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DEVELOPMENT OF THE MATERIAL SELECTION PRACTICE – A STUDY EXPLORING ARTICULATION OF MATERIAL REQUIREMENTS

Karen Marie HASLING[1] and Torben LENAU[2]
[1]Design School Kolding
[2]Technical University of Denmark

ABSTRACT
This paper explores how the material selection matrix is used in a materials and sustainability course. The matrix encourages the students to articulate material selection requirements to become more competent in exploring new materials and selecting materials for a given design task. The study indicates that students focus on technical requirements when using the matrix and justifying their selection of materials. This is surprising since the students attend an arts and crafts oriented design school and are encouraged and guided to consider non-technical requirements, as part of the course where the matrix is introduced. A possible reason for the undesired behaviour could be that students are allowed very freely to define their own matrices, having only little guidance to which requirements to use. A more formal procedure for making the material matrices is therefore proposed. The procedure requires students to use a fixed number of technical, experiential and sustainability oriented requirements.

Keywords: Material education, material selection methods, material requirements, applied learning

1 INTRODUCTION
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 their education, product design 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. Guiding students to develop a structured material selection practice serves to increase the integration of material thinking in the design practice. It furthermore aims to make designers more aware and to reflect on the materials they use.
At the beginning of their education students usually have limited knowledge of materials and this knowledge is based on unstructured personal experiences. It is essential to expand their mental materials library and teach them how to explore the materials. 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. As a consequence, it is fundamental to provide students with tools to create their own understandings of materials. Materials play an important role in, how users perceive a product and good solutions are found by examining a range of different materials and comparing the solutions based on a set of requirements.

1.1 Existing tools
A range of similar material selections tools that stress experience-related properties exist. Karana's Meaning of Materials tool serves to support designers in understanding key variables essential to meaning attribution to materials and to define patterns in particular material-meaning relationships [1]. Rognoli's Expressive-Sensorial Atlas is a collection of sensorial maps developed for interactive use with students stressing relative material properties by structuring materials by means of a linear scale (e.g. light/heavy, cold/hot and soft/hard), linking sensorial and technical properties by intuition [2]. Zuo's Material Aesthetics Database is a semiotic database, containing information about the sensory perception of materials that address questions such as, how people verbally describe sensorial properties and, what inter-relationships that exist between various responses to the sensory properties. [3]. Bang's repertory grid tool developed for communicating emotional properties in the textile

industry builds upon the repertory grid as a method facilitating a systematized focus on relevant and available means for designing future textiles and by analytically articulating textile attributes [4]. Van Kesteren has developed three material perception tools focusing on different aspects of user-interaction in materials selection: a picture tool, a sample tool and a question tool proposed to support designers in enriching their materials terminology and understanding materials' sensorial properties [5]. Johnsson et al. proposed to use a predefined vocabulary of aesthetic and perceived attributes to grasp the more intangible requirements in material selection. The vocabulary is used in the more general design teaching at the Technical University of Denmark to train students' articulation of material properties [6].

1.2 Different learning approaches

These tools for exploring material awareness aim to improve the acknowledgement of non-technical properties used in material selection processes in product design. However the tools are all developed and tested on practicing designers, research staff or students from technically oriented design educations. It is acknowledged that the degree of technical orientation is not discrete being either highly technical or crafty, but a continuum space including design education within engineering, arts and craft and to a certain degree business and production. Nevertheless none of the tools directly address students from arts and craft design disciplines.

In Denmark, designers have traditionally been educated from either arts and craft funded design schools rooted in the Bauhaus School tradition [7]–[9] of practice based knowledge construction and reflective and subjective meaning creation as vital factors [10], or technical universities funded in a more behaviouristic learning tradition [11], [12] . Furthermore, whereas arts and crafts design schools have user experience and aesthetics as focal points, engineering programs weigh technical issues high.

2 THE MATERIAL SELECTION MATRIX

The basis for discussing the use of technical and experiential properties is the material selection matrix, an educational tool used to identify requirements and choose materials for product design concepts (described in Danish in [13]). The matrix has been used in the Materials & Sustainability course for the last five years in different formats, but has not been subject to analysis in terms of its output and how it can be used for developing material courses further. Students are introduced to the tool, first with a lecture on its components, examples of approaches and matrices made by students in previous courses and then with group guidance in, how the matrix can be applied to their concepts. Halfway into the course, students present their preliminary work, where after they improve the matrix, if essential aspects have not been included.

The structure and mindset of the material selection matrix bear resemblances to established decision-making models used in design engineering such as quality function deployment matrices [14] and Harris Profiles [15] and can be identified as a modified version of a Pugh evaluation matrix [16]. One axis lists requirements and the other axis lists relevant materials. Materials are graded depending on how well each requirement is met. The procedure in using the matrix is as follows: 1) A concept or design brief is proposed, 2) a number of relevant material requirements are identified, 3) a number of potential materials are identified, 4) materials are given marks for each requirements, 5) the summation of marks gives students an indication of the best applicable material(s). Whereas the Pugh matrix uses +/- -grading with a benchmarking datum, the material selection matrix can be graded in different ways dependent on students' preferences. This is in line with the didactic approach that students should make bad choices based on reflection rather than make good choices based on no reflection. Thus the primary purpose of the material selection matrix is to make students reflect on the requirement and selected materials they base their design on. Furthermore the matrix enables them to perform structured and systematic analyses arguing for choices made.

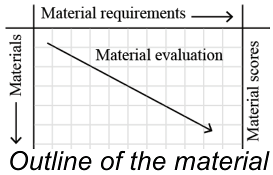

Figure 1. Outline of the material selection matrix

The matrix is a contextual tool in the sense that it works best if it is used as part of a concrete concept development process. This is beneficial for the design researcher, as it captures the potentials and barriers for how students approach the tool in a non-interventional learning situation and for the students since it is more likely that they integrate the tool into their design practice. The limitation is that the tool should be used only for understanding and materializing a specific concept in order to make sense.

2.1 Description of the study

The analysis is based on data extracted from matrices of 21 concepts developed by students within three courses in Materials & Sustainability in the fall 2012 (5) and 2013 (16) in combination with observations made during the course. The course is a three-week course on third semester for textile, fashion and industrial design students at Design School Kolding. In 2012 it was a mixed course, while the courses in 2013 were held for respectively industrial design and fashion and textiles design. The course is the last of two fundamental material courses that aim to provide students with fundamental knowledge in materials. Students are working in groups on product design projects stressing issues of sustainable use of materials. During the course students are given supplementary lectures in relevant materials and generic sustainability as well as different exercises to evoke material explorations and material awareness creation.
The matrices were made in the groups and are based on discussions and material investigations within the groups. The time spent on the matrices differs from group to group and depend on, how difficult the students find it, and the complexity of the product.

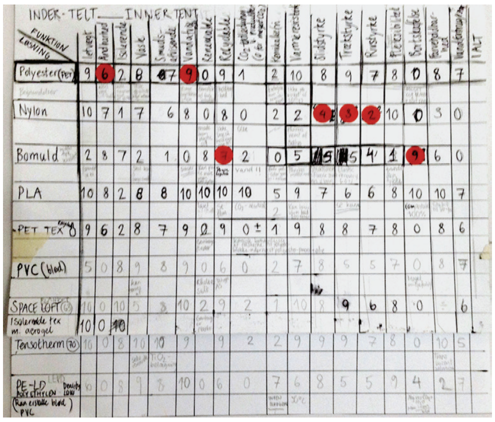

Figure 2. Example of a material selection matrix evaluating materials for a tent canvas

Figure 2 shows an example of a material selection matrix made by two industrial design students. The matrix evaluates materials for a tent canvas and lists requirements on the horizontal axis and materials on the vertical axis. Nine materials are graded (polyester, nylon, cotton, PLA, Eco-PET, PVC, Spaceloft (Aerogel matt), Tensotherm (PTFE/aerogel sandwich) and LDPE) using seventeen requirements (lightweight, breathability, insulating power, cleaning, dirt repellency, water repellency, recyclability, renewability, CO_2-emission (production), free of chemicals, heat resistancy, abrasion resistancy, tensile strength, tearing strength, flexibility, disposal and water consumption). The materials have been marked using a 0-10 scale, with additional comments placed under the marks. The empty column at right is intended for the total score for each material. The red dots do not have any function, besides correcting marks.

2.1.1 Modified course curriculum introducing material scales

In the courses conducted in fall 2013, the curriculum was modified to promote the acknowledgement of non-technical material attributes. This further introduced lectures on material identities, working with online-based material libraries from Innovatheque and Material and an exercise based on relational semantic mappings.
The exercise stresses the use of non-technical requirements in the matrix and has resemblances to the Sensory Mapping tool used by Rognoli ([2], [17]). The aim of the exercise was to make the students start reflecting upon the diversity of material properties that can be evaluated and that the perception of non-technical characteristics is highly personal. When using a relational scale, students do not have to consider whether properties are measurable or not, and the order of the materials are created by the students' intuition, experience and hands-on investigations.

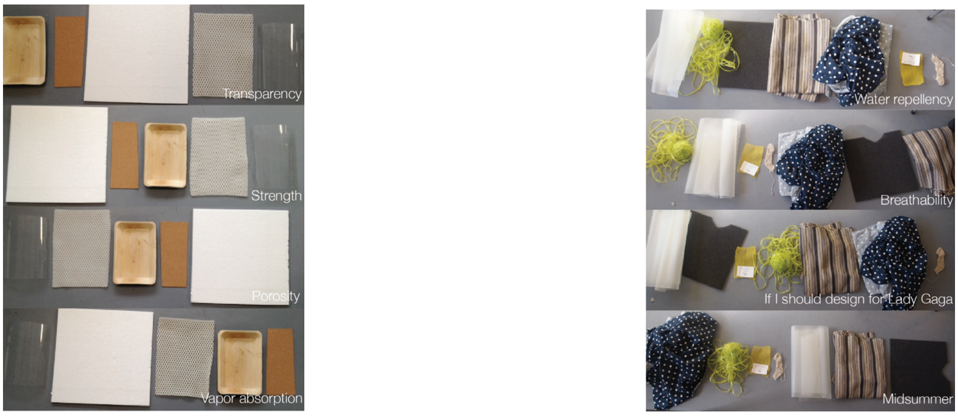

Figure 3. Examples of material scales made by groups of industrial design (left) and fashion and textile design (right) students as introduction to the material selection matrix

In groups of two to four, students were asked to order five or seven materials using five different material properties. The properties were free of choice, but had to include at least one of either technical (objective) or experiential (subjective) properties. When analyzing these properties it was revealed that predominantly technical properties were used and that the group making of the relational mapping stimulated dialogue and discussion. This forced the students to articulate and express subjective believes, and longer discussions were often required in order to agree upon, how materials should be placed.

3 FINDINGS FROM USING THE MATERIAL SELECTION MATRIX

Two aspects have been of interest in the analysis of identified requirements: the nature of the requirements and how they are structured. The former is important in order to understand the diversity of requirements being considered in material selection and the latter in order to understand, how students approach this process.

A total of 291 requirements have been identified in the three courses. In table 1 an overview of the requirements identified is given. Of the 291 requirements approximately 120 were distinct; a number that is not definite as some requirements overlap and vary in detailing.

Table 1. Overview of the requirements identified in the course in 2012 and 2013

	Groups / components	Requirements
Mixed course 2012	5 / 6	64 (average 10.7)
Fashion & textiles course 2013	9 / 11	131 (average 11.9)
Industrial design course 2013	4 / 8	96 (average 12.0)

The structure of material selection matrices

Even though the curriculum changed from 2012 to 2013, no remarkable differences occur in terms of structuring the matrix. Four main trends of characterization of structure appear:

- The majority of matrices show no structure and requirements are seemingly randomly selected and distributed
- Requirements are structured in terms of the product life cycle, grouping requirements in terms of e.g. raw materials, production, use and disposal
- Requirements are divided into functional/technical and sustainability assessments properties
- Few groups (two) have assessed materials using sub-groups containing few non-technical properties

The nature of material requirements

Even after the course curriculum was modified, the requirements tend to have technical orientation, and less than nine of the 120 distinct requirements can be characterized as non-technical. These are ‘softness’, ‘comfortable’, ‘nice tactility’, ‘Aztec-like’, Inuit-like’, ‘smooth’, ‘patina’, ‘signalling effect’ and ‘trend appeal’, A larger fraction (30-35 requirements dependent on how sustainability is approached) accounts for sustainability issues, typically combined with a product life cycle structured matrix. Examples of these are ‘separability’, ‘renewability’ and ‘CO_2 emission in production/disposal’.

Requirements are predominantly related to either production (raw materials, energy consumption, manufacturing processes etc.) or practice of use in terms of durability and maintenance (e.g. mechanical, chemical and thermal properties), which also has been indicated in a previous study based on the material selection matrix [18].

4 DISCUSSION

In constructivist and applied learning it is stressed that students should be left room for subjective interpretations of methods in order to develop individual practices [10], [11]. This has also been the case for using the material selection matrix in the materials teaching. It is difficult to conclude whether the matrix is a better material reflection and selection tool than others, as it has not been compared to others in the given context. The general expression among students is that the topic (materials selection and sustainability) is overwhelming and being required to reflect on and discuss materials selection in a structured manner is difficult.

With that said, students are challenged in multiple ways. They are being introduced to a structured selection method that forces them to reflect on their decisions, they are being introduced to a complex world of materials that can be fascinating, however yet frustrating and overwhelming to navigate in, and they have to do this within the boundaries of design for sustainability, which in itself and for even the trained designer can be a challenge. With a time frame of three weeks students express the necessity of spending time afterwards to reflect on using this method that challenges their awareness concerning product requirements and materials, as well as their use of methods in their practice.

The limited material knowledge the students have and the few lecture given in the course are by some means advantageous, as it gives open-mindedness, and encourages students to explore different kinds of materials without being (too) restricted by presumptions. Nevertheless it is also a challenge, as students tend to hold on to what is already known, and even though it is maybe not the vocabulary they would use to describe their practice preferences, technical attributes seem to be the predominant way to communicate materials. Stressing non-technical requirements and using a tool like the reflective semantic scale may have opened students' eyes to, how materials can be evaluated, but even further emphasis on non-technical properties is necessary.

Based on the analysis of the material selection matrix, it is proposed to introduce a modified matrix to provide structure and guide students in their material selection, though still challenging their reflection on material choices. This aims to provide a tool that further forces students to consider technical, experiential and sustainability assessment requirements on equal terms. The approach breaks with the previous liberal and open approach, but it serves to make experiential material characteristics more than just gimmicks or second rang requirements. Because sustainability assessment requirements can be both technical (e.g. raw materials, energy consumption, recyclability etc.) and experiential (e.g. prolongation of use based on emotional attachment), they are intertwined in the two otherwise contrasting categories of requirements.

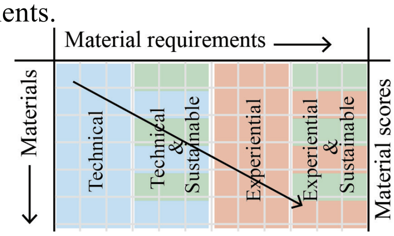

Figure 4. Schematic outline of the modified material selection matrix

To ensure higher quality and relevance in requirements used, it is proposed to apply a prescribed number of technical and experiential requirements. In the 2013-Materials and Sustainability course an average of twelve requirements were used in the matrices. The requirements used were relevant in general but could be formulated more precisely. It is therefore proposed to introduce a matrix with twelve requirements that have to comprise an equivalent number of technical and experiential requirements, thus six for each. When further addressing sustainability issues on equal terms, sustainability assessment requirements account for three of the six in each.

5 CONCLUSION

The paper discusses the experiences with an educational tool, called the Material Selection Matrix, used to create material awareness. In three studies a total of 18 groups of students have used the matrix

to choose materials for 25 components. They defined 291, where 120 were distinct, 9 related to emotional properties and 30-35 related to sustainability issues in material selection.
The majority of the matrices show no structure and requirements are seemingly randomly selected and distributed. In some cases requirements are structured in accordance with the product life cycle, grouping requirements in terms of e.g. raw materials, production, use and disposal or into functional/technical and sustainability assessments properties. Few groups assessed materials using sub-groups containing few non-technical properties. Introducing exercises with material scales to promote non-technical material attributes did not have any significant importance.
The previously applied didactic approach has aimed to give students freedom to construct and structure the matrix, as they found best, as it was believed to establish the best premises for creating reflections and awareness in the material selection process. However the paper indicates that students find it difficult to structure their material choices and to consider experiential and sustainability assessment requirements when selecting materials using the introduced matrix. Students consider technical properties, even when being encouraged and guided to do differently in the process. It is therefore proposed to introduce a modified material selection matrix with a more defined structure and stricter guidelines to, how it should be used.
The findings presented in this paper have built a foundation for improving the matrix. The modified matrix has not been tested and therefore it is not possible to conclude how it works yet. As an educator this study can function as inspiration for questioning tools and methods used. This project has offered the opportunity to reflect on the didactic approach to materials teaching and aims to create better knowledge for educators in the materials and design field.

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