

MATERIAL SELECTION IN INDUSTRIAL DESIGN EDUCATION – A LITERATURE REVIEW

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ABSTRACT

This study reviews literature on the aspects of material selection within the field of industrial design education, specifically focusing on existing material selection tools and guidelines used in industrial design education. The growing number of materials available today has created a large variety of options for industrial designers, which they are ill-equipped to handle. A key reason behind this is that industrial designers lack appropriate education in material selection. There is a large body of research in the field of mechanical engineering, examining the material selection process of mechanical engineers. There are differences in material selection activities of mechanical engineers and industrial designers, based on their information requirements during different stages of the design process. Recent research highlights a need to merge the perspectives of engineering and industrial design for teaching the subject of material selection in industrial design education at tertiary level [1]-[3]. Industrial designers have unique skills to combine technical properties and intangible characteristics of materials in the product development process. Design students need to learn how to act as ambassadors of the intangible material characteristics in material selection processes in interdisciplinary teams. This paper suggests an approach that prepares the students to work both on inspirational and analytical levels in material selection processes.

Keywords: Design education, material selection, material experiences, product design.

1 INTRODUCTION

The communication between the design and engineering disciplines is important in design education, especially when related to materials and technological processes. Design education has over time made use of and adapted some resources developed from the field of engineering, but also created its own [4]. Design education placed 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 disciplines are supported with numerous textbooks and software tools. Materials teaching in Industrial Design education is often pervaded by the tension between a natural scientific and engineering oriented topic taught in a design education rooted in a practice based and constructive tradition [1]. 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. Based on the authors’ own didactic experience over a decade, of tutoring industrial design students at bachelor level on the subject of material and manufacturing selection processes, we believe that it demands a long term strategy to overcome the related barriers in materials education. In design education, there are a few courses dedicated specially to the sensorial dimensions of materials. Several studies have developed tools to support students and professionals in material selection, taking into consideration the sensorial dimension of materials [4]-[7]. 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. Industrial designers generally gather knowledge through tailor made combinations of a number of information sources and methods, e.g. inspirational material samples, product samples, material selection software, communication with colleagues, and visiting trade fairs. The quality of the result depends on how

skilled the industrial designer is in identifying and implementing intangible characteristics of materials in the product development process. How do we teach industrial design students to make well informed decisions on materials in the product development process? We need to acknowledge that industrial designers and mechanical engineers can't be regarded in the same way, in doing so we can appreciate and take advantage of the differences as we acknowledge common ground. Common properties in material selection for mechanical engineers and industrial designers are: technical properties, manufacturing processes and environmental issues. Intangible characteristics are often considered difficult to handle in a technical context of mechanical engineering [8][9]. Studies show that industrial designers gain best understanding of materials by handling physical material samples in combination with material selection software offering both technical properties and intangible characteristics [1][2][4][10]. The terms 'properties' and 'characteristics' used in this paper are adopted from the study of Hassling [1]. Properties that relate to the physical world of materials (mechanical, chemical, thermal etc.) are based on quantitative measures. Characteristics that relate to the social world of materials (e.g. meaning and emotions) are based on qualitative experiences. Material characteristics that are particularly important to industrial designers are intangible and sensorial characteristics. The material selection guidelines used by industrial designer in different stages of the product development process differ in depth and focus depending on if they are originally intended for mechanical engineering or industrial design. The variety of guidelines and tools reviewed span from theoretical to practical.

2 MATERIAL SELECTION TOOLS AND GUIDELINES

Product development involves interdisciplinary activities. Mechanical engineering and industrial design activities are both concerned with material and manufacturing process selection, but the level of detail and the focus within the design work differs [6][11][12]. The majority of material selectors are so called property based search tools, dominated by numerical material data that is mainly of use in the embodiment or detailed design phases. Industrial designers are often involved with more comprehensive redesign of products or completely new design of products than mechanical engineers, and therefore are in general more willing to consider new materials and manufacturing processes [6]. How can then the solution space be widened in the material selection process for industrial design students? In the research project "Manufacturing processes", Lenau and Nissen [6] attempted to expand the solution space by stimulating designers and students to invest time in exploring new materials and manufacturing options. One result of the project was an on-line selection tool Design inSite, which was the first attempt to integrate intangible material characteristics and visual communication in the form of a material selection tool. Lenau [6] emphasizes the importance of an adapted interface to meet the demand of designers' need for visual communication to support the traditional way of communicating material properties and manufacturing processes via charts and tables. Visualizations have the advantage of conveying large amount of information in an effective way. By presenting pictures of product examples, the tool combines materials with manufacturing processes to stimulate the designer to find new possible material candidates and manufacturing methods, not known to the designer before using the tool.

Ashby and Johnson [11] describe the material selection process as stages from need identification, clarification of the task through concept development and detailed design to final product specifications. Technical constraints and design constraints narrow the choice until a final material can be selected [11]. Ashby and Johnson define four complementary methods for selecting materials, by deductive reasoning, inductive reasoning, through similarity and by inspiration. The methods are often combined during the selection process. The Cambridge Engineering Selector, CES EduPack, developed by Granta for design engineering is based on the work of Ashby and Cebon [12]. Ashby and Cebon [13] sum up the materials selection activity in four main steps (1) translate the design requirements as constraints and objectives, (2) screen the material world to identify materials that cannot do the job, (3) rank the materials that can do the job best and (4) explore the top rated materials. The CES-EduPack offers material selection based on technical properties, manufacturing processes, environmental and sustainability aspects. The program offers visualizations and material charts of the relations between 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. The database is product-centered and contains descriptions and data of materials and processes used to make products. The new database includes profiles of designers and manufacturers [13]. The product examples are intended to act as de-codifiers between intangible characteristics and technical properties.

The Expressive-Sensorial Atlas by Rognoli [4] is a tool focused on characterizing the sensory dimension of materials for consideration in a new product design. At the didactic level, the atlas is an interactive tool used to teach design students the sensory dimensions of materials, consisting of tactile and photometric sensations and how they correlate with technical properties [4]. The Expressive-Sensorial Atlas uses four parameters, namely, texture, touch, brilliancy and transparency. 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.1) from one sensorial extremity to another e.g. light-heavy. The subjective sensorial maps trigger relevant discussions between the students when they realize that they do not always correspond to the scale derived from objective material measurements.

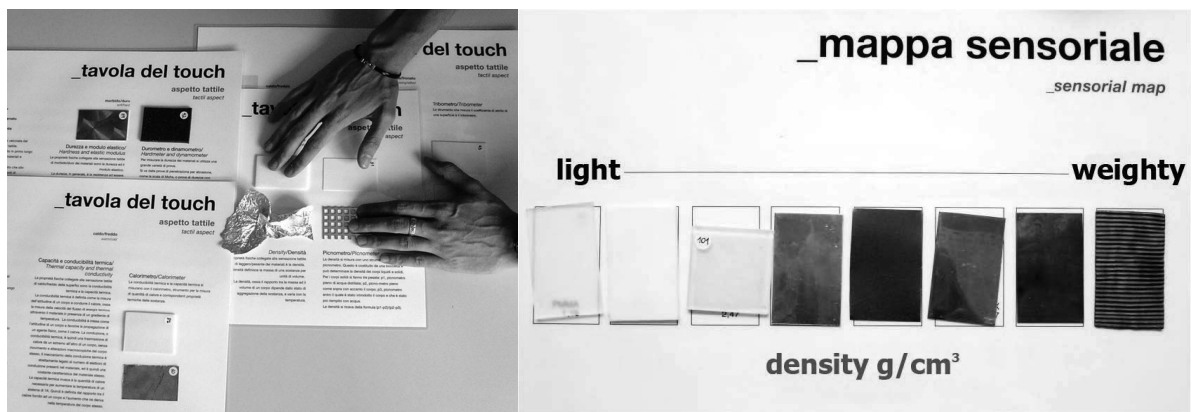


Figure 1. Property explanations and physical samples combined into the Expressive-Sensorial Atlas and developed into a scale of light/ heavy [4]

Material libraries are in some contexts seen as a way to bridge the communication gap between material science and industrial design [10][14]. Material libraries provide designers with a hands-on resource to understand materials and related properties beyond what is possible through datasheets, catalogues and online resources [14]. Material samples can be difficult to access both for design students but also non-commercial material libraries, due to obstacles caused by corporate secrecy and copyright issues, resulting from the desire to control materials. Material libraries can be seen as a part of a larger project encouraging interdisciplinary transfer of knowledge about materials [10].



Figure 2. Examples of how the picture tool was used. 1. Grouping pictures. 2. Selecting cards. 3. The sample tool motivated participants to touch and explore the desired physical properties [7]

The Materials in Product Selection tools, MiPS (Fig.2), consist of a picture tool, a question tool and a sample tool that incorporates aspects of user interaction into materials selection processes [7]. The MiPS tools aim to understand and define a material profile for a new product in terms of sensorial properties in dialogue with the client at an early stage in a project. Van Kesteren also developed a supporting MiPS technique. The MiPS tool and technique teach the design student to reflect before, during and after meeting with a client or user in the beginning of a material selection process.

Reflection is crucial in a material selection process since there is no specific answer; only contextually related material candidates that offer different solutions are available.

Meaning driven materials selection, MDMS, (Fig.3) aims to assist designers in manipulating meaning creation in materials selection. Meanings of materials are what we think about materials and what kind of values we attribute after the initial sensorial input in a particular context [15]. The MDMS is conducted in three steps with a group of people where they are individually asked to: (1) select a material embodied in a product (or part thereof) that they think expresses a specified meaning, (2) provide pictures of the material embodied in example products, and (3) explain their choice and evaluate the material on provided sensorial scales. From this point, designers analyze their results, and based on their findings they select material(s) for their product design [2]. The model offers a multifaceted framework that embraces both intangible (and sensorial) characteristics as well as technical properties that are embedded in a material. In an educational setting, 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.

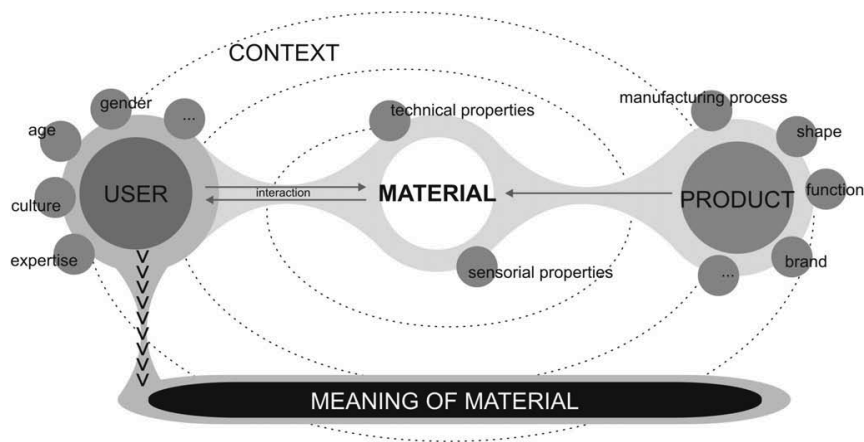


Figure 3. Meanings of Materials Model [15]

The strength of Hodgson and Harpers [16] guidelines (Fig.4) is the holistic approach to the integration of the design and material selection process. The guidelines handle how the attributes relate both to each other and to the surrounding context. 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. The guidelines are developed as a reaction to how material selection is traditionally taught in design education. By integrating cost and value, it reflects a realistic scenario that could support professional designers as well.

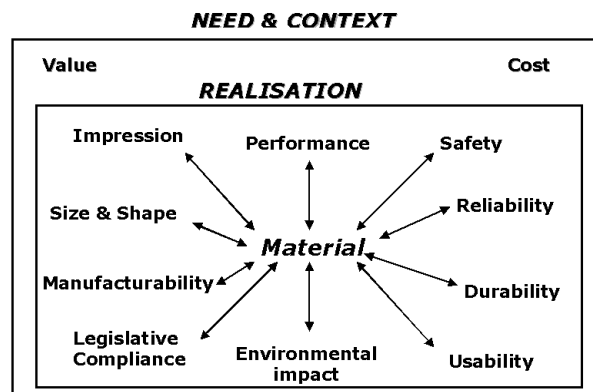


Figure 4. Relationship between materials and the elements of design [16]

3 DISCUSSION

In a design project, material selection is generally a team-based activity, with contribution from, among others, industrial designers, mechanical engineers and marketers. Few material selection guidelines and tools handle a holistic approach; in the review, only few attempts were found [2][5][16][17]. It could indicate the difficulties of developing a holistic material selection approach, offering details while avoiding oversimplification. Material characteristics are closely related to manufacturing processes and these becomes intertwined in the creation of a products function and expression [6][19]. The reviewed literature emphasizes the importance of integrating the two selection processes early in the design process to achieve a good result [6][16][20]. Industrial designers have unique skills to combine technical properties and intangible characteristics of materials in a product development process and need to act as an ambassador for the intangible material characteristics. Manufacturing and material selection should be seen as a co-evolution with ongoing rapid explorations of different combinations of the two in relation to the solution space. Regarding industrial design education, De Nardo and Levi [17] highlight the importance of understanding and managing the relationship between the materials, a structure (product) and the quality of use of a product, by combining the two mindsets of engineering and design. Students need theoretical foundation through lectures in combination with creative practice based workshops to train and refine their skills in making informed decisions. Hasling [1] points out that in many technically oriented design courses materials are taught in decontextualized and multidisciplinary courses, without special emphasis on how materials can be applied in a design process. Design students are mostly interested in applied materials and are often discouraged by the technical approach in the introductory courses. By linking the lectures to hands-on exercises in a workshop and stimulating reflection in a seminar, one can offer the students an opportunity to understand the connection between theory and practice. It is important that design students learn to reflect on their material selection activities when they attempt to convey some specific meanings through selected materials. In order to develop skills and knowledge in articulating and communicating material characteristics, design students need a vocabulary of such material characteristics. The Expressive-Sensorial Atlas and MDMS method, found in the reviewed literature, offer a vocabulary of material characteristics.

4 CONCLUSION

Industrial design needs to reclaim material education when taught in technical faculties and develop its own curriculum. An open-minded dialogue with the engineering colleagues is a prerequisite in developing a curriculum for material courses in design education at a technical faculty. Together designers and engineers need to define a mutual understanding of concepts and contexts to successfully develop a new curriculum. Pedgley, Rognoli and Karana [2] suggest a new framework based on the Bauhaus hands-on tradition and recent research [3][21] on 'experiential' aspect of materials. By applying frameworks of *product experience* to the specific domain of *product materials*, it is possible to create a solid foundation for teaching and learning materials experience [2]. Design education at a tertiary level need to offer material courses that prepares the 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. By then 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 [2].

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