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Using Creative Practice in Interdisciplinary Education

Bilge Merve Aktaş and Camilla Groth

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Interdisciplinary approaches in education help future professionals build better understanding and a common language between disciplines and individuals. To make such leaps, skills in adjusting to new situations and rapidly changing knowledge systems are needed. Such skills are intrinsic to design practice, and design and making practices lend themselves well to such personal development. Design and making activities also offer opportunities for students from different disciplines to gather around central topics and engage in interdisciplinary discussions about matters that concern everyone and to materialize their understanding while reflecting on their personal process. In this paper, we present a course design in which this type of transformational reflection might take place, and we discuss how designing and making processes can provide suitable means to build a platform for interdisciplinary discussions and learning. By examining an interdisciplinary group of students' creative processes, we found that navigating unknown situations with the explorative and adaptive mind-set that emerges through reflection creates transferrable skills that are useful in interdisciplinary interactions and communication.

Keywords: interdisciplinary education; creative practice; material interaction; adaptive processes; reflective practice

Introduction

Interdisciplinary education is becoming more important as the global challenges and opportunities of the future becomes more complex and manifold. As our knowledge systems and practices become interconnected with many types of knowledge, we need to train future professionals to adapt to rapid change and to be open to new situations and different types of problems. One way to achieve this is by bringing individuals from diverse disciplines together to communicate and collaborate beyond disciplinary borders on topics of mutual interest. Interdisciplinary education aims to bring different knowledge types together for innovation as well as working to propose creative solutions for existing real-life problems (Klaassen, 2018, p. 856). When it comes to tackling complex real-life problems, students need "openness, self-awareness, [and] personal development" for managing uncertainty while synthesizing various forms of information to generate solutions (https://doi.org/10.21606/drs_lxd2021). Further, we believe that sharing a learning experience with an interdisciplinary group of people can also become a transformational experience to gain skills for working in unfamiliar conditions. These skills and attitudes are intrinsic to design processes; therefore, we believe, design and making activities offer many opportunities for students from different disciplines to gather around central topics and ideas and concretely engage in discussions of matters that concern everyone. Additionally, design processes can introduce ways to materialize the student's understanding while reflecting on their processes. This type of education may provide a platform for self-development and growth to gain the necessary skills for translating different knowledge types into each other as well as interpreting new information. While starting with a design problem, design processes are often described as open-ended in nature and allow for a flexible and iterative process to ensure the best possible outcome. These processes bear similarities to a dialogue (Nasseri & Wilson, 2017). Such reflective dialogues may emerge through the personal intentions of the designer, the material explorations and the serendipitous discoveries during the process (Mäkelä, 2016), as well as through the co-creation process between many designers working on the same case (Bowen, et al.,



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2016; Bhömer, et al, 2012). These dialogical processes also build a personal connection, and form an emotional relationship with the practice, skill, and the outcome (Brinck & Reddy, 2019). Design processes thus involve a personal transformation and learning experience while offering a reflective tool for communicating with both self and others.

Training in such groups that transgress the disciplinary border helps students to overcome problems connected to interdisciplinary collaborations, such as the inability to understand the epistemological reference points of others or the risk of disrespecting or avoiding disciplines other than their own. Also, the ability to find a common language is needed for expressing ideas, tolerating unconventional or opposing points of views, or even moving away from one's own comfort zone in the attempt to truly understand and communicate with others on general terms (Groth, et al., 2020).

In this paper, we present a higher education course design and some of its outcomes to discuss how designing and making processes can provide suitable means for building a platform for interdisciplinary discussions and transformational learning. We will first discuss design knowledge and its contribution to interdisciplinary knowledge development. Then, we will introduce the design of the Human-Material Interaction course as an example, and present three cases from student work and discuss how design processes were used and explored with concepts from various fields. Finally, we will present four transferrable skills that we believe that the students develop in the course and that are specifically relevant in handling uncertainties, such as open-ended processes and changing situations.

Design as a Platform for Knowledge Exchange

Since Victor Papanek's (1984/1971) criticism of the object-oriented design process and the concurrent development of different design approaches, such as participatory design, co-design, social design, transition design and service design, the field of design has expanded its disciplinary borders from producing objects for everyday use to becoming a platform for transforming all levels of human life. Design has now gained the additional role of facilitating social, cultural and economic change to build better, sustainable, and inclusive futures (Gasparin, 2019). Together with this new role, design has been understood as a way of knowing and thinking rather than merely being a creative practice (Cross, 2011).

Studies have shown that designerly ways of knowing (Cross, 2011) can be applied in multidisciplinary teams to tackle complex topics. Examples that involve more than one discipline include a wide variety of topics ranging from developing patterns for knot-making in textiles through mathematical notations (Nimkulrat & Matthews, 2017) to improving public healthcare through experience-based co-design (Donetto, et.al., 2015). With design's increasing involvement in multidisciplinary discussions, design education is also being reconsidered to train future professionals that can facilitate communication in multidisciplinary groups (Augsten & Gekeler, 2017).

Design practice's involvement in interdisciplinary collaborations has been explored with the notion of T-shaped skills. The concept of T-shaped skills refers to the type of interdisciplinary knowledge-set that the design practice requires and constructs as designers develop their career over time. The T-shape is a visual representation of a person's deep domain-specific knowledge, represented by the vertical stroke in the letter T. The horizontal stroke of the T represents the designers' broad experience and their ability to apply their knowledge in new situations and collaborate across disciplines (Karjalainen, et.al., 2009; Hansen & Oetinger 2001; Barile, et.al., 2012; Madhavan & Grover, 1998). Such T-shaped skills and practitioners may be found in any type of domain and responds well to the demands for the interdisciplinary 21st century skills needed today.

When design knowledge and methods are utilized in interdisciplinary groups for conducting research or searching for solutions, the processes can result in new knowledge and new skills as well as new attitudes towards collaboration and new values for respecting different ways of knowing (Niinimäki, 2019). Therefore, both design as a multidisciplinary practice in nature and designers as professionals who need to engage in multiple types of knowledge have become significant facilitators in interdisciplinary discussions and idea development.

Material Manipulation as Transformational Learning

While design issues include abstract and intangible aspects of the world, material manipulation and making can help concretize ideas and may be a fundamental step towards transformational learning experiences. Design, including material manipulation, as a reflective practice emerges through attentiveness to situations as they evolve and transform. In such reflective practices, the practitioner follows an iterative process of analyzing situations, evaluating ideas, and deciding on the next actions (Dorst & Cross, 2001, p. 434). These

steps are repeated as the process progresses.

Donald Schön (1992) proposes that by analyzing situations as they are unfolding professionals reflect-in-action to comprehend the situation and decide upon their next action, and through reflection-on-action after the process, practitioners make sense of their processes. Having direct contact with a material and following the changes closely to evaluate the process and the evolving sensemaking is an important process that enables knowing from the inside.

'Knowing from the inside' means that the process of learning is transformational and that what we learn changes how we are in the world. Tim Ingold (2013, p. 12), proposes taking an attitude of studying *with* the study subject, which can be materials, instruments or other things, to reconfigure knowledge by going beyond territorialization of knowledge. In a way, by studying with, being with, or thinking with others, one can go beyond the surface of knowledge into its layers and depth. As a method for accomplishing studying with something and to truly understand the capabilities of the material and discover ways of being with it, Ingold proposes following the material while making an artefact rather than forcing through a preconceived idea (Ingold, 2013, p. 56).

Considering that designing and engaging with materials are often described as 'thinking through making' (Mäkelä, 2007), in which interacting with the material unpacks the emergence of the artefact, material interaction through making can become a way to gain a deep sense of knowing from the inside (Aktaş, 2020). The reflections and insights gained from material engagement can generate a common understanding of certain obstacles as people who engage with the materials can explain their insights with reference to similar actions and reflect on these from their different epistemological standpoints and experience. Building on such an understanding, we (the two authors of this paper) designed an interdisciplinary higher education course. Next, we will present the course, and some of the students' work, to answer the following question: What transferable skills emerged as a result of the students' learning activities in this course?

Designing an Interdisciplinary Course

Aalto University in Finland identifies itself as a multidisciplinary "community of bold thinkers where science and art meet technology and business" (the Aalto University webpage). A merger of six schools, from such varying disciplines as art and design, business, and schools specialized in various fields of engineering, science and technology, the university supports inter- and trans-disciplinary exchanges to fulfil its promise of generating novel solutions for global challenges.

In line with this ambition, the university developed a platform for University-wide Art Studies (UWAS) to bring students from various disciplines together within the context of artistic and creative thinking. Through a wide selection of courses that utilize arts as a means of thinking about societal issues and approaching complex systems from multiple angles, the platform brings students with different backgrounds together to explore creative ways of thinking. The course presented in this paper, the Human-Material Interaction course, has been offered as part of this platform since 2019. It is open to all students at the university, the participants being selected for the course by the course secretary. The selection system aims to ensure that the group is balanced with respect to cultural background, disciplines, sex and age. The group of 13 students that participated in the 2020 iteration of the course, and that form the data for this paper, was diverse in their backgrounds, including students from material science, computer science, business, industrial design, and art education.

The teaching methods combined contact teaching that included lecturing, group discussions and hands-on material exploration, with individual practical work for five weeks. Two materials were offered in the course: ceramic clay and wool for felting. After the initial introductions to the materials, we encouraged students to focus on one material, so that they could explore the behaviour of that particular material in depth.

Each class began with sharing the experiences and reflections from the previous week. Students came to the class having read a suggested article or watched a suggested video lecture to discuss the main topics and share their opinions on the subject matter. Although we selected the theoretical readings and video lectures from craft, design, and material related issues, we covered a wide range of sub-topics, such as phenomenological methods of studying, experiential knowledge, labour, environmental impact, waste materials, artistic research, theory of knowledge, and posthuman philosophy to show the extent of the practice's influence. After these discussions, two teachers – the authors of this paper – gave 20-minute lectures on topics related to that session.

In the second part, the students worked in the studios, exploring their material. These hands-on sessions were the most significant part of the course, and they took up to 2/3 of the contact teaching. Each class was wrapped-up by re-assembling in the classroom and sharing what everyone did in the studio (Figure 1). The

students continued working on their independent projects and material experimentation to develop a personal topic in their own time. By encouraging theoretical reflections and reflections on practical work in tandem, the course demonstrated how design and making may transform one’s personal views on social and environmental scales.

Part I	Part II	Part III
Sharing the theory-related experiences from the previous week	Working in the studio with material	Sharing the process from the studio with the course-mates
Sharing the project-related experiences from the previous week		
Lecture		

Figure 1. Each class was structured in three parts.

The Course

Throughout the course, the students were encouraged to follow their intuition and their own open-ended journeys to explore various aspects of the material and to share their processes and ideas with the group. To accomplish this, we teachers, who are also practitioner-researchers, did not provide specific technical instructions on how things should be done, other than the basic introductory workshop. Rather, we made ourselves available if a student had a particular question about a technique or tool. Nonetheless, to a great degree the students were developing their projects independently or through peer support. Some students felt the need to have clear guidelines, and for many of the students from the science field this uncertainty was very uncomfortable and unusual at the beginning. They were used to getting very clear instructions on what is expected of them and in the courses from their own fields open-ended tasks are rare. However, one of the points of this course is to set the students slightly outside their comfort zone to make them question their own ways of thinking and expectations. Although in the span of the course students gain basic skills of working with the material, the aim is not to become competent in a craft practice.

To embrace the idea of following the material *without* having a pre-conceived idea, in the first session, all students were guided by the teacher in throwing clay on a potter’s wheel while blindfolded (Figure 2).



Figure 2. Images from the studio. Photo: Bilge Merve Aktaş, 2020.

Findings from previous studies show that working with materials while blindfolded provides a powerful experience of the materials through other senses than sight (Groth, Mäkelä, & Seitamaa-Hakkarainen, 2013). This experience also prompts a mindset that is ready to enjoy failure and let go of control (Aktaş & Groth, 2020).

As the course continued, students interacted with their materials in different ways, both while blindfolded and not, and they were encouraged to pick a particular aspect of their material interaction to explore this detail more explicitly. They focused on material transformation, its use in everyday life, the tools they used to interact with it, and the meanings of the material or the practice from a personal point of view. This process was facilitated via reflective diaries including texts, sketches, and photographs to explicate their experiences. As most of the students were not from art and design related fields many were very new to this type of open-ended exploration.

For their final presentations, we did not expect finalized artworks but material and verbal narratives of a process accompanied by artefacts that showed how their thinking had developed. In the last session, the final assessment was conducted by the group and teachers together as the students presented their processes and had a discussion with their course-mates about their creative processes and the general topics that were discussed during the process. Later, they submitted essays and their reflective diaries. For their essays, the guiding questions that we gave them concerned the evolution of their project, and its societal impact, ways of transferring the course experience to their professional practice, and their takeaways from the course. Overall, the course encouraged students to follow their own thematic interests and design. This was reflected in the final presentations and essays, since all students worked with different aspects and were able to contextualize their thoughts in various areas of design and societal discussions.

Studying the Data

The discussion in this paper is based on seven out of 13 students' diaries and final essays. Three of these students worked with wool and felting whereas the other four worked with clay and ceramics. We reviewed the essays from all seven students to detect the most important parts of their experiences, insights, and reflections. We applied the procedures of thematic analysis and collected text pieces that carried information about the experiences, reasoning, reflections, and questions (see also Braun & Clarke, 2006; Fereday & Muir-Cochrane, 2006; Aktaş and Groth, 2020).

Adopting the analysis method of Virginia Braun and Victoria Clarke (2006), we initially familiarized ourselves with the data by reading it several times. Then, by identifying the aspects that the students found interesting and decided to further explore for their projects, we generated the initial codes, or patterns of thinking. These were text pieces directly taken from the diaries and the essays. After identifying these, they were grouped into themes that showed the overarching similarities between those personal references ([ibhttps://doi.org/10.21606/drs_lxd2021](https://doi.org/10.21606/drs_lxd2021)). The overarching themes were related to *Emotions, Multi-sensorial experiences, especially related to sound and touching, Unexpected and dialogical making processes, The surrounding environment, Using new and/or existing tools, Finding a way to relate to the material, and Memories from previous practices and experiences*. Most of these topics were interwoven and discussed in relation to each other. The main themes were related to four aspects: 1) the time that the students spent with the material or the practice, such as the initial surprises with the material and later finding their own ways, 2) their personal and professional knowledge, such as their approach to exploring and experimenting with the material, 3) the impact of the working space, such as available tools and making use of them, and finally, 4) making sense of bodily experiences as the design and making continue, such as iterating ideas and making several prototypes.

Findings from previous studies that tackled reflective making processes show that in a typical design-craft project, students often refer to previous experiences, emotions, unplanned making processes and the dialogue with the material (see for example Kosonen, 2018; Mäkelä & Löytönen, 2017). The frequent references to touching and exploring material behaviour can be also seen as typical reflections concerning any kind of familiarizing with new materials or processes, not unusual in other disciplines when having new experiences. However, bringing all these notions together in one course indicates its strength as a platform to initiate and prompt new and creative ways of making sense for non-designers too, perhaps exactly because it requires a whole new way of approaching a problem or theme for students who are not used to concrete material manipulation as a method for reflection. The prompting provided to share such new and explorative processes with others added a social dimension in which the personal experiences could be seen in the interdisciplinary arena on a more general level.

We also believe that some of the themes that appeared from our study are related to personal knowledge that is constructed via the disciplinary background of the students. The disciplinary thinking becomes apparent especially in techniques of exploring, such as how the dialogue of making is built and the tools that are selected to conduct these explorations. These approaches are also often contextualized from the disciplinary viewpoint of the person who is engaging with the activity. It is only natural to build new understandings based on previous experience, and to use one's own knowledge base as scaffolding when challenged in new

unknown situations (Groth and Mäkelä, 2016). To elaborate how disciplinary knowledge can be translated via crafting and design processes, we will present three examples in greater detail and discuss how students developed their projects from their disciplinary perspectives by referring to their field-specific notions to make sense of their design process and how they were able to communicate their ideas with others over disciplinary borders. We will also discuss their adaptive processes regarding how they navigated their way through the open ended and unfamiliar task of progressing from familiarizing with a material to presenting an artefact to the other students.

Examples From the Course

The three examples we selected are from students that developed and discussed their works within a context of their own discipline, but who communicated it to the others via general and interdisciplinary terms.

Student 1

Our first example is from a material processing engineer student. In her project, she worked with the wetness and dryness of clay to investigate the properties and effects of different liquids on clay. Considering the climate crisis and possible water shortages in the future, this student explored the topic of humidity and draft. She made several pieces of simple clay forms and tested the effect of different liquids, such as water, cola drink, coffee, milk, and face cream (Figure 3). After her tests, she compared the visual and structural differences between clay pieces caused by different liquids.

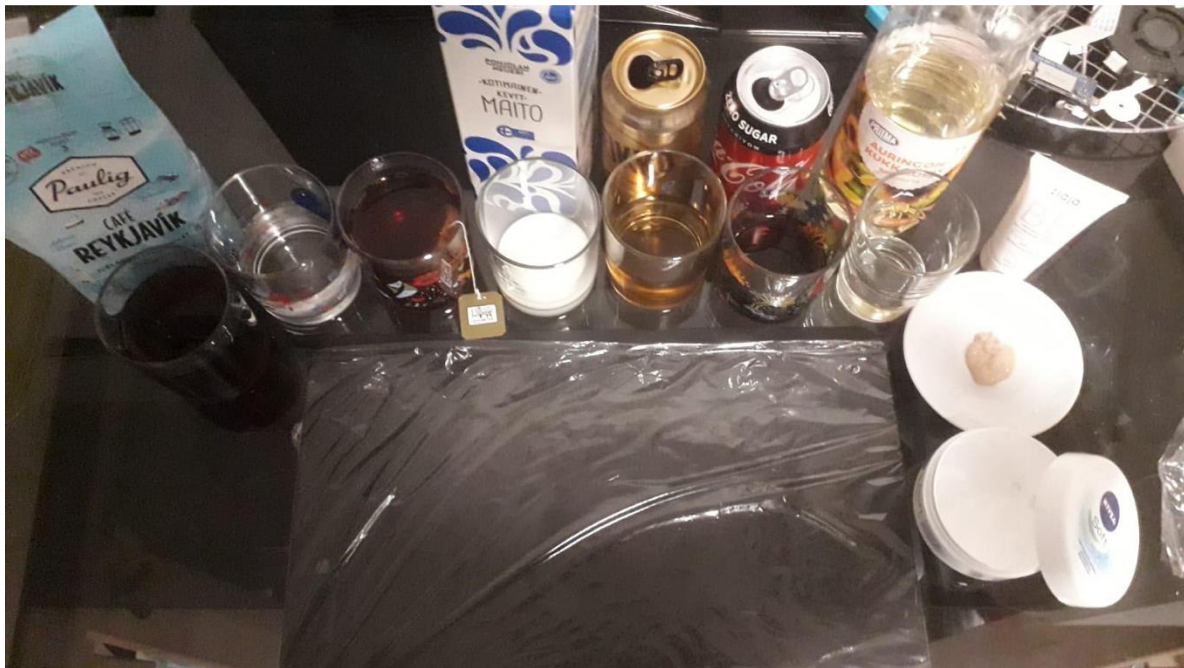


Figure 3. Student 1's set up to explore clay behaviour in different conditions, specifically with different liquids and wet substances. From her reflective diary, March 2020.

After her experiments, she documented how the clay reacted differently to these liquids. Her open-ended process emerged like a material scientist's laboratory set-up. She documented the amount of each ingredient and the sizes of the test pieces in a way that makes the experiment repeatable by others. By combining her observational notes on the senses, such as the stickiness coming from working with milk, and on the appearance of the outcome, such as the change of colour when face cream is used, she had a comprehensive list of findings (Figure 4). In her concluding remarks after the experiments, she wrote in her diary:

I'm very surprised that the use of different liquids had such a little, almost no impact on the clay itself. ... I'm just wondering how those liquids would behave during clay throwing, and if the behaviour of clay is going to be different than without throwing. ... I'm not sure if water could be replaced in the clay shaping process with any other liquid, without a change of the clay's appearance, properties, and the feeling of it. Surely there is space for experimentation, so that maybe in the future clean fresh water could be saved, and other 'not directly life crucial' liquids (for example leftovers which would be

otherwise disposed of) could be used instead to work on clay shaping. I'm very curious how the water saving process will look like in the future and how, if at all, the approach to this topic will change in forthcoming years (From her reflective diary, March 2020)¹.



Figure 4. The result of the experiment; from the left: no added liquid, water, cola drink, beer, coffee, oil, coloured cream, hand cream, and tea; top half: dried in air; bottom half: dried under foil. From Student 1's working diary.

The pondering on future potentials about how to develop new material interaction with clay and leftover liquids shows that open-ended processes continue even after the course is over because the students manage to find a personal connection to the topic. By contextualizing the open-ended process through iteration and testing, the topic becomes more relevant on a personal level. One can start building disciplinary connections while also paying attention to the impact upon the field and the environment. Indeed, at the end of the course she writes in her essay:

As a material's processing engineer, I've studied the material properties based on numbers, calculations, and software-based analysis, rather than on 'hands on' experimental practices and observation. In my next professional practices, I will think more about the material itself, not only the numbers it's described with. I will try to incorporate more 'material play', meaning considering the possible behaviour of the material under different circumstances and the possible outcomes (From her final essay, April, 2020).

Student 2

The second example is by a computer communication and information science student. He started his process by watching videos of throwing clay on the wheel that he found online and later developed an idea of what to make. After reviewing these videos and those of craftspeople from around the world, such as rural villages of India, Student 2 described his understanding using notions that are typical to his disciplinary knowledge. For instance, after describing how the craftsman turns the wheel with the stick of his broom at high speed, this student writes:

I guess the wheel having a large diameter and weight to it, which results in [a] large moment of kinetic object, [the wheel] doesn't want to slow down but keeps its current speed and the long broom with

¹ All students wrote in their diaries in English. The grammar of the excerpts is checked for minor corrections to increase their readability.

[the craftsman's] technique actually creates enough torque to gradually speed up this huge wheel. Absolutely amazing, even though I'm good with physics, the thing surprised the heck [out] of me! (From his reflective diary, March, 2020).

As he further researched ceramic artists, and came across geometric shapes made with clay, he decided to make a geometric sculpture-like shape for his explorative project.



Figure 5. The final artefact of Möbius strip. From Student 2's diary.

He focused on making a Möbius strip, which is a surface with only one side, to show an abstract mathematical concept via material (Figure 5). While making, he worked with drinking glasses and spoons as tools to give the shape and a pillow and a blowtorch to overcome the effect of gravity on the form. He described his process of making as:

I started working when the clay was too wet and also the slab was too long. [A] wide enough slab (and dry enough) fights gravity adequately. ... As the clay dried, I used my hands and fingers to work the material (as opposed to a metal spoon). The experiment nearly failed, and I had to make a really fast judgement on cutting almost 10 cm of the length to make the piece have a better proportion. ... Coming from a near failure to a success made the whole experience much more rewarding (From his reflective diary, March, 2020).

Student 2 started his process from a different point than did his course mates: from reviewing the field to find a starting point for a form. Throughout the process, his way of explaining material transformations relied on his theoretical physics knowledge. However, the real physical experiences of the material surprised him as he was challenged by the gravity on the wet clay that distorted the shape he wanted to make. Discovering how to work with materials also provided an attitude to approach his own craft, which is programming, as he wrote in his final essay:

Working with the clay and trying to mould it into this complex geometry was very challenging, but also very rewarding. ... Sometimes, however, I would get frustrated due to the slow process and try to take

short cuts, only to make things worse. ... The experience one can take home from [this] is taking “short cuts” only makes things worse [and it] is one that’s certainly applicable to computer science and programming as well. Oftentimes a problem a programmer is trying to solve is so complex, that certain short cuts are taken only to find out later that a lot of work has to be completely redone because of the said short cuts. Patience pays dividends, or [what] do they say? ... Respecting the tools and materials you’ve got and making the best of them (From his final essay, April, 2020).

Student 3

Our last example is by an art education student. She started her project with ideas around the body after one of the early lectures of the course about the relationship between the body and wearing clothes. Later, the idea developed to being inside and outside of the body, connecting the materiality of the human body with the immateriality of feelings. In her final work, based on her own experiences with her flowers, she moved from the idea of her body to the body of things that we cherish and take care of (Figure 6).



Figure 6. The felted body that takes care of the plant. From Student 3’s reflective diary.

Student 3’s work is powerful as it materializes a personal experience in a way that is relatable for other people as well. By making an image of an inside out body, she discusses “exposing one’s feelings that are usually kept hidden” (From the student’s final essay, Figure 7). Having these ideas, she developed a theme, a pattern design, and a way to display these two (Figure 6). The comprehensive approach coming from personal feelings appeared in her final essay too:

The parts of the felt are layered, often not clear ... expressing my feeling of being lost in the thick, intense feelings that are often mixed up. In a way, I related to my artworks and my own emotions were released in them while creating the pieces. ... While they are inside out, exposed and fragile they are not worthless but instead able to protect or at least co-exist with something else. I also find the material itself comforting, warm and enjoyable, and my intention would be that the person using these items would feel that [same] comforting feeling and warmth (From her final essay, April, 2020).



Figure 7: By making veins and bones, Student 3 worked with the idea of an inside-out body.

The way she discusses her project and the comforting positive feelings that it provided exemplified how to use crafting as a way of connecting with the self and translating personal positive or negative experiences to others. Considering that she is studying to become an educator, the way she opens up her experience with felting to others also exemplifies the use of crafting to construct communication around certain topics and facilitating the exchange of thoughts, experiences, and obstacles.

These three examples presented crafting and design explored through the lens of material engineering, computer science, and self-development. Building upon these insights, next we will discuss the transferrable skills that we feel are gained from the course and that might encourage steps towards the sharing of worldviews and managing open-ended and unfamiliar tasks in interdisciplinary collaborations.

Four Transferrable Skills for Interdisciplinary Collaboration

As the thematic analysis and the above examples reveal, the students' projects were significantly influenced by the time that the students spent with the material or the practice, their personal and professional knowledge from their own disciplines, the impact of the workspace, and making sense of the experiences through reflection. However, when having to share these personal experiences with others in the group, who are not familiar with the specific disciplinary background one comes from, students needed to develop ways of generalizing and communicating them in a language that is understandable to others.

The analysis also demonstrates that participating in an interdisciplinary design course can facilitate the gaining of transferrable skills that help in managing in new and unfamiliar situations such as lingering in the unknown, the courage of engaging in explorative processes beyond disciplinary norms, adapting to new situations and the skill of reflecting and meaning making. After reviewing the student's processes and creative work, and considering how we designed the course, we present four transferrable skills that we felt were acquired by the students while they were participating in the interdisciplinary design course. We believe these skills can be applied in many other interdisciplinary contexts as they help in sustaining an explorative and open-minded attitude.

The Skill of Lingering in the Unknown

The final essays and the analysis revealed that through open-ended processes students developed their own ways of tackling the ambiguous processes of developing and executing ideas. Although each student began with uncertainty, as they continued working with the material, they managed to pinpoint material aspects that they found interesting. Staying with the unknown situations can create space for turning to one's inside to discover the sort of abilities, emotions, and intuitions one has (Kosonen, 2018, p. 263). From the first making session, the students followed a process that connected to their personal and subjective experiences without forcing them to come up with a finalized artefact. Supporting such a pressure-free time to think and explore gives room for many different directions rather than anchoring the project at the very beginning, although it can be challenging to linger in such an unknown space for long.

Promoting iterative processes without getting trapped with the first available solution also provides an environment that does not measure success by the outcome but encourages open-ended experimentation.

This environment welcomes testing new ideas and treats failure as a way to gain insights. For instance, in Student 1's project, iterative making appeared as first coming up with the watery and moist feeling of working with clay. Later, she observed its impact upon the clay form, such as the cracks appearing in certain parts of the braided forms as a result of the clay drying differently. Following these insights, she experimented with the reaction of clay in working with various liquids. In this way, she resisted the pressure of "having something ready to show" the others and concentrated on what was emerging in the process, thus learning much more than she would otherwise have done.

The Skill and Courage of Engaging in Explorative Processes Beyond Disciplinary Norms

Although the students were given demonstrations and information about the basics of their materials, we intentionally avoided giving thorough instructions about traditional norms or techniques when working with the material. Rather, the aim was to think through and with the material to develop a personal view on human-material interaction free from disciplinary expectations. Accordingly, without leading the students into a predetermined way of thinking, we encouraged them explore a particular aspect of the material that inspired them the most. When the projects were not framed by the teachers, the students could contextualize the material and the practice in their own ways.

As a result of not having a strict frame or normative expectations, the students focused on various aspects of the materials from an angle that they could explain with the knowledge that they already had, and the exploration could continue in self-driven ways. For instance, after watching a video online that he found on his own, Student 2 was able to explain the process of making ceramics using language that was natural to him: physics. After connecting clay throwing to the potter's wheel and physics notations, he was able to come up with the project idea. Only after building this personal connection via self-driven processes could he start translating different knowledge types into each other. The examples show that the students were able to explore this unfamiliar practice by relying on their disciplinary knowledge. While this approach helped them develop their own sense of the project, it can contribute to the development of the explored practice from a new angle, one that is not only about the creative practice but also about other important aspects, such as environmental impact or physics-based explanations of movements.

The Skill of Adapting to New Situations

By lingering in the unknown and relying on previous personal and disciplinary knowledge, the students also developed their personal ways of adapting to new situations. With the freedom to explore aspects that might seem impractical or even irrational, students became able to free themselves from conventional expectations and norms and adapted to unexpected situations to overcome obstacles in creative and idiosyncratic ways. In the course, most students had no experience in working with the proposed materials or design processes in general. By accommodating the frustrations coming from not being in control of the material, due to the lack of experience with it, and the material transformations that occurred throughout the project, students developed their own strategies to cope with unexpected situations. The limitations sometimes also led to innovations, employment of new tools, use of additional materials, and new contexts or use areas. In Student 2's project, the student struggled to find the necessary technical solutions to create the form that he intended. Starting from his initial attempts, he tested various tools to manage the dryness and size of the clay to maintain its form, from utilizing objects for scaffolding to using a hairdryer.

The Skill of Reflection and Meaning Making

Finally, one of the most elemental skills, which is also a prerequisite for conducting interdisciplinary discussion, is the ability to reflect in and on the process and its meanings in an open-minded way with others. Throughout the course, the students gained the skill of reflecting on their processes and making sense of them. Although having a reflective diary was not a typical tool for developing ideas in their own disciplines, the students maintained their notepads and used them effectively by including sketches and images as well as texts. The in-class reflections were also encouraged, and although in the early classes such sharing was a new and unfamiliar experience, towards the end the students were more comfortably sharing their failures and successes. Thus, they gained the skill of learning from failing and experimenting with the materials and their perception towards the process became a more explorative than goal-oriented one. Reflections also facilitated the development of other skills. As students continued reflecting on their processes, they began paying more attention to how their relations and perceptions were changing. Building various relationships through reflections provides space for following personal ways of meaning-making (Aktaş, 2020, p. 90). By reflecting through writing, making and thinking, the students created their own mental and physical space to translate

various experiences into each other.

Conclusion

The reflections from the students show that the skills gained in such a course may in many ways already be intrinsic to design processes. However, we believe that they can become important skills, especially for developing interdisciplinary collaboration and communication. The abilities that are typical for design processes might be frustrating for professionals from other disciplines, particularly when projects or discussions are about explorative long-term collaborations (Niinimäki, 2018, p. 311). However, our study shows that navigating these explorative and unfamiliar situations assists in developing both patience and an open mind. Developing such self-awareness facilitates the emergence of creative and innovative outputs (Klaassen, 2018, p. 856). Courses like Human-Material Interaction that promote such open-ended, adaptive and reflective approaches can help students become used to transgressing their comfort zones and stepping into the unknown while trying to make sense of new situations. Having students from both the natural sciences, such as materials engineering and computer sciences, as well as humanities, such as arts education, also shows that utilizing crafting and design as platforms can overcome disciplinary boundaries as it provides a shared understanding of concepts to make sense of them from multiple disciplinary backgrounds. These are skills that help the students in transgressing their own disciplinary borders and develop an open mind towards alternative ways of thinking that might even conflict with preconceived ideas in their own discipline. Gaining the necessary skills for iterating and initiating ideas, adapting to new conditions and self-reflecting can enable metacognition on personal knowledge while also communicating this to others. When building a bridge between existing and newly gained knowledge, emotions, multi-sensorial experiences and the surrounding environment support the translation of various discipline-specific domains into each other. The reflections reveal that one way to facilitate interdisciplinary discussion is by motivating people to turn inwards to understand their new experiences and skills via material interaction and to reflect on these openly in a safe environment. These reflective and personal processes in a shared and supportive environment enable translating implicit decisions into articulate ones that show the progression of sensemaking, not only for oneself but also for others.

We thus propose to work together in a concrete manner to educate ourselves and each other through concrete tasks that facilitate discussion that are interesting for all participants. Our study shows that interactions with materials through design and making processes can trigger meaning making of the creative processes from both a personal and shared viewpoint that enables students from different disciplines to transfer different knowledge types to each other. To be truly transformational, these processes must be grounded in personal experiences and reflections. When these are opened up from various perspectives in group discussions, the participants' worldview has the opportunity to expand.

The findings show that interdisciplinary design courses can train future professionals to better handle insecurities and open-ended processes, work without being overly self-critical, present their own ideas in a concrete form and to share feelings and thoughts in relation to their own work. Additionally, by exercising reflective practices, students can gain experience in philosophical ponderings, participating in and evaluating other's reflective processes and, perhaps most importantly, learn that there is more than one disciplinary understanding of what the world is like and that we as participants in the world actively shape and affect the world through our interaction with it.

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