A new approach to materials in Product Design education - A shift from technical properties towards sensorial characteristics

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Abstract

This study evaluates a new pedagogic approach implemented in material courses for product design students at bachelor level education. Material education within the field of design education at technical faculties has, in general, a strong technical focus, e.g. selecting materials with predominant focus on engineering properties of materials. Product design education at a bachelor level need to offer material courses that prepares the design students to work both on inspirational and analytical levels in material selection processes. Early in the design education, students often have a precondition of materials, and they need to be introduced to an open-minded inspirational material selection process, based on scientific design methods. When developing a new curriculum for the material courses, it is important to teach materials and production methods in a contextualized setting with emphasis on how materials can be approached in a design process. Methods can be seen as mental tools that aids the design students in navigating complexity and offers them a structure to deal with unfamiliar territories. After an evaluation, we selected some methods, guidelines and tools to integrate in the mandatory material courses for the product design students e.g. the Expressive-Sensorial Atlas, Meaning Driven Materials Selection and the Material Driven Design method. The implementation were made in two steps in order to test, evaluate and further develop a framework for teaching materials courses to product design students. This study only reports the first step of implementation since the second step is under development and will be implemented during autumn 2017.

Keywords

Material Driven Design; Material education; Product design; Material selection; Teaching practice

This study evaluates a new pedagogic approach implemented in material courses for product design students at bachelor level. After a several-year long process of gathering knowledge, gaining experience and finalizing negotiations with involved stakeholders, we implemented a new curriculum in the fundamental materials courses that are mandatory for all Product Design students. The radical shift in how product design students are taught materials and manufacturing methods was possible after transferring Product Design education from the technical faculty to the design faculty.
At the beginning of the education, design students often have limited knowledge of materials and this knowledge is often based on personal experiences (Hasling & Lenau, 2014). The study indicates that activity-based or ‘hands-on’ learning, combined with scientific understanding of materials, improve the students’ abilities to articulate and make informed decisions in a design process. Professional Designers are typically restricted by a well-defined palette of well understood materials that are readily available, affordable and accessible. With knowledge and a deep understanding of materials, it is possible to challenge the mechanics and manufacturing with intelligent solutions that otherwise may not be explored (Thompson, 2011).

Initial sections of this article present the dilemma of the product design education at the technical faculty. We then discuss the use of methods in design education and present a set of methods found in the reviewed literature on materials experience, material learning, material selection and tinkering with materials. We then outline the new pedagogic approach and its implementation in two steps in the product design education at bachelor level. We then discuss the radical pedagogic shift that occurred when implementing the new curriculum. Finally, we reflect on the benefits and drawbacks of our approach and suggest potential improvements.

**Design education at technical faculties**

Design education at technical faculties is often characterized by a curriculum for materials education with a predominant focus on technical properties. Due to long scientific and technological tradition, the engineering discipline has a well developed curricula for material education supported by textbooks, digital tools, etc. Effective communication of material knowledge and design knowledge between the two disciplines - material science and design - has proven to be challenging due to their different perspectives on materials. Engineering students, at bachelor level, study well-established textbooks with scientific knowledge that is ‘unquestionable’ and developed during the past two centuries (Bucciarelli, 2003). This kind of ‘content knowledge’ can be seen as static and difficult to apply in an open ended learning exercise typical for design students. Materials teaching is often pervaded by a tension between on one hand a natural scientific and engineering oriented topic and on the other hand, a design education rooted in the practice based and constructive tradition (Hasling, 2015). There is a tendency of ‘watering down’ the material education for design students, instead of using adequate, up to date scientific methods from the field of design to cover both the technical properties and sensorial characteristics (Asbjørn Sørensen, Warell, & Jagtap, 2016).

Design education at a tertiary level needs to offer material courses that prepare students to work both on inspirational and analytical levels in material selection processes. Early in the design education, students often have a preconception of materials, and they need to be introduced to an open-minded inspirational material selection process, based on scientific design methods. The authors’ own experience suggests that students gain a deeper understanding of materials if the theoretical lectures on materials are closely linked to hands-on material experiments (Asbjørn Sørensen et al., 2016). By linking the theory and experiments in a project, preferably in the same course, students have the opportunity to apply their learning outcomes in a product development project, and this is “…effective in bridging the divide between ‘knowledge about’ and ‘experience in’ materials”, as suggested by Pedgley, Rognoli and Karana (Pedgley, Rognoli, & Karana, 2015).

**Method usage in design education**

Methods can be seen as mental tools that aid the design students in navigating complexity and offers them a structure to deal with unfamiliar territories. Methods assist design students in skill development and to reinforce practice that is necessary for developing intuitive expertise over time (Kahneman & Klein, 2009). Reflection-in-action contributes to a reinforced practice by paying attention to and learning from decisions and actions that lead to mistakes or unexpected outcomes of method usage (Schön, 1983). Methods should not be seen as mere instructions to follow but rather as mental tools or mind-set.
to understand increasing complexity and to be able to contribute with qualified solutions (Hasling, 2015). A project portfolio can be a valuable tool when used in a reflective discussion with the students about their personal experience of method usage in a design process and can thereby contribute with an valuable learning experiences.

When developing a new curriculum for the material courses it was considered important to teach materials and production methods in a contextualized setting with emphasis on how materials can be approached in a design process. Experience from the old curriculum had indicated that when design students and engineering students were taught the same courses in material and production methods the courses tended to become too general and decontextualized. Design students are generally interested in applied materials and were often discouraged by the technical approach in the introductory courses. It became difficult for the design students to relate the purely technical aspects of materials to the applied material knowledge gained through the design projects. Early in the development of the new curriculum, it also became clear that it was important to make a distinction between material selection and material exploration, as they are two different ways of approaching materials (van Bezooyen, 2014). They are of equal importance but demands different methods and mind-sets. Material selection refers to the well-defined process applied in the later stages of a design process where the materials selection criteria are defined by context of manufacturing and cost to realize an already mature product concept. Materials considered in the fuzzy front end of the design process are dealt with at a more abstract and holistic level, e.g. creating a material vision instead of defining materials requirements for product realization. This could contribute to strengthen the abilities of design students to integrate their material knowledge and skills in the design process, from the fuzzy front end to the structured back end in a professional setting.

**Inventory of methods**

A literature review was carried out with focus on guidelines and tools used in or developed for materials education in the field of design (Asbjørn Sørensen et al., 2016). The following methods, guidelines and tools were integrated in the existing material courses for the product design students.

**The Expressive-Sensorial Atlas**

The Expressive-Sensorial Atlas uses four parameters, namely texture, touch, brilliancy and transparency (Rognoli, 2010). The charts provide illustration of sensorial qualities using a sample of materials combined with a simple, concise textual definition. Design students rank material samples, based on personal sensation that result in a subjective and qualitative sensorial scale (fig.1a) from one sensorial extremity to another e.g. light-heavy. The subjective sensorial maps trigger relevant discussions between the students when they realize that the result do not always correspond to the scale derived from objective material measurements. In fig.1b, the product design students were asked to rank ten material samples from light to heavy, first subjectively and then according to density.

![Fig 1a. Property explanations and physical samples combined into the Expressive-Sensorial Atlas and developed into a scale of light/ heavy (Rognoli, 2010).](image)

![Fig 1b. Material samples ranked from light to heavy by product design students, first subjectively and then according to density, in the top row.](image)
**Meaning Driven Material Selection**

Meaning driven materials selection, MDMS, (fig.2) aims to assist designers in manipulating meaning creation in materials selection (Karana, Hekkert, & Kandachar, 2010). The model offers a multifaceted framework that embraces both sensorial characteristics as well as technical properties that are embedded in a material. The guidelines help students to understand how the complex combination of manufacturing methods, shape and function relates to the user experience defined by, for example, expertise, gender, age, and cultural background.

![Meaning Driven Material Selection Diagram](image)

Fig 2. Meanings of Materials Model (Karana et al., 2010).

**Hodgson and Harper**

Hodgson and Harpers guidelines (fig.3) offers an overview of how a range of 10 materials related product attributes contribute to the realisation of Form, Function and Fabrication in a product. These in turn ultimately determine both the cost and value of the product, which must ultimately match the need or market (Hodgson & Harper, 2004). The guidelines support the design student in exploring the potential and consequences of each attribute in relation to the surrounding attributes as well as the need and context. By integrating cost and value, it reflects a realistic scenario that could support professional designers as well. Reflection is crucial in a material selection process since there is no specific answer; only contextually related material candidates that offer different solutions. The guidelines are developed as a reaction to how material selection is traditionally taught in design education.

![Hodgson and Harper Diagram](image)

Figure 3. The process, illustrated schematically, involves putting the materials at the heart of the design process, as the integrating element permeating all aspects of the design (Hodgson & Harper, 2004).
The CES-EduPack

The Cambridge Engineering Selector, CES EduPack, developed by Granta for design engineering is based on the work of Ashby and Cebon (Granta Design, 2016). The CES-EduPack offers material selection based on technical properties, manufacturing processes, environmental and sustainability aspects. The program offers visualizations and material charts of technical properties. The material charts can preferentially be used in combination with other tools in the design education to explain the complex relations between technical properties and intangible characteristics.

The 2016 version of CES-EduPack offers a new beta-version database for engineers and industrial design students called the Products, Materials and Processes database (fig.4). The database is product-centered and contains descriptions and data of materials and processes used to make products. The product examples are intended to act as de-codifiers between intangible characteristics and technical properties (Granta Design, 2016).

![Example of datasheets from CES-EduPack](image)

Figure 4. Example of datasheets from CES-EduPack 2016 Database Products, Materials and Processes. The first datasheet describes the product Cylinda line Hot by Arne Jacobsen, the second and third describes the material stainless steel used in the product (Granta Design, 2016).

Material Driven Design

The Material Driven Design (MDD) Method facilitates design processes in which the materials are the main driver (fig.1). The MDD-method encourages hands-on interaction with the material at hand, from the first encounter through to exploring and understanding the material in detail with its unique qualities and limitations (Karana, Barati, Rognoli, & Zeeuw van der Laan, A, 2015). By working with an explorative approach, the designer understands the material in depth e.g. experiential qualities, physical properties and ‘the material’s purpose within a situational whole’. The MDD-method guides the design student in a journey from material properties and experiential qualities to materials experience vision, then to experiential qualities, material properties and finally to products. Activities to support this journey are organized under four main steps as: (1) Understanding the Material: Technical and Experiential Characterization, (2) Creating Materials Experience Vision, (3) Manifesting Materials Experience Patterns, (4) Designing Material/Product Concepts.
In order to create a meaningful application, designers need to move from material characterization to a holistic vision (Step 2 of MDD). They also need to enable novel experiences by crafting the vision into a meaningful application (Steps 3 and 4 of MDD).

The MDD-method can be used in different scenarios and Karana et al. suggest the following scenarios:

1. Designing with a relatively well-known material. Although the material is likely to have some settled meanings in certain contexts the designer seeks new application areas to evoke new meanings and to elicit unique user experiences.

2. Designing with a relatively unknown material, which will be accompanied by a fully developed sample (e.g., liquid wood, D3O, thermochromic materials, etc.). The material is unlikely to be linked to established meanings, giving the designer an opportunity to define application areas through which unique user experiences, identities for materials, and new meanings may be introduced.

3. Designing with a material proposal with semi-developed or exploratory samples (e.g., food waste composites, living materials made of bacterial cells, 3D printed textiles, flexible OLEDs, etc.). Since the material is semi-developed (i.e., proposal), its properties are to be further defined through the design process in relation to a selected application area, also to generate feedback for further materials development (e.g., elasticity of a food-waste composite, durability of a 3D printed textile, etc.). Furthermore, since the material is novel, it is difficult to recognize and is in need of the designer to propose meaningful applications through which unique user experiences and meanings will be elicited.

Implementation of design methods

A several-year long process of gathering knowledge, gaining experience and finalizing negotiations with involved stakeholders made it possible to implement a new curriculum in the fundamental materials courses that are mandatory for Product Design students. How does one then implement the methods found suitable for the materials courses in the Product Design bachelor programme? The first step of implementation was made in the existing materials courses, without changing the learning outcomes in the
course syllabus, instead literature, methods, tools and the pedagogic approach was updated. By doing it in two steps it was made possible to test, evaluate and further develop a framework for teaching materials courses to the product design students. The second step of implementation has been to restructure the Product Design bachelor programme and write new course syllabuses. This study only reports on the first step of implementation since the second step is under development and will be implemented during Autumn 2017.

**Applied materials and tools for model making in Product Design 15ECTS**

The course ‘Applied materials and tools for model making in Product Design’ (last course in the 1st year) has been given with the same course syllabus since spring term 2012 (fig.6). Product Design has been responsible for the planning and execution of the course and Material Science have offered the same series of lectures for students from product design and mechanical engineering since 2007.

![Figure 6. ‘Applied materials and tools for model making in product design’ 2012-2015.](image)

The lectures were criticized by the engineering students for being too general, not theoretical relevant enough and ‘moving forward too slow’. The design students found on the other hand the lectures ‘too theoretical’, not able to link the lectures to other learning activities in the courses and ‘moving forward too fast’. The reasons for giving the same series of lectures were a well-established practice in the technical faculty and the financial benefit of joint studies. The theoretical parts of the material courses examined in written tests were often criticized for not evaluating the students’ ability to link theory to applied design problems. Knowledge in this form can be considered static, included in a textbook and stored in memory to be recalled at the time of the exam, not allowed to be considered as an active, creative knowledge production of the moment (Bucciarelli, 2003).

When restructuring the course the main goal was to facilitate knowledge creation in the intersection of theory and hands-on material experience. The difficulty in a multidisciplinary teaching environment was that different members of teaching staff have been trained in different research paradigms. It was a prerequisite to succeed that all involved teachers in the course had a common vocabulary and an understanding of the methods and guidelines introduced, not only the ones they taught themselves. Material Science chose not to offer new lectures for the design students but assisted instead the design teachers in developing a new lecture series. The lectures were developed in the spirit of active learning (Felder & Brent, 2009) with brief interludes of practice and feedback to offer the students an understanding of the more complex context of, for example, the relation between technical properties and sensorial characteristics. The Expressive-Sensorial Atlas (Rognoli, 2010) was introduced and used during the lectures as a way for the students to explore the relationship between what is perceived subjectively and what is measured objectively (fig.1).

The content of the lectures were also adapted to design students’ pre-knowledge of materials and developed to reflect the latest research in the design and materials domain. The number of
commercial materials available is rapidly increasing and the traditionally used taxonomy of material families is gradually decomposed with hybrid materials such as composites. Therefore, it is fundamental to provide students with tools to create their own understandings of materials (Hasling & Lenau, 2014).

![Table]

| W 1 | W 2 | W 3 | W 4 | W 5 | W 6 | W 7 | W 8 | W 9 | W10 | W11 | W 12 | W 13 | W 14 | W 15 | W 16 | W 17 | W 18 | W 19 | W 20 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Workshop driver's license part 1 & 2 | Materials: theory (material families, technical and sensorial properties, material selection methods, materials and manufacturing methods). | Mechanics of materials: theory & applied | Design project: Design a handheld consumer product with a basic function in two materials. (Technical drawing, 3D-modelling, modelmaking, materials selection processes.) |

![Diagram]

Figure 7. ‘Applied materials and tools for model making in product design’ 2016.

By restructuring the course (fig.7), the interaction between theory and hands-on learning were put in the centre, as we believe the students gain a deeper understanding of materials if the theoretical lectures on materials are closely linked to hands-on material experiments. In practice that could be a lecture on the material family of metals in the morning followed by working with tube bending and welding in the workshop later in the day. The students were given a material and manufacturing assignment were they was asked to replicate the same object in four different materials (metals, wood composites, polymers, textiles or ceramics). The students received a technical drawing of the original object with instructions to choose the most suitable technique for each material. When finalising the four objects the students should analyse each object using the Meanings of Materials Model (Karana et al., 2010) and compare the results in a seminar. New technical drawings of each object was produced and the students were asked to reflect on the complex combination of manufacturing methods, shape and function and how it relates to the user experience together with the teachers. The Mechanics of Materials were developed by a teacher from Material Science, from being a combination of lectures and theoretical calculations, into lectures and an applied two-day workshop were the students were asked to build constructions and put load on until they collapsed and the elaborate on the result. Second part of the course the students were given a design project were they applied their newly acquisitioned experience in and knowledge about materials in a design process. Simple causative or one-to-one relationships between materials, products, sensorial experiences, meaning attribution and emotional responses do not exist. Effective teaching and learning in this area must expose students to the complexity of contextual issues, whilst emphasising that with complexity comes richness in diversity and novelty (Pedgley et al., 2015).

**Materials and production methods 15ECTS**

The course ‘Material and Production methods’ (1st course 2nd year) had the same historical background as the previously described ‘Applied materials and tools for model making in Product Design’. After experiencing mainly positive effects of the new pedagogical approach a radical change was implemented by introducing Material Driven Design (Karana et al., 2015) and Flipped Learning (Network,
2014) as key components in the second mandatory materials course ‘Material and Production methods’. In the traditional teacher-centred model, the teacher is the primary source of information. By contrast, the Flipped Learning model deliberately shifts instruction to a learner-centred approach, where in-class time is dedicated to exploring topics in greater depth and creating rich learning opportunities (Network, 2014). The Flipped Learning model was chosen as it actively involves the students in knowledge construction as they participate in and evaluate their learning in a manner that is personally meaningful. The pedagogic approach harmonizes well with the experimental and explorative spirit of the MDD-method. The students were introduced to the theoretical framework of Material Driven Design in a series of seminars where the class became a part of structuring the MDD-activities and timelines in the course (fig.8). It is important to encourage students to work explorative and also learn from failures in the iterative process of tinkering with materials and as a consequence create a certain degree of flexibility in the timeline. The students were asked to apply the MDD-method to material proposals that were semi-developed/exploratory (textile waste and coffee ground) or with a relatively unknown (mycelium). Learning to investigate a material in an explorative yet structured way increased the integration of material thinking in the design process and made the design students reflect on the materials they use.

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Figure 8. ‘Material and Production methods’ 2016.

The MDD-method became integrated in the course structure so that the different learning activities supported each other, e.g. the pull test (fig.9) in the applied mechanics of materials module was performed on the material samples (fig.10) the students produced in the course. The benchmarking of materials became connected to the methods used in the production economy module and so forth.

Figure 9. Material samples produced by one group of students in the course ‘Material and Production methods’ 2016 followed by a pull test of the final sample.
Figure 10. Material samples developed from textile waste by students. Cotton fibers mixed with a tapioca based polymer.

Working with the different steps of the MDD-method in a course structure is rewarding but challenging for both teachers and students as it demands good communication between everybody involved or else some of the synergies in learning activities are lost. We would like to suggest that parts of the MDD-material are further developed, e.g. the pictures used for the experiential characterization, creating instructional material for teachers so that more design students could benefit from the method.

**Discussion and conclusions**

This study has offered the opportunity to reflect on the didactic approach to materials teaching in product design. The challenges of applying a new pedagogical approach to an existing course syllabus rendered mainly positive experiences. After implementing the new pedagogic approach and methods Material Science has shown interest in developing their own material courses for the mechanical and material engineering students. The field of engineering, especially related to materials, could benefit from adapting these methods into their material education. It could contribute to a more efficient understanding of the sensorial characteristics that are linked to the technical properties. It could also contribute to less miscommunication between engineers, designers and non-technical professions in the product development process, often characterized by a multi-disciplinary work. Materials constitute the physical appearance of a product, and choosing the right materials is fundamental for, how a product will function and how it will appear. As part of the product design education, students have to develop a material practice that incorporates material thinking in their overall design practice and this includes how materials are evaluated and selected (Hasling & Lenau, 2014).

The results so far indicate that the students have gained better understanding of the complex context of material related activities in a design process. There is a tendency of greater variation of relevant material candidates in the design projects instead of the ‘usual suspects’. Sustainability has surprisingly become a naturally integrated part of the materials courses and is no longer treated as a separate attribute but have instead become embedded in the design process. The students developed their material vocabulary during the courses, contributing to a higher quality and precision in the discussions. We hope that this study can inspire to introduce Material Driven Design in more design educations.
References


