Material mediation and embodied actions in collaborative design process

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Material and embodied practices are an intrinsic part of craft and design education. This article reports a study in which textile teacher-students designed three-dimensional toys based on children's drawings. Three students in each team worked on the given materials and designed the shape of the toy together. Materials for designing were either: 1) pen and paper, 2) masking tape and thin cardboard, or 3) wire and non-woven interfacing fabric. After the modelling phase, the final toys were created by sewing. Research data consisted of the video recordings of three design sessions representing the various design materials given to the students. By conducting multiple levels of analysis, we examined how the participants used materials and gestures to support their communication. The results highlight the strengths of 3D modelling techniques, particularly through comparison with the drawing technique undertaken by one design team. We found that simple material tools support students' design process and suggest this could be applied to other design settings.

Keywords: collaboration, craft, design, embodiment, materiality, mediation

Introduction

Research on social creativity suggests that the core of design thinking is not the individual human mind but groups of minds using artefacts and tools in a collaborative process (Binder et al., 2011; Perrone, 2013; Sanders & Stappers, 2008). In collaborative design activity, various representations and artefacts have a central role as memory aids and communicative resources; they function as mediators between team members (Cross, 2011; Perry & Sanderson, 1998). Collaborative designing is connected to co-design spaces (Sanders & Westerlund, 2011), where the physical co-design space can be a mirror of the conceptual co-design spaces and afford the visual and material display of the artefacts that are produced and discussed during the design process. Likewise, as Binder et al. (2011) have argued, that it is crucial to provide design teams sufficiently rich material resources and design tools to support inspiration and social interaction.

In the collaborative design process, the participants exploit the physical, social and cultural features of their design task context in order to reach decisions about their task. We make use, here, of an overview of collaborative practices in professional and academic design studios (Vyas, van der Veer & Nijholt, 2013). They summed up three broad themes by which design professionals support communication and collaboration: 1) use of artefacts, 2) use of space, and 3) designer-based practices (e.g., use of body). Firstly, material design artefacts, such as sketches, drawings, storyboards, collages, cardboard, clay or foam models and physical prototypes play an important role in supporting collaboration between co-designers. Secondly, designers create artful surfaces and project-specific spaces full of informative, inspirational and creative artefacts by externalizing their work-related activities (see also Keller, Pasman & Stappers, 2006). Thirdly, designers apply bodily and social practices to stimulate creativity in their work.

Recent studies have stressed the physical and embodied nature of craft teaching and learning (Ekström, 2012; Illum & Johansson, 2012; Kangas, 2014; Koskinen, Seitamaa-Hakkarainen & Hakkarainen, 2015). In the craft classroom, verbal and non-verbal communication as well as the embodied and material aspects are intertwined. For example, craft teachers' gestures and body-based interaction support verbal instructions (Koskinen, Seitamaa-Hakkarainen & Hakkarainen, 2015), and craft teachers use verbal language to make students aware of the embodied nature of craft making (Illum & Johansson 2012). Ekström (2012) puts the matter as follows: "it is in and through embodied experiences of the instructed activities and relevant materials that instructions achieve their local sense and meaning" (p. 90).

Since the use of artefacts, gestures and other bodily representations for discussing craft and design ideas are common in classrooms and design studios, there is a need for closer examination of these processes in order to understand and support the mediated and embodied nature of craft and design practices. A critical research topic, which has been poorly addressed, is how materiality affects interactions in creative and collaborative settings. Physical artefacts are representations of the work that emerge during the design process, and materiality is a vital aspect of the design representations, giving participants indications about the conceptual and material aspects of the design ideas (Jacucci & Wagner, 2007). External representations (graphical and physical) in various phases of the design process provide different kinds of prompts to test design ideas. Furthermore, various representations facilitate the evaluation of ideas and elaboration of the design task (Lahti, 2007). In our study, we compare how different design materials and gestures support idea development during co-designing. The main research question is divided into two sub-questions: 1.What kind of gestures is used during co-designing? 2. How do the teams differ from each other in their design process?

Collaborative designing through and around design artefacts

When people collaborate, their communication and coordination acts go beyond linguistic signals and involve the use of material artefacts, locations and physical spaces, i.e., material signals (Clark, 2005). Design researchers (e.g., Gedenryd, 1998; Jacucci & Wagner, 2007; Ramduny-Ellis et al., 2010) have emphasized that designing is often material-centric, that interacting with and through physical materials is an intrinsic part of the design process. Material artefacts (also called intermediary objects) have three main features in design activity: 1) mediation, 2) transformation, and 3) representation (Boujut & Blanco, 2003). Intermediary objects are either representations of the product or of the design process (Perry & Sanderson, 1998). Creating a design object involves a transformation process of physical materials. This process gradually leads to a common understanding of the situation and creates a common ground for all participants. Thus, various artefacts have a central role as communicative resources; they function as mediators between team members (Cross, 2011).

Genuine design collaboration depends on the actors truly sharing the same object, as opposed to organizing their common efforts by merely coordinating their joint activities (Lahti, Seitamaa-Hakkarainen & Hakkarainen, 2004). Within collaborative design, the phenomenon of conversational grounding has received attention (Reid & Reed, 2007): the mix of signaling methods during design interaction. Collaborating designers use 1) descriptive, 2) demonstrative, and 3) indicative methods to establish a common ground. Furthermore, conversational grounding and workspace activity is dependent on the type of design problem (Reid & Reed, 2007). An interior design problem, with its requirement of the precise orientation and location of objects, requires mainly simple pointing gestures (i.e., indicative methods), whereas an engineering design problem, with its emphasis on shape, movement in space, and conceptual solutions to the problem, requires high levels of demonstrative and descriptive support (e.g., sketching and figural gesturing).

A review of the research literature examining the role of sketching in designing indicates that sketching has a crucial role in generating, developing, and communicating ideas (Goel, 1995). Through the visualization, design ideas, proposed solutions, and decisions are made explicit and visible. However, sketching may not be as helpful for students as it is for professionals in the development of new ideas (Laamanen & Seitamaa-Hakkarainen, 2014; Menezes & Lawson, 2006). Visualization is not only drawing on the paper; the term covers the use of many varied forms of representations. Pei, Campbell and Evans (2010) have classified design representations into four main types: sketches, drawings, models, and prototypes. Further, Brereton (2004) categorized external design representations according to various levels of tangibility, ownership and abstraction. According to these dimensions, representations vary from transient to durable, from abstract to concrete, and from self-generated to ready-made. Words articulated in a design discussions are transient representations, whereas representations such as transcripts, sketches, and prototypes are durable; they last and can be referred to. Whereas sketches and scale models leave many details undefined, real prototypes specify more details and material properties of a design object.

Designing is, from the very beginning, focused on creating and developing design ideas that are given a material form (Jacucci & Wagner, 2007; Ramduny-Ellis et al., 2010). In the design process, ideation and externalization of design ideas play a crucial role. In the early stages of designing, visualization helps to define and clarify the task and explicate the constraints of the task (Welch et al., 2000). Later, externalization helps to identify two types of information used by the designers: design information concerned with the visualization, aesthetics, and usability of the product; and technical information, such as assembly, mechanisms and materials (Pei, Campbell & Evans, 2010). Charlesworth (2007) has stated that "each mark on paper or displacement of material on a piece of foam or clay feeds back information allowing a designer to see, often by accident, new directions for his original thoughts" (p. 44). Therefore, the selected key ideas have to be given a material form by means of practical exploration, model making and prototyping.

Design students must be encouraged to experience that physical interaction with form, which allows ideas to develop and mature and which provides them with the tools they need to develop designers and practitioners (Charlesworth, 2007). Seevinck and Lenigas (2013; see also Kangas, 2014) 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. Our research setting is a continuation of design exercises of this kind and reports a pilot study where first-year textile teacher students designed three-dimensional toys through simple design materials.

Research setting

The collaborative design assignment was a part of the course called *Basics of Craft and Design Studies*. The course was a compulsory first-year course of Craft Teacher Education, at a Finnish university. The course consisted on lectures about the nature of design problems, the theories of the design processes and the role of visualization and craft education. The aim of the course was to learn to collaborate and to carry out an entire design project for the first time in the studies. Team work following the lectures was organized as collaborative design sessions constructed around an open-ended and authentic design assignment. At the time of the study, autumn 2012, the design assignment was to design a three-dimensional toy based on a child's drawing. Later, during the *Sewing Technology* course, the student teams produced their toys from textile materials. Most of the toys were later donated to the children who made the drawings.

Figure 1: Children's drawings (i.e., Zebra, Car and Unto) as starting points for collaborative designing.

34 first-year textile teacher students attended the courses, from which 9 students volunteered to participate in the study. The teacher decided the constitution of the design teams so that each team consisted of three or four students. The design assignment comprised several subtasks: 1) collecting a child's drawing (see Figure 1), 2) making a mind map and a material collage, 3) making a model and patterns, 4) making a prototype, and 5) sewing a toy. From these, the third phase was videotaped for the present study. The videotaped teams were labelled according to the name of the toy they produced: Team Zebra, Team Car and Team Unto. Materials for designing and model-making were either: 1) pen and paper (Team Zebra), 2) masking tape and thin cardboard (Team Car), or 3) wire and non-woven interfacing fabric (Team Unto). The selection of materials was partly the same as in the previous study (Ramduny-Ellis et al., 2010) in order to study further the importance of producing low-fidelity prototypes at an early stage in the design process.

Research method

In the video research, the data analysis is usually based on the disciplined observation of the video recordings (Derry, 2007; Goodwin, LeBaron & Streeck, 2011). We adapted Ash's (2007) methodology of three levels of analysis–macro, intermediate, and micro–for tracking the collaborative design process. At the macro level, we analysed the main focus of design activities for each team. We divided the video data into three-minute units and identified the types of activities in each unit: We analyzed 1) constraints, 2) ideation, 3) model making, and 4) pattern making. Then, we created flow charts of the design activities of each team. The flow charts showed that the three-minute units included either one main activity or two parallel activities. Based on the flow charts, we selected three significant events from each team's activities (intermediate level). The selected events provided representative slices of time from various phases of designing, exemplifying various kinds of activities: 1) analyzing + ideation, 2) ideation + model making, and 3) pattern making.

For the micro level analysis, each statement of the significant events was displayed with the help of Chronologically-Oriented Representations of Discourse and Tool-Related Activity, i.e., CORDTRA diagrams (see Hmelo-Silver et al., 2008). The unit of analysis was a verbal utterance. We were investigating whether the utterance represented 1) a design constraint, 2) a visual or technical design idea, or 3) something else. In addition, we examined how the participants used representational gestures and materials to support their verbal communication. The classification comprised three aspects: 1) pointing gestures, 2) descriptive gestures, and 3) description through material. Consequently, we were able to compare how these embodied design activities changed during the design process and how the design process differed from team to team.

Results

As mentioned in the introduction, designers extensively utilize the material qualities of design artefacts in their work. Material artefacts and other resources of design studios promote a collaborative design process that is based on the construction of the shared, design object. However, it is necessary to explore more precisely how materials impact on idea development in a design education context, where the material and spatial arrangements of the design studio are set in advance. This starting point differs from the situation where the professional designers themselves arrange their creative and resourceful surroundings.

The time used in the videotaped sessions (i.e., making a model and patterns) varied from 60 minutes to 75 minutes between the design teams. During the session, the teams worked independently, examining the child's drawing, analyzing the constraints of designing, proposing, testing and evaluating the design ideas and the emerging solutions. Figure 2 presents the distribution of four design activities in each team. Analyzing constraints and ideation occurred simultaneously or sequentially during the design process, especially in Team Car and Team Unto. This is an important point when the design process is seen in terms of the co-evolution of problem and solution spaces (see Dorst & Cross, 2001).

Unlike the other teams, Team Zebra had only a pen and paper for designing the shape of the toy. They engaged in discussions about the details of the drawing and the challenges of making a three-dimensional toy. Much of the discussion focused on ideation instead of analyzing the constraints. In other words, students focused on finding appropriate solutions for the design by proposing and evaluating design ideas. However, it appeared that without the physical interaction with form they had difficulties in transforming the child's two-dimensional drawing into a three-dimensional object. After about 40 minutes of discussing and drawing, a team member even tried to fold the paper in order to find a solution for the zebra's hoof. In the latter half of the session, Team Zebra produced a preliminary sewing pattern which followed closely the outline of the drawing.

Figure 2 reveals that both modelling and pattern making differed between Team Car, which worked with masking tape and thin cardboard, and Team Unto, which received wire and non-woven interfacing fabric for their 3D model. Team Unto started modelling from the very beginning of the session, and later on, the sewing patterns were created with the help of the model. In contrast, Team Car first decided the cushion-like form of the toy and built the model after pattern making. In the first phase, they created a body for the car, and thereafter, focused on designing the shape and patterns of the tailgate.

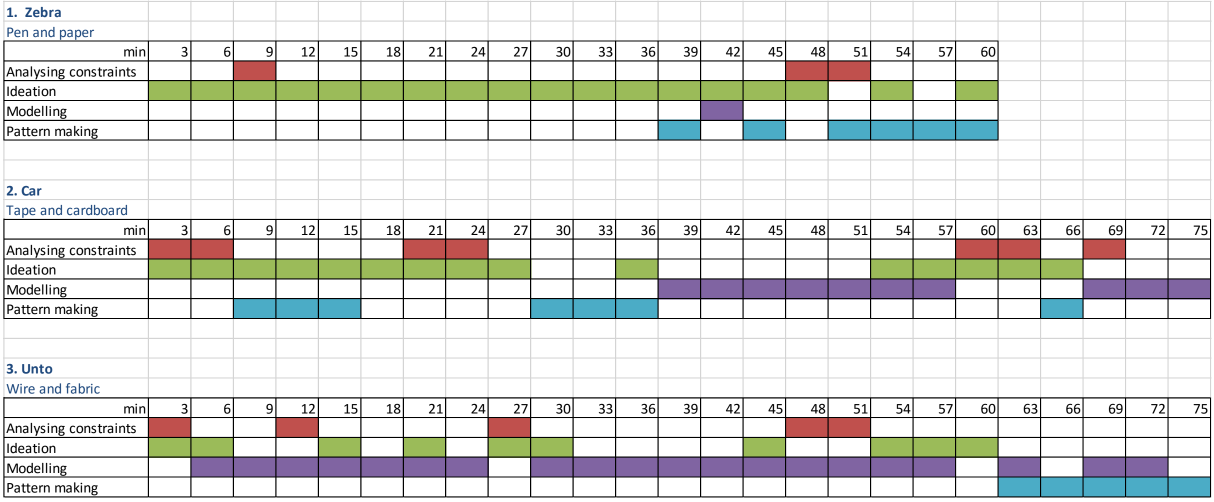

Figure 2: Design activities in each team.

The fact that the collaborating students were present in the modelling and pattern making allowed them to monitor the progress of their design activity. Because they could see one another, they could also use their body language and gaze to communicate information. Tang (1991) has reminded us, "it is important to not only see gestures, but to see them in relation to the sketches and other objects in the drawing space. The spatial relationship between hand gestures and their referents is a resource used in interpreting collaborative drawing activity" (p. 151). In order to examine how the different aspects of discourse related to each other and to the use of design materials and gestures, we created CORDTRA diagrams for three selected events in each design team. In the following, we will present three of these diagrams: 1) the event where Team Zebra focused on analyzing constraints and ideation, 2) the event of ideation and model making in Team Car, and 3) the event of pattern making in Team Unto.

In the following, we will provide more detailed description of the students' collaborative design processes based on the intermediate and micro level analyses. Pseudonyms A, B, and C are used for the students in the figures and transcript samples.

Team Zebra – challenges in spatial thinking

The CORDTRA diagram (Figure 3) is from the very beginning of the Team Zebra's design process, when they started to draw the figure of the zebra on paper. During this event, they discussed the constraints related to the child's drawing as well as the size and details of the toy under consideration. The analysis indicated that the students often used pointing gestures when they discussed constraints whereas descriptive gestures supported ideation. The connection between these gestures and verbal statements was also found in the other events and teams. The following excerpt highlights the role of the child's drawing as a starting point for ideation. The line numbers correspond to the utterance numbers of the CORDTRA diagram in Figure 3.

> 11 B: How about this corner? How should we actualize it? In that kind of rippling? [pointing gestures, descriptive gestures]
>
> 12 C: Uhm, how accurate did it have to be?
>
> 13 A: I don't believe, we probably can tinker with it, it's probably easier to actualize when it's straight. [pointing gestures, descriptive gestures]
>
> 14 C: Yeah.
>
> 15 A: The ears probably a little… [descriptive gestures]
>
> 16 C: Yeah, that precise.

One of the intriguing aspects of the Team Zebra's design process was the students' concern whether they were doing the" right thing". The students wanted to know if they were making the right decisions– that is, whether their interpretations of the design task and proposed design solutions were appropriate. At the beginning, Team Zebra took the child's drawing in a very literal sense. Later on, they decided to transform the two-dimensional drawing into a really three-dimensional toy because they thought that the child artist would appreciate it. In a nutshell, while the idea in the drawing belonged to the author of it, the idea of the toy was shaped by the students interacting with each other and with the drawing.

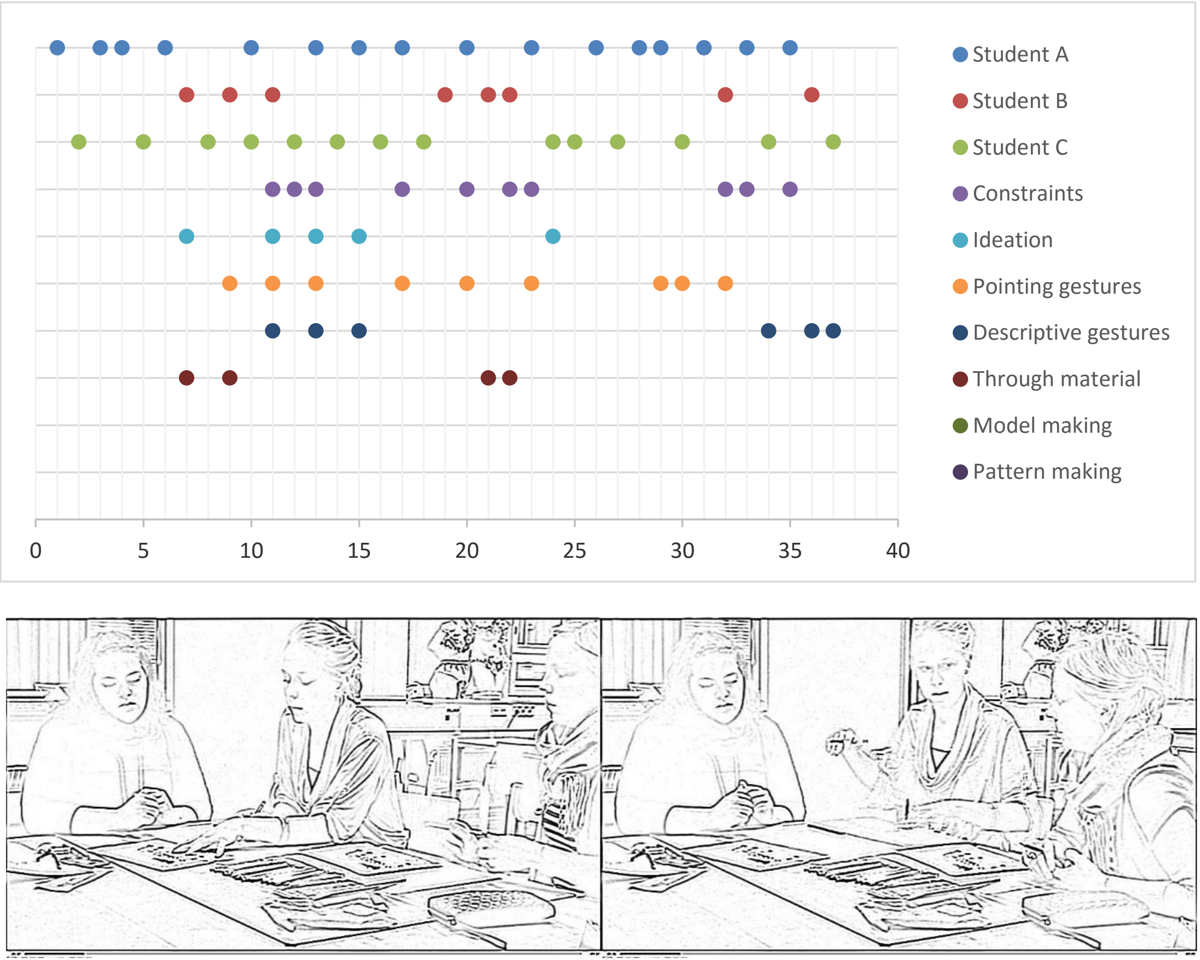

Figure 3: CORDTRA diagram from the first selected event (02:00–05:00) in Team Zebra and the gestures related to the utterance No. 11.

CORDTRA diagrams indicated that the students creatively made use of their bodies while explaining a design idea and while referring to design constraints like the child's drawing. According to Murphy (2005) collaborative "imagining is always mediated by objects: not just mental objects, although surely they can play a part, but also by material, verbal, organic, and gestural objects that all serve, in various ways, to help constitute the act of imagining" (p. 140). In Team Zebra, the lack of modelling materials prompted to some alternative activities instead of using material objects. For example, one team member used a body posture as a metaphor for the construction of the toy:

> Student B: If I, like crawl then it needs to be divided into four parts... just how would we get the crotch seam... (3rd CORDTRA; 49:18-49:26)

To conclude, Team Zebra had difficulties in determining the shape for the toy. The team members were a little bit frustrated and helpless with the given design materials (i.e., pen and paper). A previous study of clothing design and construction found evidence that mixing flat-pattern design with concrete 3D steps of testing or draping on a model probably help the students in their spatial thinking (Salo-Mattila, 2014). Team Zebra worked without proper materials of 3D modelling, and the opportunity for sketching was an insufficient medium for stimulating and developing design ideas. However, sketches may serve more productive purposes for professional designers. For example, graphic representation in architectural practice has been found (Murphy, 2005) to involve a wide range of capabilities along with talk and gestures.

Figure 4: The pattern after the videotaped session and the final product made by Team Zebra.

Figure 4 presents the sewing pattern for the zebra after the videotaped session. The students have written on the paper that it is the first version, and it is later going to transform into a 3-dimensional form with many separate pieces. As the photograph shows, the final zebra consisted of several pieces. In other words, the videotaped session was not so useful for the students, and they had to develop the idea further on later sessions. Prototypes can be made at any stage of the design process, but they can be more valuable if used in the early phases of the process.

Team Car – creating a common ground for idea development

The simplest prototypes are those made of paper or thin cardboard. Their advantage is that they are inexpensive to create, easy to change and they can be produced by anyone. The analysis of the Team Car's design process indicated that it was even possible to build simple functionality (i.e., a tailgate) in the paper prototype (see Figure 5) and provide an understanding of user experience. The CORDTRA diagram in Figure 6 is from the end period of the design process (50:00–53:00) when Team Car had completed the body for the car and was discussing the mysterious hatch in the drawing.

Figure 5: The tailgate in the final product and in the paper model made by Team Car.

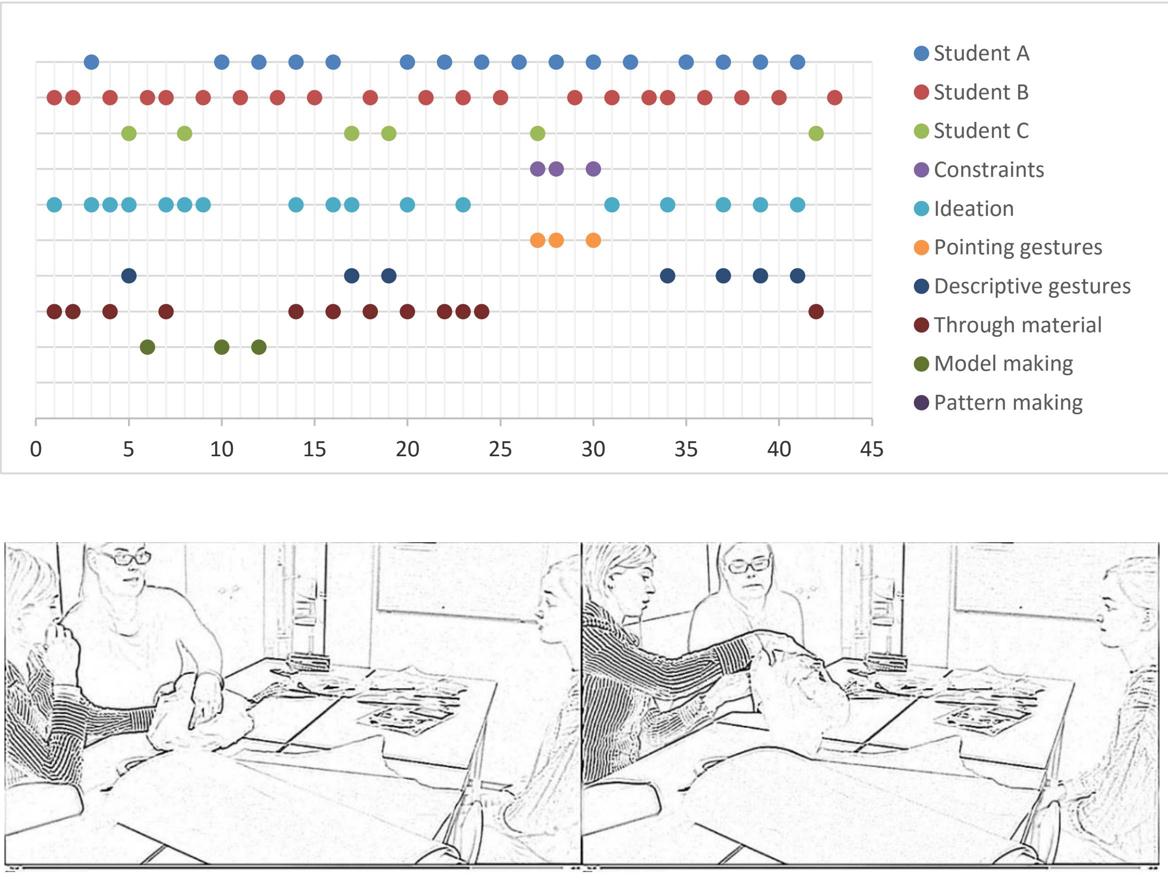

Figure 6: CORDTRA diagram from the second selected event (50:00–53:00) in Team Car and description through material related to the utterances No. 18 and 20.

14 A: The tailgate goes here. [description through material]

15 B: Does it come on both sides or only one?

16 A: I was thinking that it'd be back here. [description through material]

17 C: Yeah, it is. [descriptive gestures]

18 B: Yeah, yeah, also here. [description through material]

19 C: Yeah, there too, then it reaches to there. [descriptive gestures]

20 A: It is in principal, this is the car's end, the tailgate is here, connected from there. [description through material]

21 B: Aha.

22 A: That's why I was worried, so let's do it like this. [description through material]

23 B: I was thinking, that we'll have it like in the picture, and we'd have this hole right here. [description through material]

24 A: From this direction. [description through material]

25 B: Yeah, I didn't really understand.

26 A: Yeah.

27 C: In the picture it goes to the side. [pointing gestures]

28 A: This comes from here, a bit over, so this Väinö [name of the child artist] could have thought that it's the tailgate. [pointing gestures]

Description through material was an integral part of ideation (see Figure 6) in Team Car. The paper model was the object of interaction; it was pointed to and talked about. In other words, it worked as a vehicle for communication. Furthermore, the paper model provided a means for students to interact with, react to, negotiate around, and build upon an idea. The previous excerpt illustrates how the team members achieved a common ground of understanding through the material artefact. A clear 'Aha!' moment (i.e., utterance number 21) resulted from the complex interaction between verbalization and material signals. Material signals, according to Clark (2005), fall into two main classes: directing-to and placing-for. In directing-to, people request addressees to direct their attention to objects, events, or themselves. In placing-for, people place objects, actions, or themselves in special sites for addressees to interpret. Both these classes occurred in the micro level analysis of the video data.

Because models and prototypes direct the thinking of design team, they can also narrow the range of design possibilities. Using prototypes can create blindness toward other and maybe better ways of considering the issues. Related to this paradox, Ramduny-Ellis et al. (2010, p. 68) raised a question how to maximize the benefits of physical materials in developing new ideas, whilst avoiding the practical and cognitive limitations they create. For this reason, the interactive use of gestures, talk, and material artefacts helps design teams to find design solutions beyond the existing models and prototypes. As Murphy's study (2005) demonstrated, it is possible to imagine the design in action by simulating it with hands, words and graphics.

The way the design project is approached and, therefore, also the final outcomes are very much a product of personalities and skills of those involved, and further, the process itself influences the participants (Cross & Cross, 1995). Typically, first-year university students have widely varying skill levels in sewing and form giving with textiles. For example, at the beginning of the session, one member in Team Car brought out spatial details like darts and seam lines, but the others had difficulties in imagining how the three-dimensional form is developed in two dimensions. Their process gradually led to a common understanding about the design situation and they decided to make a cushion-like form for the car (see Figure 5).

Team Unto – collaborative construction of the design object

On the basis of three level analyses, it appears that working with wire and fiber fabric best supported these students' spatial thinking. In Team Unto, the students were constructing the shape of the toy from the very beginning of the session. The basic form of Unto, "just like a tepee", was articulated already at 01:45, when building of the wire framework began. The results indicated that the appropriate social and material design setting facilitated joint design thinking, productive conversations and shared efforts among the students in Team Unto. However, the third CORDTRA diagram (see Figure 7) involved fewer problem-solution statements with pointing and descriptive gestures than the other two CORDTRA diagrams. During this event, students A and B were focused on pattern making and student C was finishing a cap for Unto:

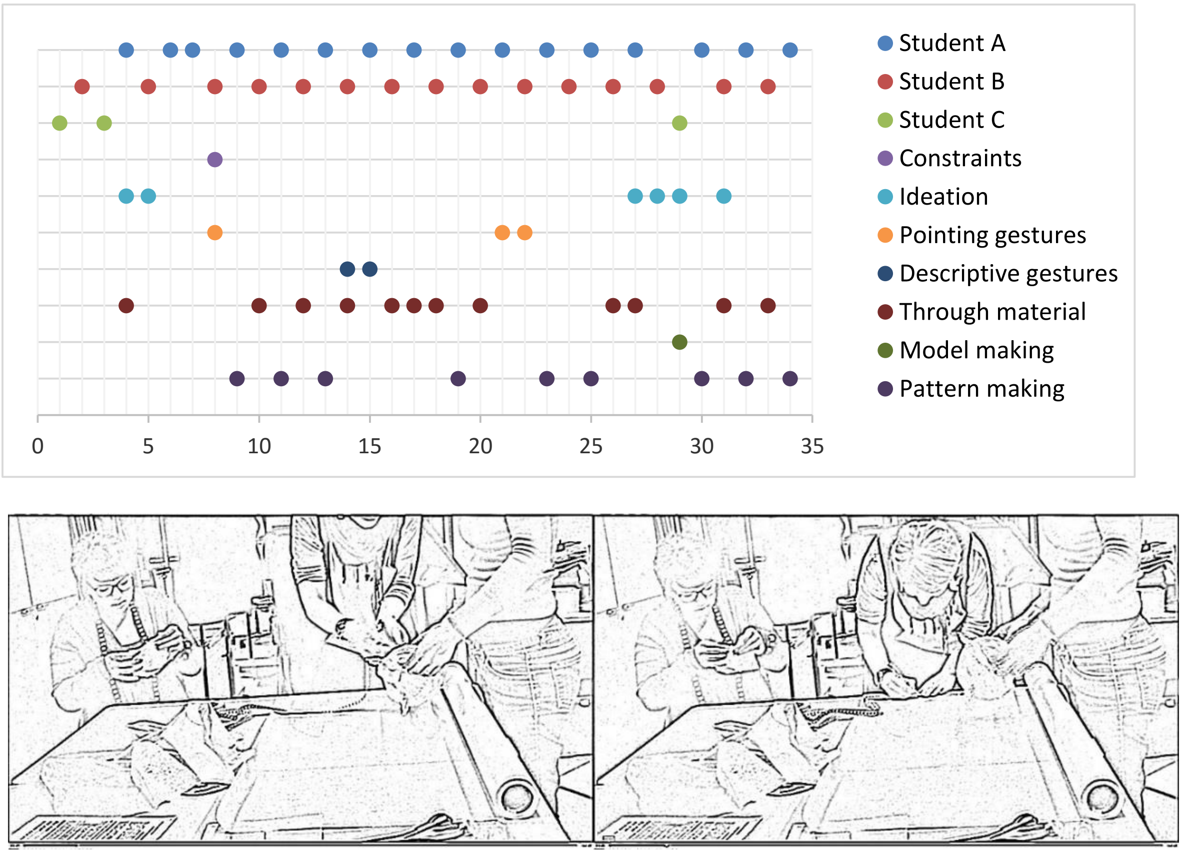

Figure 7: CORDTRA diagram from the third selected event (60:40–63:40) in Team Unto and model making related to the utterance No. 29 and pattern making related to the utterance No. 30.

26 B: Should we take from here... and go in this direction? [description through material]

27 A: Is the purpose of this to take the diameter a little thinner because this is so high? [description through material]

28 B: No, in my mind it doesn't need to be.

29 C: I think it could be a bit wider by the bottom. [model making] [A measures with a measuring tape]

30 A: It's pretty close to 19 centimeters. [pattern making]

In successful collaboration the whole pattern of conversation is focused and coherent, and the team members build upon each other's contributions (Cross, 2011). Team Unto managed to construct a coherent design context by structuring the design problem and by sharing and testing design ideas in order to generate solutions. Besides conversation, the whole set of material artefacts made by Team Unto appeared to be coherent (see Figure 1 and 8). Overall, the results of the different modelling techniques in three design teams support previous notions of the value of design artefacts as a medium for stimulating and developing ideas. Nevertheless, the present evidence is that drawing and sketching alone is likely to hinder rather than promote idea development among novice designers.

Figure 8: The model, prototype and final product made by Team Unto.

In general, we can conclude that the students in all teams took responsibility for their design learning—they determined the design context and how to proceed with the given materials. This required a shift from teacher-centered to student-centered learning and from individual learning to group learning. However, it was typical that students wanted to know if they were doing the "right thing" during the collaborative design process (see also Ashton & Durling, 2000). For this reason, a carefully formulated design brief is an essential part of the design learning process. Students should be encouraged to understand the nature of the open-ended and authentic design assignment and to create user-centered designs based on criteria determined by the students themselves.

Discussion

Embodied cognition stresses the way tools, physical materials and social processes all work in concert in order to support sense-making processes. In our study, we have looked at how given materials impacted on problem definition and idea development during the collaborative design session. The modelling materials—i.e., masking tape and thin cardboard or wire and non-woven interfacing fabric, especially—appeared to facilitate exploratory and explanatory design activity. On the one hand, these materials helped in generating 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. Even the design team with a pen and paper used paper once as a material for construction by folding a detail of the shape. After all, as Ramduny-Ellis et al. (2010) remarked, rather than limiting students "to a single prototyping material, a combination could be offered at different stages of design to observe which are chosen, how they are used, and indeed when they are not used at all" (p. 69).

Despite rapid technological change, material representations (e.g., hand-drawn sketches and mock-ups) continue to have a place in exploration and idea generation within the design process (Charlesworth, 2007). It seems that simple material tools support students' design process and could be applied to different design settings (see also Alesina & Lupton, 2010; Ramduny-Ellis et al., 2010). However, it is also important to have contact with real construction materials (i.e., embodied experiences). In craft processes this is natural (see Ekström, 2012; Illum & Johansson, 2012), but the power of embodied experience is evidenced, also, in other design disciplines, such as architectural education (Gore, 2004). Our study focused on the modelling and pattern-making phases whereas contacts with prospective fabrics became realized in the making of the material collage, prototype and final toy. Moreover, the students discussed material choices slightly along with modelling, for example the use of stretch fabric or special filling materials in order to get desired features for the toy.

Since the present study involved intensive investigation of a small number of students, the data do not support the drawing of comparative conclusions; in particular there is no direct evidence permitting the assessment of the degree to which students' performance may have been better with some alternative design materials and tools. Instead, the designing of the toys illustrated the connection between conceptual, material and embodied thinking. Material artefacts allowed the students to interact with one another through the object itself, as design activities were mediated and made visible through them. Materiality affected both the process and the outcomes of design activity, constraining and inspiring the work of the students. In addition, differences in children's drawings likely influenced on the nature of the design process. More abstract drawings required more interpretation among the students, and thus they fed students' imagination and communication. Besides material artefacts and verbal statements, embodied actions played a substantial role in the collaborative design process. Collaborating craft makers can indeed come to know the design world and its distinctive properties through exploration and work with their own hands.

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