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The Knowing Body in Material Exploration

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ABSTRACT

This article explores the role of the knowing body in material exploration and highlights the body as an important contributor in the formation of knowledge in the field of design. Our research involved gathering drawings, diaries and weekly and final reflections from 19 Masters students in Design during an eight-week course. Out of this data, we selected two student cases for our study. We analysed their material exploration processes from the point of view of their embodied engagement with material and found that previous tactile impressions and images of materials are important in the choice of materials, and that the actual physical manipulation of materials helps in resolving complicated spatial design problems, as the design is taken into the lived experience. The findings suggest (1) that the transition from the student's two dimensional design process to physical material explorations is complicated due to the change of modality, and (2) that previous material experiences, gathered through the body, guide the student already in the imaginary material exploration, even before physical manipulations start. As a result we suggest that experiential knowledge formation in physical material exploration is an important element in general design education.

KEY WORDS

Body, experiential knowledge, material exploration, design education

INTRODUCTION

The role of the body is not yet fully recognised in the process of knowledge creation in today’s society, where cognitive abilities are valued and stressed (Claxton, 2012, p. 1). In contrast to this, the creative fields—art, craft and design especially—are concerned with knowledge generated through bodily interaction with material.

This experiential knowledge relies on sensorial information that is situated, subjective and often implicit, evading explicit formulations (Biggs, 2002 & 2004; Niedderer, 2007; Neidderer & Reilly, 2010).

Considerable amounts of research in the art, design and craft field are focused on investigating the possibilities of gaining knowledge through making, and reflecting on the produced artefact (Biggs, 2002 & 2004; Mäkelä, 2007; Niedderer, 2013). In contrast, only little attention has been attributed to the body in the formation of knowledge in this context. Through the emergence of embodied cognition studies (Johnson, 1987; Lakoff & Johnson, 1999; Noë, 2004, 2009; Varela et al., 1991), the theoretical ground is laid for including the body in the knowledge generating process and also in the field of art, design and craft. Although art and design fields to a large degree involve the senses and the performance of the body in daily practices, relatively few researchers have touched the issues of embodiment in connection to design and material exploration (for examples see: Fredriksen, 2011; Groth et al., 2013; Groth et al., 2014; Kangas et al., 2013; Ojala, 2013; Rompay & Ludden, 2013). While embodied cognition studies have not yet considered design issues properly, design studies have just recently started considering issues of embodied cognition.

For this research we utilized the Qualitative Case Study Methodology developed by Robert Stake (1995) and Robert Yin (2003). We present two students’ material exploration processes that took place in an educational context. The students were participants of the Design Exploration and Experimentation course (DEE) at the Aalto University, School of Art, Design and Architecture, Department of Design, in Helsinki, Finland. The course supports the students’ own explorative process from concept to artefact, and material explorations are recommended.

Some of the themes that emerged from the analysis were touching on issues such as: the students’ use of their previous embodied knowledge in overcoming challenges with new materials; the importance of the tactile aspect (using the sense of touch in the decision making process regarding materials); and the felt experience of materials (including its link to emotions and shared social and ethical values). Most importantly, we detected an imaginary material exploration phase which preceded the physical material exploration.

In this article we focus on this imaginary material exploration in between the sensitive transition from drawing and planning to material implementation in the design process. We discuss how the phenomenon may be seen from the point of view of embodied cognition, as we believe that the students used their experiential knowledge in overcoming their difficulties during this phase of designing. Following from this, we present the theoretical frame that has informed our study by discussing how embodied cognition is rooted in phenomenology and the study of experiential knowledge. We then link this way of thinking to how embodied cognition might be understood from a practitioner’s point of view in the field of art, craft and design. Finally, we describe our research setting and discuss the two cases in detail.

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THE KNOWING BODY

Many fields, not least the creative arts, are based on implicit knowledge that is intuitive and immediate, without apparent reasoning. This may seem as not requiring the mind to work. For example sport is sometimes mistakenly referred to as an occupation that ‘involves lesser kinds of thinking, or none at all’ (Claxton, 2012, p. 1). The body is thus being perceived of as the non-thinking agent, and the mind as the thinking agent.

This dichotomy is being challenged by embodied cognition theory. Embodied cognition theory is based on the philosophy of the mind, specifically phenomenology that most strongly argues for the knowing body. Phenomenology holds that, due to having a body, we are restricted to a subjective view of the world seen from the perspective of our situated body. The world shows up for us and we perceive it as such through our senses (Husserl, 1907/1989). But, since our body is kin-aesthetic, we can move to a new position and perceive the world from another perspective. In this way we accumulate our knowledge by movement and interaction with our surroundings.

The French philosopher Maurice Merleau-Ponty further developed the idea, especially in his book *Phenomenology of perception* (1962/2010), where he elaborates on the body as the center of knowledge making and lays part of the foundation for embodied cognition theory. Enactivist theory, a branch of neuroscience, confirms the embodied cognition theory and shows how the human mind is built by the interaction with the environment (Varela et al., 1991). Neuroscientist and Philosopher Alva Noë further elaborates the research of Francisco Varela et al. (1991) in the field of cognitive science and questions the mind as the sole knowledge creator and even the brain as the sole place for the mind or consciousness (Noë, 2004, 2009).

Through embodied cognition theory, we may draw a different image of the body and mind that is perhaps easily recognizable by practitioners in the creative fields. We can suggest that the mind, instead of being situated only in the head, would be distributed throughout the experiencing body (Noë, 2009). Through our attention we specify a part of the body that is extra mindful at specific times (Varela et al., 1991)—for example when listening to a specific sound, tasting wine or threading a needle. In this respect we can understand our whole body as a thinking thing as opposed to only our mind being a thinking thing (Noë, 2009). The mindful or knowing body is the position we argue from throughout this article.



Figure 1 /
DEE course student's material exploration.
Photo by Camilla Groth.

DATA COLLECTION AND ANALYSIS PROCESS

We investigated the role of the body in material exploration by utilizing data gathered from the DEE course. The eight-week intensive course works as an educational experiment and research platform focusing on design students' personal creative process and their individual way of managing its phases (Kosonen & Mäkelä, 2012; Mäkelä & Löytönen, 2015). The students fill in consent forms regarding their participation in the research that is conducted in this platform.

Each year around 12 students participate in the course (figure 2). The course was designed especially for students that study in the Industrial and Strategic Design program, as in their curriculum studio-based practices were rare and individual design projects were often replaced by group work. However, it seems that the design students benefit from handling processes typical to fine art (see for example McDonnell 2011, p. 569).

During the course the students document their process in working diaries and share its phases in weekly and final reflections (figure 3). The final outcome of the process is an artefact that is presented in an exhibition (figure 4). The students first develop their concepts with the help of different types of drawings and representations. This is considered as a typical way for designers to approach design tasks (Goel, 1995; Rodgers et al., 2000, p. 451; Scrivener et al., 2000, p. 465). When the design is developed to a convincing stage, material exploration starts. In a few cases material exploration starts in a very early stage, letting the material agency affect the concept creation.



Figure 2 /
DEE course students and teachers on an
inspirational journey to Heinävesi.
Photo by Jaana Lönnroos.

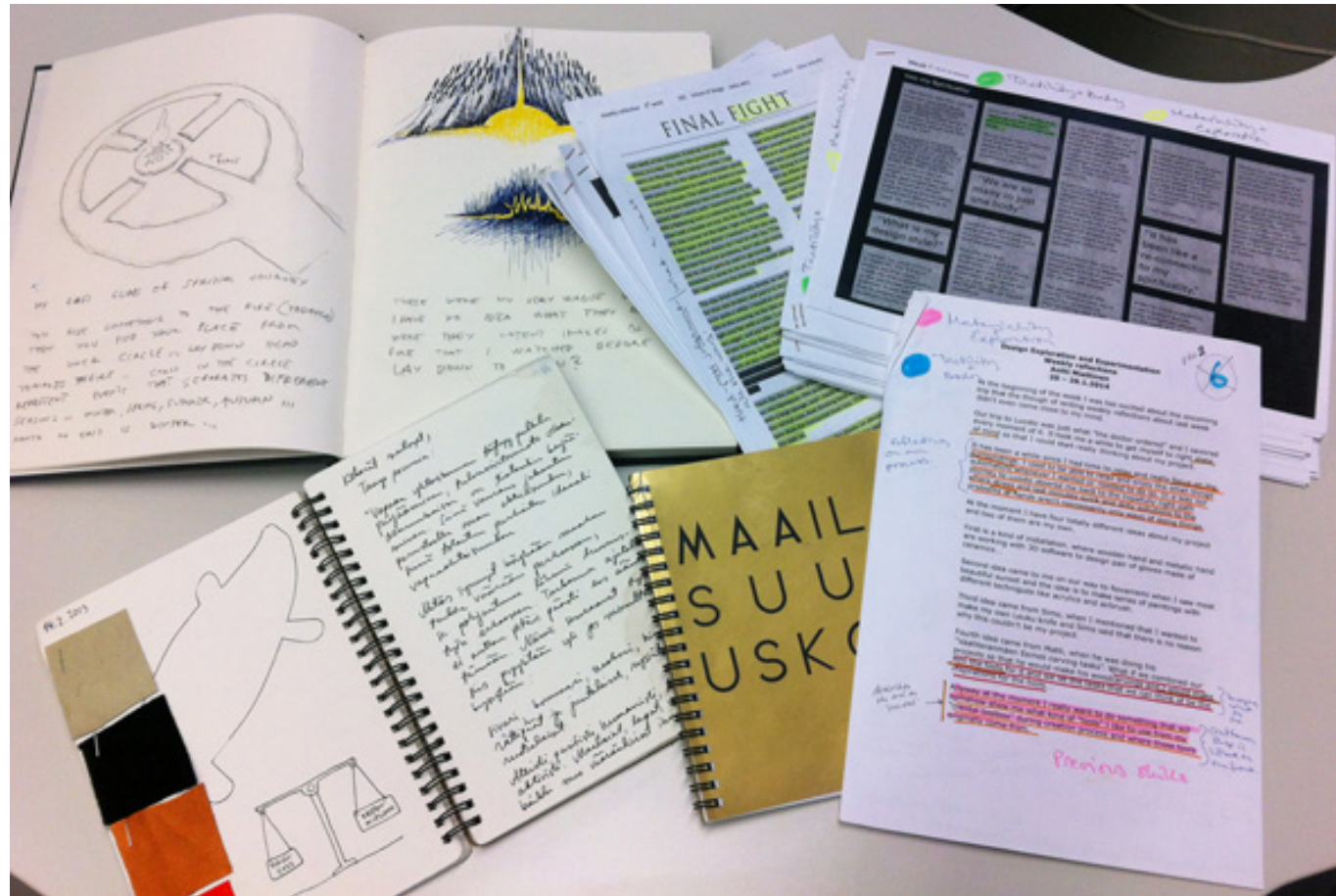


Figure 3 /

Top Left: Examples of the weekly reflections, diaries and final reports produced during the DEE Course.

Photo by Camilla Groth.



Figure 4 /

Bottom Left: The DEE Course Exhibition opening at the end of the eight weeks long process.

Photo by Camilla Groth.

In this study, in order to see what themes were emerging from the data, we first made an initial analysis of all data gathered during DEE courses from two years, involving 19 students in total. Based on this initial analysis, we selected two cases that were closely linked with our specified theme for the research at hand, i.e. material exploration and, in particular, a connection with embodied cognition.

The data chosen for the deeper analysis consisted of the two students' own diary notes, drawings, photographs, weekly reflections and final reflections produced during the course, one case being from the year 2013 and the other from year 2014. As the focus was on the students' use of their body in knowledge creation during material exploration, we chose two students whose processes were rich in this type of data. Although their cases are similar, their processes are not, and so being they highlight different aspects of embodied knowledge in the design process. By presenting these processes in a dual case study we are able to complement the image and show how the cases confirm each other.

As the students seldom reflect openly in their reports or diaries on their experiential knowledge or bodily interaction with the material, we also interviewed the two students. The questions were open questions followed by a directed question based on the themes of tactility/body and material/exploration. The students were not told what themes were searched for in their answers. The transcripts of the two interviews were analysed through a thematic content analysis (Fereday & Muir-Cochrane, 2006). Furthermore, when related drawings and visuals were available, they were utilized to give more depth to the content analysis. The quotes and transcripts of the interviews were translated from Finnish to English.

The combination of inductive and deductive coding enabled us to take the theoretical aspects of embodied cognition into account in our analysis process. The initial themes were searched for on the basis of our theoretical framing, that is the themes of tactility/body and material/exploration. Subsequently these were developed according to the themes that were emerging from the data.

The emerging themes from the analysis touched on the issues of how the students used their previous embodied knowledge in overcoming challenges when encountering a new and unfamiliar material. The artefacts made were found to carry with them embodied memories of felt experience from the time of making. The tactile aspect of the materials and the use of the touch sense was important on many levels, but especially in the process of deciding which materials to use. In encountering a new material, the two students referred to skills gained in other materials—thus utilizing their previous experiences and general embodied knowledge to overcome new material challenges. The felt experience of materials was also linked to emotions and shared social and ethical values. As noted previously, mental material exploration was detected to precede the physical material exploration.

CASE DESCRIPTION: ANTTI

The theme of the 2014 DEE course was *Journey*. Antti and his fellow students travelled to Lapland for five days to gather inspiration for their individual projects (figure 5a). As the course proceeded, Antti's project became 'a journey of material exploration' concerning the physical feel of a material and how we are fooled by our senses when one material is juxtaposed with another—leaving a feeling of the material to be somehow 'wrong'.



Figure 5a & 5b /
Below: Snowy landscape and one of the DEE students in Lapland, Finland (a) and local crafts (b).
Photos by Antti.



Antti has a craftsman's background: he is a metal smith by his first education. He was inspired by the Lappish craft (figure 5b), especially traditional leuku knife, a large and heavy knife used for light wood chopping and butchering, and he decided to make one just as a starting point for the course. Without much drawing or planning, Antti started his process by approaching the material. Not having the appropriate material at hand though, he made the blade for his knife out of aluminium instead of steel, thinking that it was good enough for a mock up (figure 6a). Making the knife in parts, he only experienced the whole after he had assembled the parts, and was stirred in his senses when he picked up the knife from the working table:

I felt like 'what on earth is this?' It looked like a leuku, but when I picked it up it didn't feel like a leuku at all. That weight is so confusing! You just know it is not real.

After this experience he decided to explore different materials (figure 6b) from the point of view of what they felt like in relation to their expected use and function: If the leuku knife were to be made of glass, or ceramics, what would it feel like to hold? What would it have left of its functionality? Would it be a tool, or reduced to a mere concept of a tool, or would it become an art object?



Figure 6a & 6b /
Above: The leuku blade being made in aluminium (a) and leuku knives in glass, steel, ceramics and aluminium, made by Antti (b).
Photos by Antti (a) and by Camilla Groth (b).



Antti writes in his final report that he had known the difference between a real knife and a replica for the tourist industry since he was a child. He thought everyone knew the difference, but was surprised when meeting tourists who thought they had bought a real, functioning knife. He says that even if the knife looks real, you will immediately recognise it as a replica the moment you try to use it.

As Antti started designing the leuku knives in different materials, he was intrigued to use ceramics, a new material that he had not used before. The difference between the imagined use of ceramics in his design and the actual making with clay took him by surprise. When confronted with this new material, he was confused at first due to the unexpected feel and behaviour of it. The uncontrolled material gave him a feeling of distrust in himself as a maker. In the interview he says that he had no help from previous knowledge of other materials as the clay was behaving in a completely unexpected way (figure 7).



Figure 7 /
Below: Ceramic material tests. Antti utilized his mould making skills for metal in the moulds for cast porcelain, but the clay is not behaving as molten metal. Photo by Antti.

I had practically zero experience of ceramics. I had no use of my mental skills toolbox in this case; the material was just behaving too differently to what I was used to.

In his working diary (figure 8) Antti draws an image of the skills he has accumulated during his life, naming them his 'toolbox'. In the interview Antti is referring to these as his 'mental toolbox' although they are very body-based practises. It is clear that he has many different kinds of skills and therefore also many skill-learning experiences in his life. During the interview he says that he is used to trying old 'tricks' and methods that have proven useful in previous situations when confronting new materials. He also considers new materials a positive challenge.

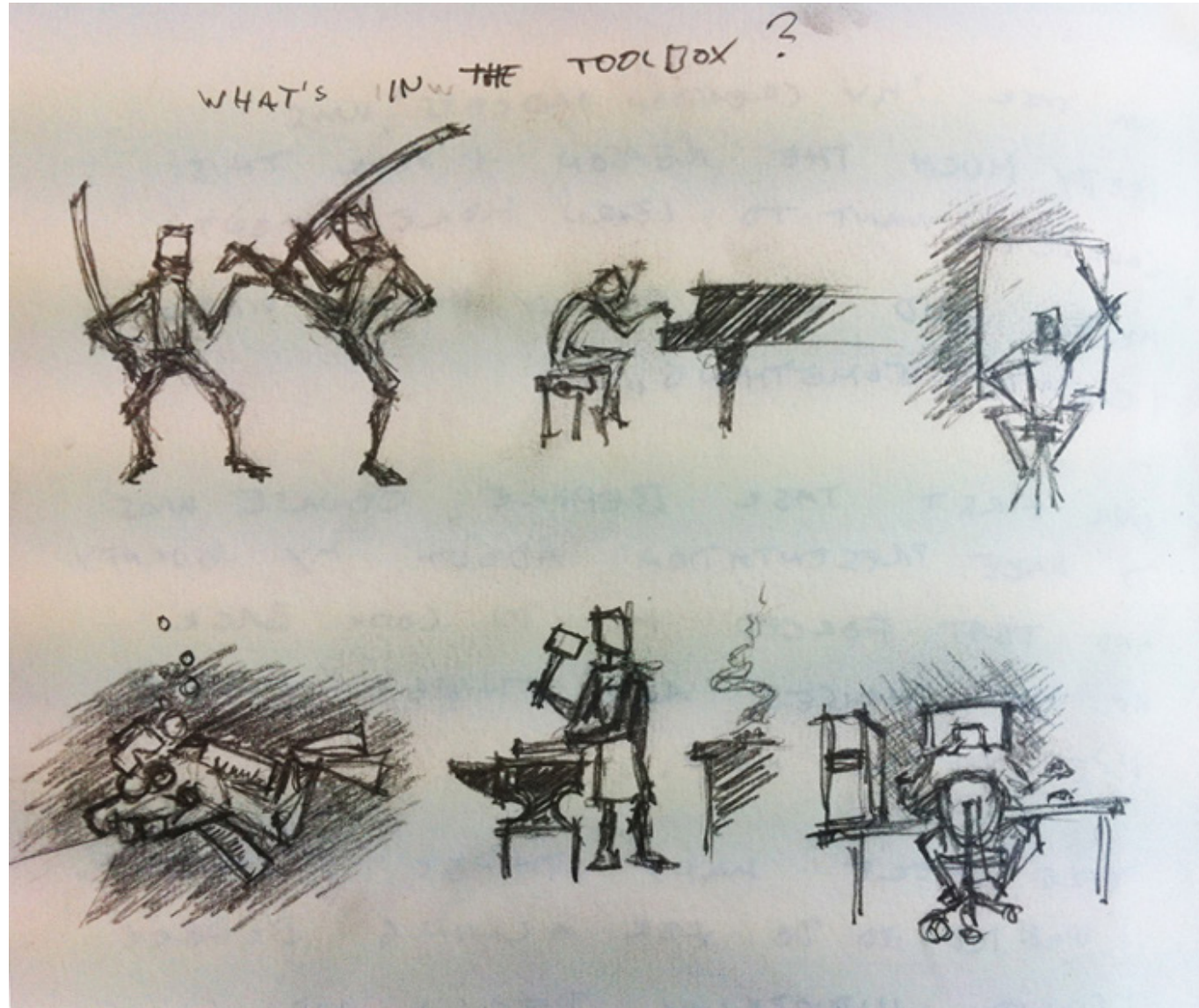


Figure 8 /
Above: Figure 8: Antti's diary drawing depicting his skills 'toolbox'. Photo by Camilla Groth.

Although maintaining that the challenge of the new material, ceramics, took him by surprise and that he had no help from his previous skills, he is still clearly using working methods from his own field in tackling the material. When feeling helpless in front of the soft and plastic clay, he waited until the clay hardened a bit. In this way, he was able to carve the shape of his leuku knife handles (figure 9a) out of the clay, with a knife. He then smoothed the surface with sand paper, utilising the same method he would have used when making wooden knife handles.

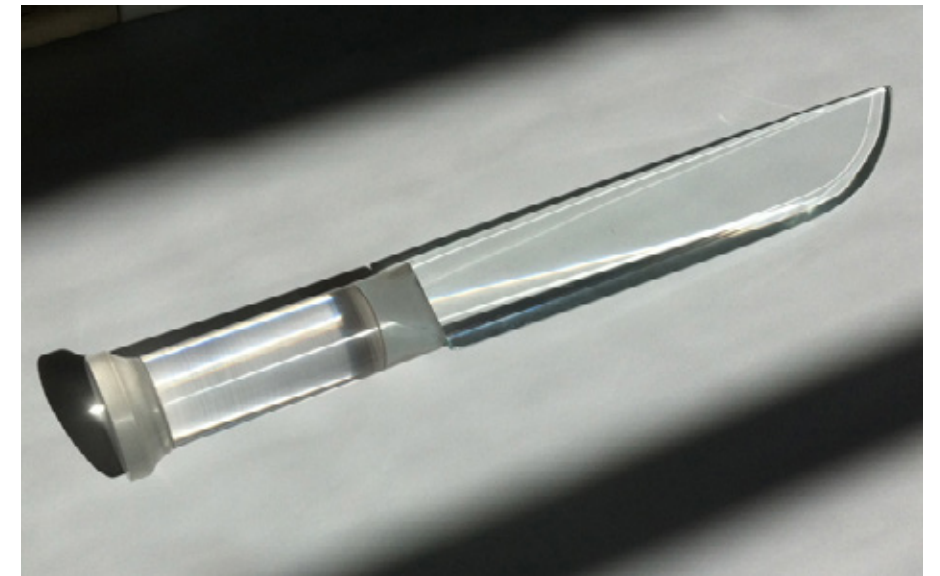


Figure 9a & 9b /
Clay handles for the leuku (a) and the glass leuku knife made by Antti (b). Photos by Antti (a) and Camilla Groth (b).

In Antti's case, the end result of the course was a selection of leuku knives that create a mixed feeling in regards to the expected feel of the materials, playing on our general notion of embodied material knowledge (figure 6b). In the interview, Antti describes the feel of lifting the glass leuku (figure 9b):

It feels so strange. Like if it was only an idea of a leuku knife. This is like the construction of a knife made by someone who has never known what a knife is used for or who doesn't know what kind of entity uses one.

CASE DESCRIPTION: SALLA

Salla participated in the DEE course in 2013, when the theme of the course was *Religion, Belief and Faith*. The students travelled to Heinävesi, a site for Orthodox religion in the east of Finland. Salla felt her own position as a Lutheran Christian more determinedly in contrast to the orthodox traditions, that to her seemed overly artificial and materialistic.



Figure 10 /
A nun in the Lintula Convent, Heinävesi, Finland.
Photo by Chien-Ting Hsu.

During the course Salla worked on her concept of a *non-God* in response to what she experienced at the Orthodox convent in Heinävesi (figure 10). The work was based on the idea that the biggest religion in the world is money. She decided to make a natural-size golden pig for the worshippers of this money religion (figure 11a). The material choice for the pig was important and Salla went to great lengths to find the right 'feel' of material that would fit her purpose. The emotional feeling that the finished pig should awake in the audience is the feeling of disgust and meanness, but at the same time of wealth and luxury.

In her working diary Salla set about her material exploration by listing materials that could be interesting and then striking out the ones that were not disgusting or luxurious enough. She then made four physical models (figure 11b), using the four remaining materials on her list. In the interview she describes these tests as her most significant material tests, as through them, it was possible to compare the tactual experience of the materials:

It was important to make these four small pigs in different materials so that I could get to feel and see them; well most of all to feel them as in the end the way they look is not that different.

In her final reflection she explains that the small padded pigs helped to evaluate the emotional connotations of the materials—such as too kind, too cheap or too nice for her intentions. During the interview she adds that by making tactual pigs, she was also able to let her friends and fellow students feel and evaluate the materials, in this way confirming the social and ethical value and general understanding of the material:

And of course, since I had made those little pigs, I handed them to people and asked what they felt and what impressions they got from the material. Which one they found the most disgusting.

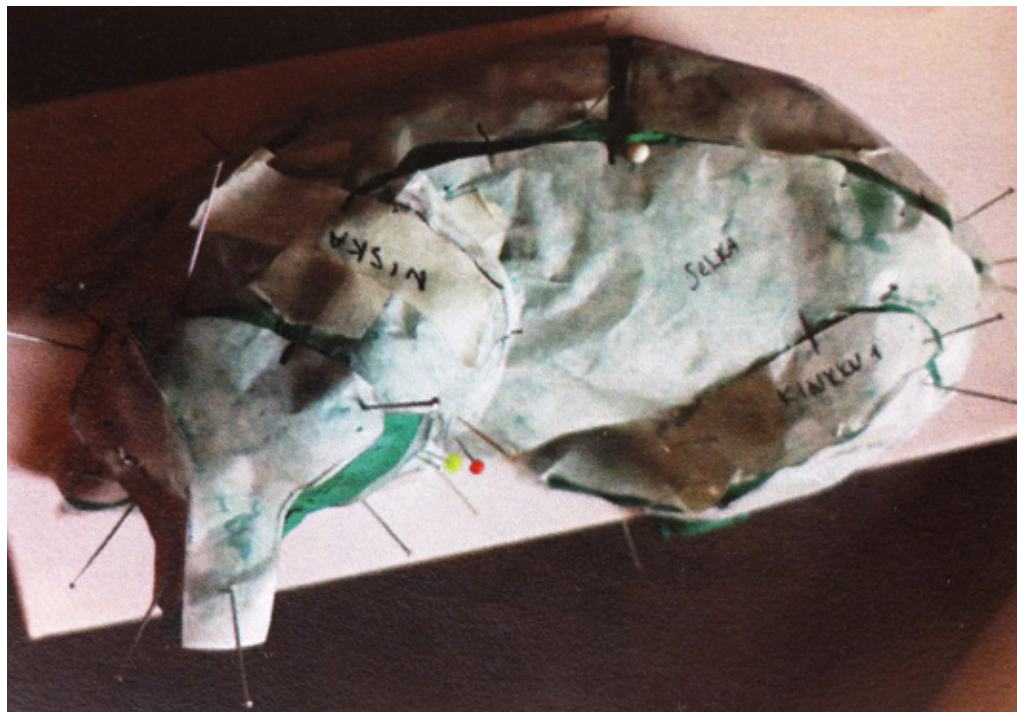


Figure 11a & 11b /
Drawing of the golden pig by Salla in her working diary (a) and Salla's pig-shaped test pieces made out of velvet, satin, leather and plastic (b).
Photos Camilla Groth.



In her final reflection she lists the materials and the notions connected to them as a result of her own and her friends' opinions. She found that the plastic pig was experienced as the most disgusting but since it was plastic it was also seen as a cheap material and thus not experienced as luxurious. Men thought the velvet was most disgusting while women liked it and thought it was comfortable. Leather was agreed to be the most disgusting, luxurious and mean material.

Figure 12a & 12b /
Salla's play dough pig model (a) and the model
with tracing paper showing the seams and shapes
for the leather parts (b).
Photos by Salla (a) and Camilla Groth (b).



When Salla had made the decision to go for the leather material, she made a small model of the pig in play dough. She needed a body to model her leather pieces over, because she could not imagine what shape and size the joint leather pieces would have to be cut into. But the change of prototyping material, method and mind-set from two dimensions to three dimensions was not uncomplicated. A dressmaker from her previous education, Salla was unfamiliar with moulding in play dough, she was surprised that the smallest changes in the moulding process changed the entire object from all sides. Finally a small model of the pig was made (figure 12a). Salla placed tracing paper over the pig (figure 12b) in order to simulate how the leather would be cut and constructed, and finally sewed into the shape of a pig.

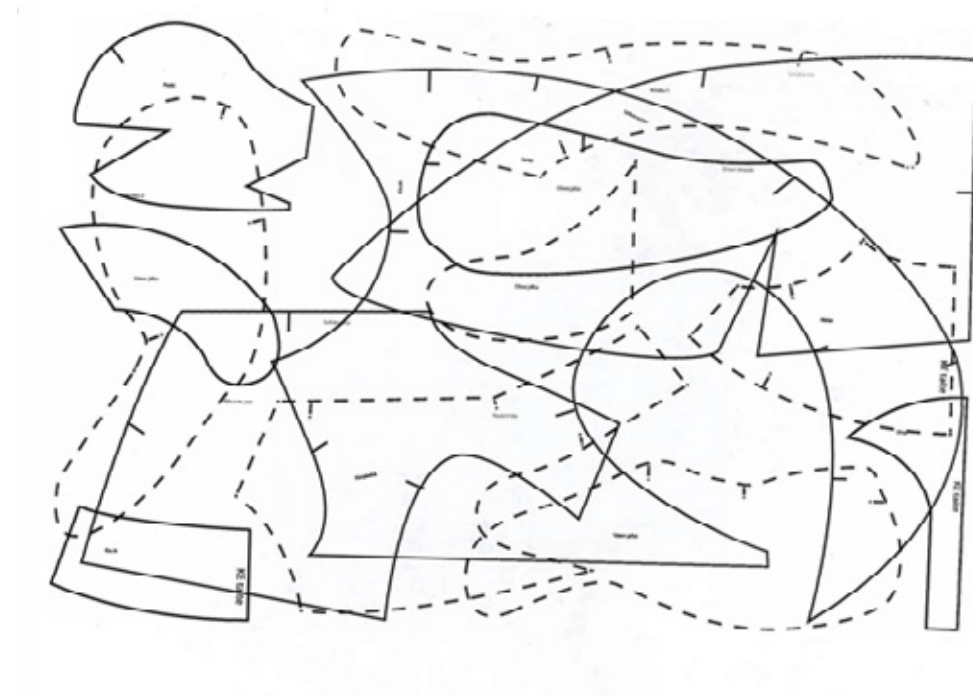


Figure 13 /
Design for cutting the leather parts for the pig.
Vector image by Salla from her final report, 2013.

The tracing paper pieces were copied and converted into vector lines on a computer, then enlarged 700% (figure 13). The leather was then cut accordingly in 1:1 size. When the pieces were sewn together, a new material surprise lingered ahead. The massive amount of leather, eight leather jackets that went into making the pig, weighed tens of kilos. The plan to fill the pig with chicken net and cotton had to be revised and strengthened with a metal construction. The result is a natural size pig (figure 14).



Figure 14 /
The Golden Pig by Salla, photographed in
the DEE course exhibition by Camilla Groth.

DISCUSSION

Both Antti’s and Salla’s material exploration was about the felt experience and the feel of materials. The feel of the materials is connected to emotions evoked by the material, either when viewed or when touched directly. It is only with previous experiences of materials that there is a pre-knowledge to judge new experiences against. We connect these general understandings of a material to the embodied knowledge of these materials, which is revisited in the design process before actual physical manipulation. Both students were working with this type of embodied knowledge, and they based their work on the belief that the viewer shares their general understandings about the materials used.

Often a material has general connotations that may be utilized in the transferal of a certain feel through an artefact (Rompay & Ludden, 2013, p. 7). Some materials have use-areas that are commonly known and are attributed with expectations of a certain context. Other materials convey an emotion based on what the material feels like. The material feel links to feelings and emotions that work as motivators or as hindrances of the project. Both Salla and Antti were connecting feelings and emotions to the touch-feel of a material, using the same word, ‘feeling’, for both emotional feeling and physical touch related feeling. In Sallas’ case the feeling is connected to atmospheres and images that the felt experience connects to. In Anttis’ case it is a more personal feeling of contentedness, discomfort or confusion towards the right or wrong feel of a material. Even so Antti expects other people to have a similar expectance and experience as he has towards the material, and his artwork plays with exactly this notion.

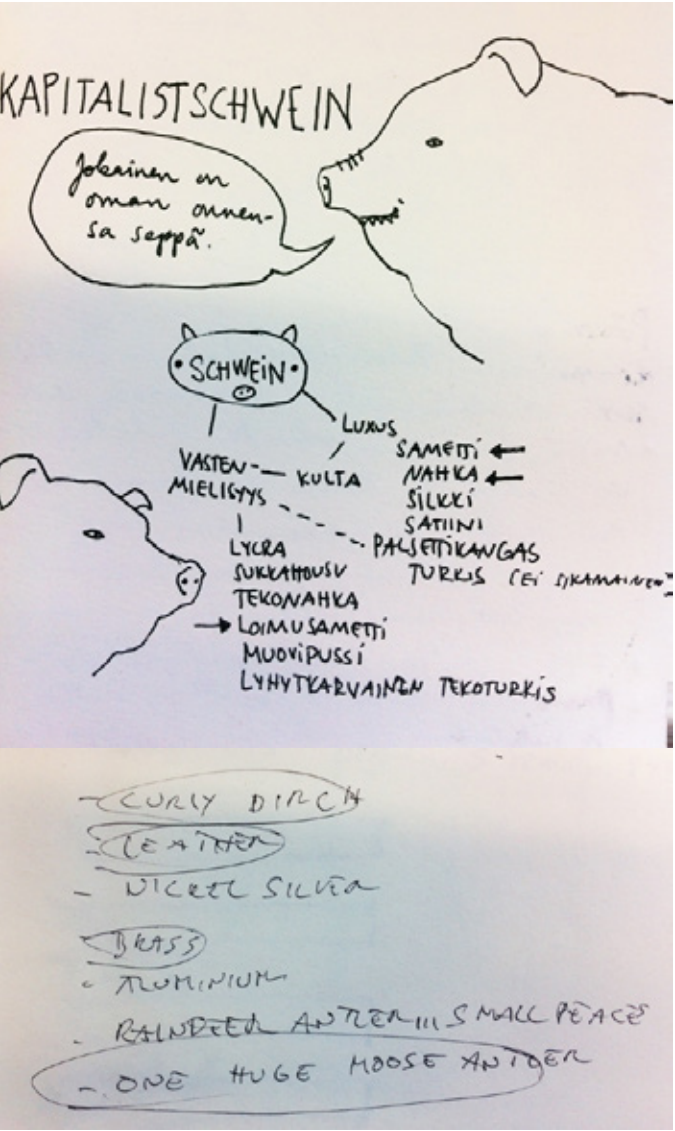


Figure 15a & 15b / In Salla's diary material choices are indicated by arrows (a) and in Antti's diary by circling (b). Photos by Camilla Groth.

IMAGINARY MATERIAL EXPLORATION

Before starting the physical material exploration for their final pieces, both Antti and Salla go through a sort of imaginary material exploration of potential materials. In the interview, Salla reports that she did most of her material exploration in her head:

I never really made that many material tests because I was imagining mostly in my mind what the different materials would look and feel like. That’s how I reduced my choices.

She explains further that in this imaginary material exploration, she tried to imagine what the different materials were like. She brought to her mind objects that were made of these materials and their contexts that she had encountered previously:

I was thinking of objects that typically are made from those materials, and what images they brought to my mind. Even before I made the little pigs, I listed different materials and their properties.

Both Salla and Antti list materials in their diaries that they try out in their imagination before making a decision for which materials to include or exclude in their physical material exploration. In Salla’s diary, the chosen materials are in the process of being indicated by arrows (figure 15a) while in Antti’s diary, the chosen materials are circled (figure 15b).

In our discussion Salla links the touch feel of the material with cultural and social connotations and contexts that are connected with the material generally:

It is not only the touch feel, but also the combination of memories and images linked to the materials and in what circumstances they have been seen or what kind of reputation they have generally. For example if it is connected to a bourgeois living room like velvet, a shiny BMW like leather or an evening dress like satin. Or then ‘throw-away’ culture as in plastic.

It is evident that the imaginary material exploration process is based on previous bodily encounters with the listed materials. The potential materials are not explored in drawing form, but they are listed in writing and then imagined. Both students hold the opinion that materials are too difficult to draw from memory and that a drawing describes a material’s properties poorly. In the interview Salla says that drawing takes her to a certain point in designing, but to get to the next level she needs physical material exploration:

I see drawing more like searching for a shape and giving shape, the material is what brings it to the next level. Drawing or modelling on a computer is about what it looks like, and how it works. But the material is about what feelings it awakes. OK, the material is also affecting the way it works but anyway it is the emotional side that is important. By drawing you can of course imitate materials but it is never at all the same.

In the interview, Antti describes the same problem:

How would I be able to draw a material? If I draw something that looks like glass on paper, I imagine what it looks like, how it reflects light and what I can see through it, but it still doesn’t convey anything about the material. It is only imagination... The information that a drawing can convey is much more narrow compared to what the artefact conveys.

In both cases the selection of materials are imagined as lived experiences and applied mentally as the material of the new artefacts that are envisioned in their minds. In this process some materials are deemed not worth trying and others are considered for being tried out in physical form. Although availability and economical strains affected the material choice to some extent, the final decision of which material to take further is in Salla’s case determined by touch. Only after physically confirming her imagined experience of the materials, she made the final decision to go with leather as her material. In the interview Salla reports: ‘What finally determined my choice was the way the material felt in my hands. Because it confirmed my image of it and the connotations the material conveyed’.

Touch thus played an important role in the decision making process as it confirmed the imagined image of the material. Salla goes on to explicitly say, that vision is giving only half of the perceptive view, and touch fills the missing part:

Touching confirms what is expected, especially with familiar materials. If the materials are new, then one might have some expectations that can become different after actually touching them. It’s like you get only half by looking and remembering and then holding it completes the impression.

We link the phenomena of the imagined material exploration to the dual-space search investigated by Pirita Seitamaa-Hakkarainen (2000), who developed a model around the design process as relying on two design spaces. The first of these is the *composition space*, i.e. visual designing, including shapes, patterns and colour. The second is the *construction space*, i.e. technical designing, including materials, construction and technical details (ibid, p. 2). According to Seitamaa-Hakkarainen, the designer is performing a *dual-space* search back and forth between these two design spaces in order to solve design related problems, even before starting the physical material manipulation. The constraints of the material properties are also considered in this process, and experts have an advantage over novices due to their larger amount of domain-specific and experiential knowledge (Ibid, p. 2). Seitamaa-Hakkarainen draws on Anttila (1993) and explains that the designer creates an internal image of the finished

design and through testing redefines this image until the image meets the realized design when finished (see also Ahsen, 1984). We suggest that the imaginary material exploration (that may also be described as part of a dual space search and refinement of an inner image of the finished design) is based on experiential knowledge gained through bodily interaction with materials over time. The choices and decisions on materials in the design phase are made based on previous bodily experiences and shared conceptual notions of the materials in question. Our case study proposes that in this space, between the imagined design and the material implementation, many students dwell for a considerable amount of time, before initiating physical material exploration.

THE LIVED EXPERIENCE

When the physical material exploration is introduced, the design switches modality and enters our physical world of lived experiences. The object or prototype has many sides and surfaces, some of them are on the other side from us, allowing us to see the whole object only through interaction with it and by turning it in our hands or by walking around it. In line with phenomenology, our knowledge making process is thus subjective and linked to the kin-aesthetic ability of our bodies, as we gain knowledge by acting with our environment. We can detect these elements in our students’ experiences of producing material artefacts or prototypes. For example, in her final course reflection, Salla describes her difficult process of transforming the two dimensional drawn idea into a three dimensional model:

From having drawn the pig several times I had a pretty good idea of what I was about to make, but the three-dimensional realization—expectedly—took it to a new level. The play dough moulding revealed challenges that I could not have imagined with my pen and paper. The smallest changes in the form made the pig look like a dog or a cow.

Taking the design into the lived experience, in the form of a prototype, may also help resolving spatial aspects unimaginable in two dimensions. Design researcher Kaiju Kangas (Kangas et al., 2013) describes how bodily interaction with a prototype aids in a problem-solving task. In her study, children were co-designing a lamp, but it was only when the children made the physical prototype that they were able to resolve the problem of the hanging construction that had puzzled them during the drawing process. The children used their bodies in measuring of distances and heights for the lamp and even climbed up the table to envision how the lamp would hang (Ibid., p. 39).

In a similar way, Salla was able to resolve the unimaginable aspects of her design by exploring them physically. Having made the play dough model of the pig, Salla fitted strips of paper over the model in order to envision how she needed to cut the leather material and where the seams might go (figure 12). In her final reflection she points out that this would simply not have been possible to do in two dimensions:

The assembling of tracing paper over the pig model was a useful way of extracting the complicated shape for the leather pieces. The shapes became very strange looking and my two dimensional working methods and imagination would never have been enough to create them.

EXPERIENTIAL KNOWLEDGE BUILDS ON PREVIOUS EXPERIENCES

In her research, design researcher and teacher Biljana Fredriksen (2011) studied children's meaning-making processes during their experiences of working with materials. She found that previous bodily experiences played a part in the sense making of new experiences (Ibid., p. 65). In our case study, both students are using their previous experience and skills in combatting the challenges of a new material. Antti's previous sets of skills might not have been the right skills for the task at hand, but nevertheless the skill of learning new skills aided him in overcoming the unexpected challenges in the sense making of a new material. Antti says in the interview that: 'A person, who does not possess any kind of material knowledge at all, will take a long time to learn about any new material'. When Antti was pouring liquid clay into his plaster moulds, the clay got stuck to the sides of the mould and would not travel all the way to the base (figure 7). The mould was too narrow and the plaster dried the clay before it reached the base of the mould unlike the hot liquid metal that Antti was used to handle. Antti solved this problem by lifting the jug of liquid clay higher and in this way he got more weight and pressure in the pouring stream, pushing the liquid clay all the way down to the base. This was a general principle he found successful in both specific fields and he used this "trick" in the new material domain.

Also Salla referred to dressmaking skills as she pinned the tracing paper over the clay dough pig model, something that a novice designer might not come to think of in a similar situation. We link this notion of expertise to Pirita-Seitamaa Hakkarainen, who found in her research on the composition and construction techniques of novice and expert designers in weaving that the experts were able to consider both the visual elements and the technical constraints in a parallel way in their design process, and that this helped them to succeed in their material implementation at a later point (Seitamaa-Hakkarainen 1997, pp. 153-154). Through this case study, we further believe that such domain-specific skills also help developing general design skills due to accumulated experiential knowledge—knowledge that may be used in a trial and error strategy.

In the group of 19 students whose work was initially analysed for this research, there were also cases where the material exploration was experienced as a real problem. For example, one of the students spent most of the time imagining different kinds of material solutions to his design, leaving the actual physical material implementation to the last few days with poor results. His ideas for a prototype were too complicated to be manufactured and every starting point had to be reversed or interrupted. In a video recording of a shared discussion on the students' intuitive making in material, the student said: 'My hands were not skilled enough to manipulate the material.' Later he also said: 'I could not make what I wanted to so I made something else instead.' Contrary to Antti and Salla, lack of previous material exploration and material skills deprived this student of any starting point for his material implementation, and the design was dwelling in an immaterial state until the very end.

Our findings are indicating the need to acknowledge the knowing body in design teaching. The implications of embodied cognition are now also getting attention in the general field of education. In line with this development, physicists Marcus Kiefer and Natalie M. Trumpp (2012) are pointing to the importance of real world material manipulation in education. According to them, appropriate sensory motor experiences are necessary for human cognition to develop at the highest level (Ibid., p. 19). They claim further that in line with embodied cognition studies it has been found that sensory-motor interaction with the environment

during learning results in more durable and richer knowledge (Ibid., p. 20). The important role of the environment and material manipulation in education has also been noted in another study in the context of the DEE course. In their study Maarit Mäkelä and Teija Löytönen (2015, p. 180) found out that matter can have an unanticipated or unexpected contribution to the learning process and proposes that materiality, in fact, has its own agency and thus teaches in its own way. (See also Malafouris, 2008).

As crafts persons and designers, we may understand learning a skill as training our mindful hands until they perform better. Our hands, in working with a material, slowly test, try, experience, fail, try again and in this way *change us* as makers towards becoming tuned in with the material. Enactivism and embodied cognition theory, as mentioned before, supports the idea that our interaction with the environment changes us and develops us (Hari & Kujala, 2009; Noë, 2004 & 2009; Varela et al., 1991). Through the perceptual feedback of our actions with the environment, or a material, we gain experiential knowledge that helps us recognise and judge future actions.

Drawing on Husserl's phenomenology, Merleau-Ponty sees sense perception as an original modality of consciousness, 'the primacy of perception' (Merleau-Ponty 1964/2010, p. 12). This means that when learning through experience, we cannot know what something is like without perceiving it. When we touch a material, we immediately become aware of it. Also Varela et al. claim that there is not first *sensing* and then *thinking*, but a sense-reflection that is a singular event (Varela et al., 1991, p. 19). They suggest that the nature of reflection, instead of being an abstract and disembodied activity, is rather a form of experience in itself (Ibid., p. 27). Our mindful hands know the shape, temperature, orientation and surface structure of the material instantly, as if our hands could think.

CONCLUSION

In this article we have acknowledged the role of the body in knowledge creation within the field of design. As a result of our case study we consider material exploration an important part of the students development into a skill-full designer. Drawing and concepts are fundamental when determining the shape and the function, but does not come as close to the lived experience, as does the material prototype.

Materials have an important role in conveying felt experiences that affects the emotion of the user. Further, materials have general connotations as we share concepts and understandings about their nature, images and values. Tactile aspects are important in the evaluation of which materials to use, as well as in evaluating the finished product. During material exploration the student has a possibility to iterate his concepts based on the physical interaction with the material, and while doing so he makes important decisions for the continuation of the project.

Even before the student starts the physical material exploration, while performing a dual space search between the composition and construction design spaces, an imaginary material exploration takes place, one that is based on previous bodily experience of the imagined materials. When imagination reaches its limits, the physical material exploration and the resulting prototype takes the concept to the next level, that is the experiential level, where the design may be experienced bodily.

When encountered with new material challenges, previous skills and physical material explorations help in making sense of the new material and its behaviour. Physical material explorations thus strengthen the student's confidence in managing new materials, also in the design phase, giving the student a wider and deeper skills-toolbox to work with in the future.

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