 2) knowledge, and 3) practical skills. The personal awareness and attitudes embrace interest and knowledge about one's environment along with the ability to perceive the environment accurately. Pedersen (1999) defined the environmental competence as a capacity to deal with one's environment in effective manner. The awareness of environments refers to the people experiences of the places and buildings they encounter in their daily life whereas the environmental competence refers to learning about the environment. There are convincing arguments that for example the participation on the environmental projects prepares children for active citizenship, teach useful design skills, and increase environmental competence and awareness (Horelli and Kaaja, 2002). However, very little research has been done to assess how children's competence and awareness increase during these kinds of projects.

In the following, we introduce two design learning projects, where professional designing, multimodality, environmental competence, and critical understanding of the design practice were deliberately fostered.

Two design learning projects

"The Artefact Project: Past, Present and Future" and "Architecture Project: City Plan, Home and Users -- Children as Architects" engaged elementary students in longitudinal collaborative inquiry and designing. Both projects were designed together with the class teacher and took place in her classroom in Laajasalo Elementary School, Helsinki, Finland. The Artefact project started at the beginning of their second term of fourth grade, and continued across 13 months until the end of their fifth grade (139 lessons in total). This project was followed with the Architecture project, which took approximately 45 lessons (about 2-3 hours a week) during five months. During both projects, the leadership was provided by a professional designer together with class teacher. In addition, a technology enhanced learning environment, Knowledge Forum, was used throughout the projects.

Both integrative projects based on the following ideas: 1) intensive collaboration between the teacher, the designer, and the researchers, 2) integration of many school subjects, such as history, mathematics, mother tongue, biology, geography, visual arts, craft education, and design & technology education, and 3) integrating conceptually-driven (minds on) inquiry with a materially embodied one (hands on), for solving a real-world problem.

We collected extensive video data (approximately 56 hours) from the Artefact project. In addition, we collected textual data from the Knowledge Forum database, as well as students' visual representations, models, and pictures from both projects. All data has been analysed previously using qualitative content analysis; also systematic analysis of the video data has been conducted. From the databases, mainly the contents of students' notes have been analysed (Kangas et al. 2007; Seitamaa-Hakkarainen et al. 2012a; 2012b); the analysis of the video data has focused on contents of discussions, use of design artefacts, and embodied design activities (Kangas et al. 2011a; 2011b; in press). In this article, we will provide some excerpts of the data, highlighting the essential aspects of design thinking and making.

The Artefact Project

In the first longitudinal school project "Artefact project: Past, Present and Future", the aim was to study the role and diversity of artefacts as part of Finnish culture. 32 students, aged 10-11, participated in the project. Each student team was asked to choose one artefact for deeper investigation. The item had to 1) be used daily, 2) have a long history, 3) be originally made by hand and 4) be used by hand. Students chose items which most of them had used and which they found interesting: a clock, a spoon, money, a lock and a key, a jewel, a ball, and a lamp. They studied the historical evolution of these items; explored the physical phenomena (such as electricity) related to them; as well as designed present-day lamps and future artefacts.

In the present paper, we focus on the lamp designing phase, which was the second to last phase of the project. It lasted 11 sessions (each session was 45–135 minutes, depending on the class schedule) during a period of two months. The design process was carried through in 13 teams of two to four students, by sketching, drawing, and building prototypes or models. The students also regularly presented their designs to the whole class. The expert, a professional interior designer was present in the classroom; there were extensive, varied interactions between him and the students. These included face-to-face discussions with the whole class, small team conversations, and sharing of comments through the Knowledge Forum. The investigation of the lamp design led the students towards the last stage of the project focused on projecting, in terms of design, how their chosen artefacts would look in the year 2020.

The Architecture Project

The aim of the Architecture project was to develop elementary students' environmental competence about architectural design principles, as well as to learn architectural concepts and design practises. The same students (N=29) were now 6th graders, 12 years old, and their task was to design seven different apartment buildings for an actual building site planned by the City of Helsinki.

Before starting the actual architectural designing phase, the students studied how living conditions (i.e. housing) have changed in different historical phases. They worked in teams (four to five students in a team) to produce knowledge for each teams' views of KF as well as for shared views of the whole class. The project aimed to develop students' understanding of various design constraints related to building requirements, utilities of the space, users' needs and effects of traffic etc. Further, various aspects of designing houses or apartment and associated design constraints were discussed. The building site was divided into seven parts and each team was asked to design its' own particular apartment building. Consequently, the students were guided to develop shared design ideas and solutions, create and test prototypes, as well as jointly plan advancement of their process. The city plan model, calculation of gross floor volume, scale drawings and scale models were constructed and loaded to KF's database as pictures and texts. Expert-like working familiarized the students with planning regulations, requirements of building site, and different kinds of scale models that architects are working with.

Results

The aim of the present article was to underline the relevance of design learning by introducing the two design projects. In the following, using data from both projects, we highlight certain crucial aspects of design knowledge, embodiment and competences fostered during the projects.

Design constraints and professional design knowledge

It is crucial to understand the important constraints and specific features determining the product to be designed, in order to improve, for example, the functionality of the end product. During the lamp designing phase of the Artefact project, the designer described his own design process and drew students' attention to the essential points of lamp designing. Later during the process, one of the most important constraints was to consider the needs of the user as the starting point of designing. While the designer was introducing the design task, he focused the students' attention to these needs by asking students to consider questions about usage of the lamp, such as where and what for. The designer's questions were also written down in a KF note by the teacher. The note was visible through the shared view (i.e., the teacher's computer screen shared through the data projector) while the students started developing their design ideas, helping them to focus their attention on the constraints related to the use of their lamp.

Furthermore, part of design expertise is its own language, the expressions and discursive practices that are distinctive within that world. During the lamp designing process, the students became accustomed to the language of designing and associated conceptual artefacts in their continuous interaction with the designer. He used authentic, professional design terminology that was in many cases naturally adopted by the students in the course of their designing. For example, ‘swan neck’ (a flexible shaft used in lamps) was a new term for the students. The designer introduced the term in his first presentation:

Excerpt 1a.
Designer: (*showing design sketches on transparencies*) The same idea evolves so that here is a swan neck. Do you know what it is?
Theo: It's this thing that can be kind of, bent at any point.
Designer: Yea, like that. So it's a simpler solution than these joints
(*Session 1. Designer's presentation. Video data*)

After this the term was, for the first time, used by a student in a KF note (Figure 1). The designer continued using the term in his interaction with the students. Gradually, the new term was taken up by the students; they started using it frequently in the discussions with the designer, in their KF notes, and in their presentations:

Excerpt 1c.
David: How long is the swan neck?
Dane: I'm not too sure yet, but it is pretty long as if it was short it couldn't hold up the light.
Designer: You need to design it with that fact in mind, so keep in mind if you actually need a swan neck and what kind of leg your lamp will have.
(*Session 6. Team presentation. Video data*)

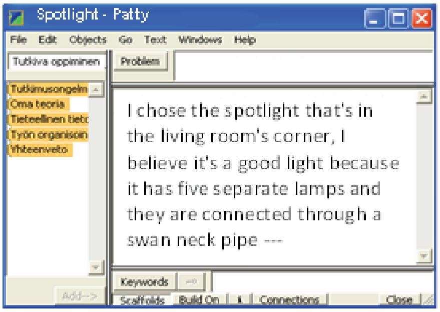

Figure 1.Excerpt 1b: Student's KF note

In addition to providing professional terms, the designer also supplied the students with tools and materials for visualizing their ideas, and demonstrated how to use sketches to support envisioning of the object being designed. The students produced many sketches during designing and each team also drew blueprints of their final lamps.

Similarly, in the Architecture Project the design task was a very complicated, authentic problem: to design apartment buildings for various user groups at a building site planned by the City of Helsinki. The quantity of external design information was needed at the beginning of the design process: The students were given an aerial map of the local area as well as basic information regarding city planning, such as City Plan, permitted building volume, gross-floor area, and so on. Thus, the architectural design process started with all students performing a joint analysis of the design context, and reflection on what issues need to be taken into consideration in the construction design: soil, map, the size and location of the building site, pile work, traffic, water plumbing and electric wiring, strength calculation, and budget. Various aspects of designing houses or apartments, and associated design constraints were also discussed in the classroom. This way the students were able to portray a holistic view of all aspects related to architectural design and their design context.

During massing and composition students needed to consider different kinds of specific design constraints related to the building site: traffic, effects of sun, permitted building volume etc. All of them were real and important aspects related to architectural design context and requirements for permitted buildings. Central concepts, such as maximum permitted building volume, the height of eave (i.e., height of roofs), and massing, became familiar. Similarly to lamp designing, the students adopted architectural vocabulary, which became evident in their KF notes and on reflections of the process:

Excerpt 2.

When starting the planning of the construction, you have to keep in mind is the building site near the sea, what kind of land it's on and whether it's on flat land or on an hill. Because during the design phase it's important to know which side has the best view (a view towards the sea is obviously the best). The land the house is important because if it's on a ridge a part of the building has to be built under the ground. Electrical wiring and water pipes also need to be dragged to the house. Access to the house is also important as usually they are important if the owner plans to move at some point. The yard has to be well taken care of and there should

> be plenty of trees and brushes so there are places for children to play. The most important element is of course who lives in the area and whom the house is made for as a house made for a grandmother and a family moves in, the family may not enjoy it nearly as much. (*Community House -team's KF note*)

Collaboration and embodied thinking

When we analysed one team's interaction (Nina, Leila, Emma) during the lamp designing more closely, the significance of collaborative handling of various materials and tools, as well as visualizing and model making became apparent. The team generated many design ideas; altogether they produced 17 different ideas for a pendant lamp. At some point, Nina presented an idea of a hanging pendant lamp where the light would come from both the bottom and above of the shade. Although the idea was still very sketchy, Leila immediately showed her interest by asking clarifying questions and building on the idea. Nina was not so interested in her own idea, and she moved on to the next, but Leila continued developing and sketching the idea of the hanging pendant. She was eager to reach the decision about the final idea and kept pushing Nina and Emma to make the decision with her by asking repeatedly where and what the lamp would be used for. Finally Leila's attempts succeeded and the team made a decision that the lamp would be used over a dining table, in a kitchen or dining room. Through Nina's sketching, Leila's clarifying questions and repeated requests to consider the needs for the lamp, and Emma's idea to include squares on the shade (an idea presented previously), the team gradually approached their final idea. After reaching the decision on the final idea, the team's activities matured towards more successful collaboration. Their attention was jointly focused, the object of activity was mutually shared, and they were also organizing their activities collaboratively (Barron 2000).

Later, the technical aspects of designing were in the focus of discussion; the same team carefully considered the dimensions of parts of their lamp. This sub-task of determining the measurements was difficult for the team to concretize; therefore, externalization and objectification were needed.

The role of embodied thinking, i.e., handling of tools and use of space, became more evident in this design phase. At first, the designer showed the girls how they can hold a measuring tape towards the ceiling to help them in visualizing the lamp's size (Figure 2, left). This prompted the team to begin consideration of how high up the lamp should be so that nobody's head would bump into it. They went back to their drawing desk, and used also a light bulb for designing and sketching the measurements of their lamp (Figure 2, middle). They climbed over another desk, in order to envision the dimensions more accurately. One of the students held a telescopic pointer, the second a sketch of the shade, and the third one was assessing the whole from a distance (Figure 2, right). Throughout the event, the team moved back and forth between the two desks, measuring, drawing, and gradually adjusting the measurements until satisfactory and mutual decisions were reached.

Figure 2. Employing tools and dimensions of body and space for designing measurements of the lamp

Developing design competence and awareness

The aim of the Architecture project was to develop students' understanding of architectural design principles and domain specific concepts. To provide students with an authentic experience of architectural designing, we created a learning environment that simulated architectural practices. Thus, the project included the use of KF software, hands-on drawing, and modelling activities to support students' design inquiries. Toward that end, elementary-school students were engaged in an architectural project involving a variety of knowledge practices, working with conceptual and material tools and artefacts. The designer had an important role in familiarizing the students with planning regulations, requirements of the building site, and different kinds of scale models used by architects. At the end of the project, each student described his or her design process, and we considered those KF notes as reflecting their "learning outcome". We analysed how the students were using the correct architectural concepts in general, and how the main design concepts and aspects were connected to each other.

According to Pedersen (1999) environmental competence means a capacity to deal with one's environment in effective manner; the development of environmental competence is an informal process that continues the whole life span but educational settings, especially those that involve active participation, the competences can also be facilitated. During the project the students developed environmental competence related to architectural appreciation; they had some knowledge about space utilization, and they were able to assess, analytically, their surroundings. As stated earlier, during the project, they considered the effects of traffic (roads) and light for the location of the buildings. Further, at the end of the project, all students were able to provide accurate descriptions of the architectural design phases; they realized, in varying degrees, the importance of the size and location of the building site, the requirements for building site and planning regulations (city plan). The developed competence involved elaborated architectural concepts and furthermore, explicated, for example, the importance of space planning (i.e., interior spaces), utility or function of the designed spaces and reflected the users' needs of the building. Moreover, these concepts were related to each other as the following example shows:

Excerpt 3.

You need to take into the consideration building permits and gross-floor area. You need to consider what kind of people (families, elderly people, adolescent) and what will be devoted in the design. We decided to make community house, so we

> thought about all the suitable spaces that will be common in the house. We decided to design for the young athletic adolescents…. (*Gemma's KF note*)

To summarize, the results revealed that students clearly learned to use accurate architectural vocabulary; they learned to name various architectural design phases, and moreover, they had acquired practical environmental skills to designing the environment during the project.

Discussion

The projects described in this article aimed at improving quality of elementary-level education by engaging very young students in design and making practices. An engagement in such activities involves working with complex problems; these arise in authentic situations often ones never before encountered; thus addressing them fosters the development of competencies for knowledge creation (Bereiter 2002). Further, the purpose of the projects was to examine how collaborative designing may be used to facilitate learning in the process of developing and elaborating shared design artefacts. The projects showed that with the expert support very young students are able to solve multifaceted, complex design tasks. We argue that the value of craft education in the modern society is to be found in the knowledge creation and creativity.

The challenge for the craft education in Finland is that the origins of design problems too often come only from the student's personal context and are narrowed to student's personal needs; the repertoire of different kind of design problems and tasks have neglected. The essential notion for the teachers is that design tasks should also reside outside; tasks with origins and priorities (aesthetical, functional) from certain situation or from "client", are educationally significant. In designing their local environment and products, very young students learn how to exercise creativity within challenging constraints, communicate visually, and work in teams.

The holistic craft process is emphasized in the Finnish National Curriculum for Basic Education. The holistic craft process includes the ideation, testing and making, evaluation as well as reflection. Designing is not only limited to the ideation phase, but also includes careful analysis of the design context and definition of design constraints. In the project cases presented earlier, the student teams learnt, with the help of the expert, to reflect on what issues need to be taken into consideration when designing certain object or environment. Expert-like working familiarized them with specific functionalities of the ordinary lamps, planning regulations, and requirements of building site that designers and architects are usually working with. These projects helped inculcate useful, design skills for students as well as enhanced their "cultural" awareness and competence.

The craft education provides a rich environment for collaborative learning (Hennessy and Murphy 1999; Murphy and Hennessy 2001). It provides direct experience for students with materials and technologies. Design activities develop the ability to enhance and transform ideas through the visualization and students learn to view the same information from many viewpoints, and to represent various solutions and alternative forms of presentation. The mediation of the different material artefacts, materials and tools is the heart of craft education.

We argued that craft education, including designing and making, offers enormous potential for integrated and inclusive curriculum, especially in elementary level education. Design learning relates to the solving of authentic problems in our daily lives, and challenges the teachers to provide more authentic learning context and to create activities that go beyond the traditional curriculum. It also provides a very promising learning environment for expert-student partnerships. The Finnish National Curriculum for Basic Education introduces several thematic entities, that should be covered and taught in integrative way; the curriculum also provides a lot of possibilities to connect all the thematic entities with craft education, and to conduct longitudinal design projects. Students' access to integrative authentic learning environment enable them to 1) intervene creatively to model, adapt and develop ideas as an interactive process, 2) become creative problem solvers and designers and 3) participate in tomorrow's rapidly changing technologies in some level. The teachers should take this opportunity and build-up collaborative community in their schools. We argue that emphasising longitudinal, authentic design projects provides new value for craft education and will help to prevent it to fall in marginalization of the school subjects.

In general, the purpose of craft education and design learning is to provide a framework for teaching students to become actively involved in shaping their environment. The findings of our studies indicate that in order for learning by designing to be effective, it is best founded on projects based on real-world problems and projects eliciting processes that resemble the multimodal ways of thinking and acting that professional designers engage in their everyday working life. Taking part in the collaborative design process provides opportunities for learning the foundational design skills by engaging the students in carrying out various concrete and material, as well as epistemic and conceptual activities. In the course of these activities (i.e., drawing, writing, measuring, and model making) they learn to conceptualize, reflect, and communicate their design ideas. Furthermore, design learning provides unique opportunities to develop students' awareness of material culture and built environment. Sawyer (2012) argues that the cultural model of teaching and learning designing (i.e., studio model) has implications beyond art and design education. It may help learning scientists to resolve longstanding tensions faced in, for example, educational reforms in STEM disciplines. Our results support these arguments; the multifaceted design tasks integrate skills which are also needed in science, technology, engineering and mathematics.

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