Infusing Design Expertise in Elementary Students' Collaborative Design Process

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The general aim of the present study was to provide insights into how experts might infuse disciplinary expertise into D&T classrooms and how they might construct authenticity based on professional design practices. We describe elementary students' collaborative lamp designing process, where the leadership was provided by a professional designer. The present study explored how the *design world* was reproduced within the classroom, and what was the role of social and material scaffolds in implementing the authentic practices of professional designing. The 17 video recorded lessons of lamp designing and the *Lamp Designing* view of the project's database constituted the data sources of the study. The results indicate that the collaborative production of the design world within the classroom promoted the creation of an authentic and meaningful design learning process. The diverse social and material scaffolds that the designer provided had a significant role in supporting the students' idea generation and sharing of their knowledge.

Keywords: participatory learning, authenticity, learning by collaborative designing

INTRODUCTION

This study explores the opportunities afforded by authentic design tasks and the participation of a professional design expert in elementary students' collaborative design process. Our main goal is to provide some insights into how design experts might infuse disciplinary expertise into Design and Technology (D&T) classrooms and how they might construct authentic processes based on professional design practices. Focusing on the socio-cultural approach, particularly on the research of collaborative learning, we will draw attention to the participatory aspects of design learning. *Participatory learning* (Jurow, Hall, & Ma, 2008) means that learning involves external domain experts working with students in the setting to bridge between school practices and community practices (Hakkarainen, 2009; Roth & Lee, 2006; Wenger, 1998). Although the student-expert partnerships have mostly taken place in science studies, there are no solid reasons for not using participation approaches in the D&T field as well. Design activities and design learning provide students important opportunities to work with complex design tasks within authentic and meaningful learning contexts. These kinds of authentic design problems enable students to adopt complex, flexible and creative actions as they identify, pose, transform, and abandon solutions.

Participatory learning and communities of practice deal with the authenticity of learning, and participation of the social practices of culture (Lave & Wenger, 1991). The central idea of this study was to describe pedagogical practices that allow one to acknowledge the role of design expert's participation and the role of material artifacts in design learning. We will focus on collaborative and participatory aspects of design learning, and underline the pedagogical approach *Learning by Collaborative Designing* (LCD, Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010) behind our study. The model depicts designing as a spiral and cyclical process, and highlights the role of physical artifacts, material objects and abstract models as essential parts of the process. The model consist of several phases such as creating the design context, defining the design task and related design constraints, creating conceptual and visual design ideas, experimenting and testing design ideas by sketching, modeling and prototyping. In collaborative design learning 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. The critical role of external domain experts underscores the value of the physical context (i.e., diversity of concrete objects or material artifacts, interaction with tools) and social interaction (i.e. peer collaboration, scaffolds provided by teacher or domain experts) in order to make design tasks shareable. Hence, the following specific research questions were addressed:

1) How was disciplinary expertise infused in elementary students collaborative design process?
2) What was the role of social and material scaffolds in implementing the authentic practices of professional designing?

In what follows, we will first, discuss the role of scaffolding in D&T settings, both scaffolding as a social interaction as well as scaffolding mediated by material artifacts. Then, we will report our empirical study, elementary students' collaborative lamp designing process, where the leadership was provided by a professional designer.

Social and Material Scaffolding in Design and Technology Setting

Research into cognitive scaffolding (Wood, Bruner, & Ross, 1976) and procedural facilitation (Bereiter & Scardamalia, 1987) has indicated that, when provided with external, supporting tools and structures and real-time guidance, students can be helped to succeed in cognitive processes, otherwise impossible. Scaffolding means providing resources that enable a learner to do more than he or she could, alone (Davis & Miyake, 2004). The scaffolding notion has a strong implication for classroom learning in the way the teacher supports the learners in their thinking and activities. Modeling, coaching, and scaffolding are the core of traditional apprenticeship, where learning is supported through the processes of observation and guided practice. According to Collins (2006), methods that emphasize the apprenticeship approach to learning offer students opportunities to observe, engage in, and create or discover expert practices in context. The more cognitive aspects of apprenticeship can be supported through articulation, reflection, and exploration. These methods are based on verbal scaffolding as well as observation of the performance; modes which are very typical also in D&T education. However, the non-verbal forms of scaffolding are very crucial in D&T contexts. Gestures such as pointing, referring to objects/artifacts and tools, support and guide the design process along the verbal scaffolding (Johansson, 2006). Hennessy and Murphy (2001) called these forms 'sensitive assistance', which comprises structure and help, as well as non-verbal forms, such as sketching, physical resources and tools.

The traditional assumption of scaffolding is that it involves adults working face-to-face with learners and that the adult is in dialogue with the learners. This *social* aspect of scaffolding can be extended by accepting that it is not only more able adults or peers who can provide scaffolding. The other aspect of scaffolding is *material,* embedded in technological tools, physical artifacts, activity structures, and shared knowledge practices incorporated in learning processes (Davis & Miyake, 2004; Hakkarainen, 2009; Pea, 2004). The sociocultural theory as well as the situated learning theory emphasizes the close connection between verbal language and mediating physical artifacts and tools. This connection is particularly strong in collaborative D&T settings where the joint problem solving activities are oriented towards creating a shared, and often material, object (Hennessy & Murphy, 1999; Johansson, 2006; Murphy & Hennessy, 2001). Different representations (graphical and physical) provide different kinds of prompts to test the design ideas. In the design process, the interaction with two- and three-dimensional models (sketches, mock-ups, prototypes) allows students direct possibilities to explore and evaluate a proposed solution's form and function. Through social interaction or discourse design ideas, proposed solutions and decisions are made verbally and visually explicit and visible. The visible and externalized ideas are shared and assessed, and joint decisions can be made. Hennessy and Murphy (1999; Murphy & Hennessy, 2001) emphasize that the complex and physical nature of D&T activities means that they offer many opportunities for developing shared objects and understanding. They also provide a common referent for discussion between the teacher and the students (Johansson, 2006).

Designers are "working with things"; they express their ideas in "things themselves" rather than merely words (Baird, 2004, p. 148-149); designed artifacts literally carry, bear, and embody knowledge comparable to that of theories. Learning to work with such *thing knowledge* (Baird, 2004) is an essential aspect of appropriating design and engineering practices. Cultural artifacts assume both conceptual and material aspects as practical instruments and as artifacts of collective memory; they bring "developmental histories" of past activities to the present. Design activity is fundamentally creative in nature; participation in world of design is a deliberate process of creating future-oriented, "tertiary" design artifacts (Wartofsky, 1979) that embody and materialize ideas created by the students themselves. Consequently, in D&T settings material artifacts and tools have a central role in mediating the learning and scaffolding processes. Demonstrating some aspects of the design process with material artifacts is a typical form of scaffolding in design education. Furthermore, concrete materials and tools, and testing with models and prototypes support the development of ideas by adding the material aspect to the conceptual ideas. In D&T contexts, material mediators support the externalization of students' thinking, helping them to overcome the difficulties in verbal interaction.

METHOD

The present study explored the opportunities afforded by authentic design tasks and participation of a professional design expert in elementary students' collaborative design process. The overall goal was to provide some insights into how design expert might infuse disciplinary expertise into D&T classrooms and how he might construct authentic processes based on professional design practices. We describe a part of a longitudinal study project, "The Artifact Project", where the aim was to break boundaries of traditional schoolwork by fostering students' inquiring and designing with the help of various experts (for detailed description of the project, see Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010).

Participants and the Setting of the Study

The Artifact project was organized in an elementary school located in a middle-class suburb of Helsinki, Finland. 32 students (13 boys) participated in the project; out of these, 7 students had linguistic or other educational problems. The focus of the present study, the lamp designing stage, took place in spring 2004 and lasted 17 lessons during a period of two months. At that time, the students were fifth graders, 10–11 years old. The participating expert, a professional interior designer specialized in lamp and light designing, was present in the classroom during the whole time of the design process. The interaction between him and the students varied from face-to-face whole-class discussions, to small team discussions, and to discourse within Knowledge Forum database. The lamp designing process was followed through in 13 small teams (2–4 students in each), by sketching, drawing, and building prototypes or models. The students also regularly presented their designs to the whole class. Table 1 depicts the main contents of each design session, and as an example, the activities of one student design team during the sessions (referred as "the team"). One session includes one to three lessons (45–135 minutes), depending on the class schedule.

Table 1 The main content of the design sessions of the lamp designing process

Number of session	**Main content of the session and the team's activities**
1	Designer's presentation on general themes of lamp and light designing, and the proceeding of the design process First design task was given for homework: Examining and analyzing existing lamps
2	Students' presentations on existing lamps Forming of the student design teams The second design task was given: Designing new lamps The team begun their lamp design process by developing design ideas.

3	Repetition of the second design task The team worked on their chosen design idea, a chequered pendant lamp, by designing some of its' details
4	The team worked in KF, designing and thinking of the materials and the expenses related to the lamp. At the end of the session the team designed the height of the lamp.
5	Designer's presentation on different light bulbs The team designed the measurements of their lamp, and drew it in its' natural context/environment
6	Designer's introduction to different kind of representations for the lamp (drawings, prototypes, models, scale-models) Team presentations on proceeding of the design process The team started to construct the prototype of the lamp
7	Team presentations on their chosen representation techniques The team constructed and colored their prototype
8	The team continued designing details and preparing the prototype. The prototype was finished.
9	The team worked in KF, considering coloring alternatives and the name of their design
10	Designer's introduction on preparing the final presentations. All the teams pulled together their notes from KF and prepared poster presentations of the lamps. The team redesigned the name of the lamp and drew the lamp to the poster in its' real context/environment.
11	Final presentations (process + product) by all the teams

Data Collection and Methods of Data Analysis

The research on the Artifact project relies on extensive video recordings of classroom practices. The lamp designing stage was recorded in its entirety, except for two or three occasions where the students, for example, scanned their sketches in the database. This was usually done when the designer was not present in the classroom, in between other school activities. For the present study, we selected all the lamp designing episodes where the designer interacted either with the whole class or with the small teams. These episodes were further segmented into smaller *design events* (N=106), each distinguishable from the others on the basis of the noticeably different content or context (Chi, 1997; Derry, 2007). The length of the events varied from less than 30 seconds to over 15 minutes. One event was a coherent whole, beginning from the point where the designer started interacting with the students, and ending when their interaction was drawn to an end and something else (like peer collaboration) begun. For example, the designer's interaction with one team on some particular issue was identified as one design event. The analysis on the video material was performed by following the procedures of qualitative content analysis (Chi, 1997) with the help of ATLAS/ti software. The categories of the analysis were mutually exclusive, and the design events were identified according to their main content.

The coding scheme (see also Table 2) consisted in four different main categories: *social setting; LCD design inquiry phases, designer's activities and use of mediating artifacts*. First, we identified four distinctive *social settings* in the classroom during the lamp designing process: 1) the designer's presentations, 2) the students' presentations, 3) whole-class discussions, and 4) designing in small teams. Second, the *design inquiry phase* of the process was determined in accordance to the LCD-model: 1) creating the design context, 2) defining the design task and constraints, 3) creating and elaborating design ideas, 4) experimenting and testing design ideas (sketching and prototyping), 5) evaluating design ideas, constraints, and process, and 6) distributing expertise. Third, we categorized the *designer's activities*. He

1) provided his own experience and knowledge, and 2) anchored this new information by providing students with common experiences. The designer also 3) provided scaffolds for idea generation, and 4) furnished scaffolds for sketching and prototyping. By 5) identifying the design constraints, he reduced the complexity of the design task and increased the chances of students' effective action, 6) Focusing attention by marking relevant task features is closely related to identifying design constraints. In addition, the designer 7) modeled more advanced solutions, and 8) provided demonstrations. Modeling more advanced solutions is a part of the scaffolding process (Pea, 2004), in D&T settings a typical form of modeling is demonstrating, i.e. visualizing some aspect of the design process with drawings or material artifacts. The designer also 9) reflected the students' ideas and processes, enabling students to compare their performance with others (Collins, 2006). In addition, the designer 10) supported students' knowledge sharing and 11) provided feedback for the teams. The fourth level of analysis focused on the *use of mediating artifacts* in the interaction between the designer and the students. Several materials and tools were used during the lamp designing process, for example, designer's and students' sketches, lamps and light bulbs, prototype materials and tools, as well as Knowledge Forum notes and annotations. To test the reliability of the coding scheme, two independent coders classified approximately 15% of the transcript video events resulting that an inter-rater percentage of agreement was .88, which was considered satisfactory. In the present study we emphasize only some of the designer's activities and his interaction with the students in order to describe how disciplinary expertise was infused into the classroom.

RESULTS

The lamp design process started by reproducing the world of designing within the classroom. It started by the designer's a full-length two-hour lecture. He described his own design process and arrested students' attention to the essential points of light planning. The context for designing and the design tasks was created and defined during the designer's presentations and the whole-class discussions during and after the presentations. Altogether, he gave 4 presentations during the 11 sessions, providing his own experience and knowledge to the students and anchoring this new information to students' previous knowledge and identified the design constraints. The next three presentations provided shorter introductions to the diverse types of light bulbs and different representation techniques. With his knowledge and support, the students were encouraged to construct and participate in the world of designing. This promoted the collaborative creation of meaningful and authentic design context and task, i.e. the foundations for students' idea generation. Thus, the designer played the main role for creating the design context and highlighting the design constraints. Since the students did not have any previous experiences of design process, they needed the expert's support for identifying design constraints. However, the context and the task were also further developed in the later sessions. For example, the designer provided new information, or the design constraints were identified in a more detailed level.

The Table 2 provides the general view of how the different social settings were related to the design inquiry phases (LCD –model) as well as corresponding designer's supporting activities and mediating artifacts. All phases of LCD model as well as designers supporting activities were visible throughout the design process.

Table 2. Social settings, design inquiry phases, designer's activities and mediating artifacts during the lamp designing process.

Social Setting	**Design Inquiry Phases**	**Designer's Activities**	**Mediating artifacts**
Designer's presentations Whole-class discussions	Creating Design context Defining Design Task	Providing own experience/knowledge Anchoring experiences Identifying design constraints	Designer's sketches, notes, photos Lamps, light bulbs Designer's KF notes, shared view
Designing in small teams	Creating and Elaborating Design Ideas Experimenting and Testing Design Ideas (sketching and prototyping)	Scaffolding idea generation Scaffolding sketching and prototyping Focusing attention Modeling more advanced solutions Demonstrating	Students' sketches, notes, prototypes Prototype materials and tools KF notes and annotations
Students' presentations Whole-class discussions	Evaluating Design Ideas, Constraints, and Process Distributing Expertise	Supporting knowledge sharing Reflecting Providing feedback	Students' sketches, notes, prototypes, and posters KF shared view

The actual design practices were implemented in the work of the student design teams. The students created, elaborated, experimented, and tested their design ideas, and the designer supported this with various social and material scaffolds, offering the students direct exposure to authentic professional practices. He focused the team of students' attention on the relevant features of their designs, visually represented some of these features with drawings or demonstrations, and modeled more advanced solutions. In sessions 2, 6, 7, and 11 the students presented their ideas and processes, sharing knowledge for the creation of the design community. Through students' whole class presentations and discussions the designer distributed expertise among the students, encouraged the evaluation of their design idea and focused their attentions toward design constraints. In these phases the designer supported the sharing of students' knowledge, reflected their processes, and provided feedback.

Infusing Design Expertise

Part of the design world is its own language, the expressions and discursive practices that are distinctive inside that world. The infusion of design world became a part of the classroom discourse in use of the design language. Using language means participating in discourse; language is a resource rather than a representational medium (Roth, 1998). During the lamp designing process, the students were accustomed to the language of designing in their continuous interaction with the designer. The designer used authentic, professional design terminology that was in most 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:

> Extract 1a. The language of designing
> 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 27.2.04]

After this the term was first time used by a student in a KF note:

> Extract 1b.
> I chose the spotlight that's in the living room's corner, I believe it's a good light because it has five separate lamps and they are connected through a swan neck pipe. .---
>
> [Student note after session 2. KF database 10.3.04]

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:

> Extract 1c.
> Student from the class: 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, student team's presentation. Video data 18.3.04]

However, sometimes the teacher's support was needed for adopting new terms. At session 6, the designer introduced different options to represent the lamp designs. After briefly explaining the different alternatives, he discussed them with each team, making suggestions of their possible representational techniques. At the beginning of the next session, the teacher proposed to the designer that he repeat and clarify the information on representation techniques:

> Extract 2. The teacher supports the adopting of the language of designing
> Teacher: Could you Tim, go over what these possibilities are, what kind they are, what it means, what prototype means and what is a working prototype?
> Designer: Who knows what a prototype is?
> Theo: A kind of model which shows how everything works.
> Designer: Exactly, a natural size model which works. What then is the difference between a prototype and the finished product?
> Theo: The only difference is that, umm, there is only one copy and it's not mass-produced..
> Designer: Yea, you can use different materials as in the final product. So you could make the prototype out of cardboard if you wish. What then, is the mock-up?
> Dane: Something that doesn't work.
> Designer: Yea, but it's the right size but it doesn't work. Then you could make a miniature model out of it, for example, if you have a plan for a foot-lamp, which is big enough that it'd be easier to make a miniature model instead of a mock-up. If a miniature or mock-up isn't practical then you could just draw a blueprint, which you need to do anyway before the model can be made.
> [Session 7, whole-class discussion. Video data 25.3.04]

The teacher had realized that the students were not familiar with terms such as 'prototype' or 'mock-up', and she supported the designer by combining the languages of designing and learning. This encouraged the students to give their own explanations, providing the designer with clues to their understanding. Thus, he was able to re-formulate the new information in a way most useful for the students.

Implementing Design Practices

The main activities during the lamp designing process were creating, elaborating, experimenting, and testing design ideas in the student design teams by sketching, drawing, and building prototypes or models. The ideas were generated during all the sessions, except the first (designer's full-length lecture) and the last (student team's final presentations) session. The designer circulated in the classroom and guided the students into the practices of professional designing by providing continuous support and feedback to each team regularly. The student's generated several design ideas, and the designer provided scaffolds for developing these ideas further.

One central aspect of the design process is the designer's way of using variety of visual representations, written notes, graphical organizers and models for storing, representing, and developing emerging ideas. The design artifacts are also future-oriented because they may hint how their design could be improved or changed (Wartofsky, 1979). During the lamp designing process, mediating artifacts had an essential role in the designer-student interaction. The students used their sketches and models to explain their ideas to the designer, and he used sketches and different material artifacts for visualizing diverse aspects of the design process.

Externalization and representation of the design ideas require knowledge of various representational techniques, and skills to use the techniques as a matter of routine, and as tools for developing design ideas. Hence, learning of design practices also includes learning of different representational techniques. While guiding the students to the practices of expert designers, over one fourth of the designer's activities consisted of providing scaffolds for sketching or prototyping. The designer guided the students in drawing professional illustrations of their designs, considered the materials and the construction of the models and prototypes together with the teams, and made suggestions for the structure of the teams' final presentation posters. The participants were literally working with foreseen and envisioned artifacts.

However, envisioning the non-existent lamps and representing them appeared to be difficult for the students and required both social and physical scaffolding. For example, a team of two girls designing a pendant lamp had a hard time imagining and drawing their lamp from different angles. The designer was busy with other teams and only explained briefly to the girls that they have to draw the side view and the cross section of their lamp. The team did not completely understand these instructions and ended up drawing a picture with a view from more than one angle. Then the designer with the help of the teacher improvised a demonstration with paper cups and the team's drawing:

Figure 1. The designer and the teacher demonstrate how to visualize a lamp from different angles

Simple physical scaffolds as paper cups and drawings were central to the teams' understanding; the demonstration helped the girls not only to realize the side view of their pendant, but also gain the knowledge of how to envision the lamp from different angles. For expert designers this is basic knowledge, but novices, such as elementary students, have to learn how it is possible to envision and represent something that does not yet exist.

The designer invited the students to share their experiences and questions by asking them to give presentations regularly during the lamp designing process. Giving presentations was an important part of design practices; creation of a presentation encourages students to reflect and justify their ideas and make their reasoning clear. In most of the presentations external representations of the designs (sketches, models, KF notes on the shared view) were used as mediators to support the presenting and the discussions after them. During the presentations the designer provided support and feedback to the students, and reflected their processes, enabling them to compare their performance with others (Collins, 2006). For example, in session six, the designer asked each team to present their in-progress designs spontaneously in front of the class.

> Extract 3. Student team presents their design in-progress
> Ann (presenting team's ideas with sketches on paper and on the shared view): So here would be this kind of pipe or that kind of metal thing and there would be many of these kind of lamps so more than in the picture, the circular kinds. And in the middle would be a bright halogen lamp and it is a roof lamp. And when the halogen lamp heats up it would become very hot so we thought that we would put these sticks and at the end would be this ball or...
> Natalie: Button.
> Ann: … button, which you could use to change the bulb's position. And so you could have each lamp pointing in a different direction so it lights up many places. There's a picture how it lights the area, so it lights kind of all directions.

The designer supported the presenting team by asking for clarifications to details of their design. This discussion went on for a while, but other students from the class started to participate in the discussion with critical comments: they were not convinced why it was necessary to be able to move the lamps. The team could not explain this, so the designer used a loupe to demonstrate the lamp's movement:

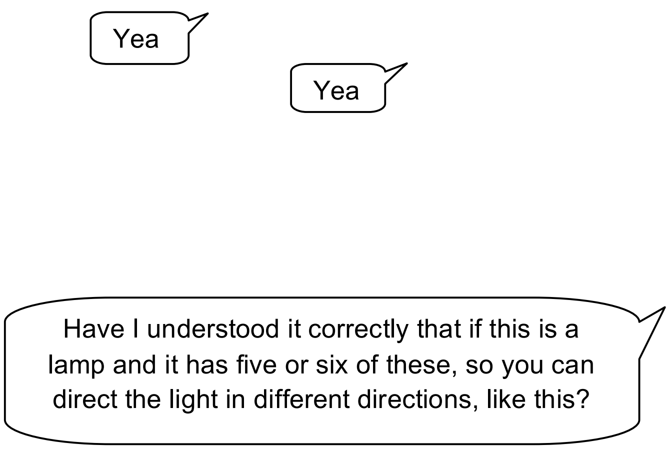

Figure 2**.** Designer demonstrates lamp movement with a loupe

This short demonstration assured the other students; however, they continued presenting critical comments concerning the appearance of the lamp. The designer and also the teacher carried on supporting the presenting team.

To conclude, the designer brought the world of designing as well as associated practices into the classroom. With the designer's knowledge and support, and through appropriating his practices, the students were able to “figure” (construct, configure, and participate in) the world of designing.

DISCUSSION

In the present study we emphasize the designer’s activities and his interaction with the students, in order to describe the pedagogical practices that allow one to acknowledge the role of expert’s participation in design learning. The complex nature of designing stimulates authenticity (Hennessy & Murphy, 1999). Authentic learning activity is coherent and personally meaningful as well as purposeful when embedded in locally cultivated, social practice relevant for a particular, in this case design-related, culture (Hennessy & Murphy, 1999; Murphy & Hennessy, 2001). The designer's continuous face-to-face interaction with the student teams was central in implementing authentic design practices in the classroom. The designer provided diverse social and material scaffolds, offering the students direct exposure to professional practices. These scaffolds helped the students to develop their ideas further and to represent their designs to others.

The material mediators of scaffolding had a central role in the interaction and sharing of design practices; with them, the designer's tacit knowledge became visible and available for the students. Furthermore, the students' sketches, models, and notes provided clues and hints to their design thinking, offering the designer opportunities for scaffolding (Hsu & Roth, 2009). These material mediators supported the verbal interaction, helping the students to explicate their ideas as full participants of the world of designing.

Participatory learning (Jurow, Hall, & Ma, 2008) can expand learning beyond encapsulated traditional schooling by supporting partnerships between students and expert practitioners from the surrounding community. Facilitation of creative design practices within a classroom is about creating shared knowledge practices, that is, *epistemic practices* of working with knowledge, channeling the participants’ efforts in ways that elicit collaborative advancement of knowledge, including creation of design artifacts (Hakkarainen, 2009). Collaboration competencies include both the capabilities to explicate, externalize, and materialize one's own ideas and knowledge, as well as the capacities of productive participation in co-creating and jointly developing ideas originated by the fellow inquirers. During the lamp-designing process the designer, on the one hand, supported the students in sharing their knowledge, encouraging them to use expert practices and language while presenting their ideas. On the other hand, he promoted the constructive evaluation of students' ideas.

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