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MEANING DRIVEN MATERIALS SELECTION IN DESIGN EDUCATION

Elvin Karana
Delft University of Technology, NL

ABSTRACT
The shift towards more intangible aspects of materials in design practice has not been adapted to the design education system yet. In informal discussions with design students across years, we saw that students find it difficult to integrate their technical material knowledge with design practice. This may be because materials are still taught as a separate (and technical) domain for design activity and because material knowledge is usually transferred without considering user experiences and user contexts. Developed in Delft University of Technology at the Department of Design Engineering, Meaning Driven Materials Selection (MDMS) is a method which aims *to encourage designers to systematically involve meaning considerations in their materials selection processes*. This paper presents the results of a workshop which was conducted with 140 third year bachelor design students in Greece for the aim of testing the usefulness of a MDMS in design education.

Keywords: materials selection, design education, meanings

1 INTRODUCTION
Designers aim to select the most appropriate material(s) from a list of candidate materials. Many scholars in the field of materials and design put more emphasis on the technical properties of materials, manufacturability possibilities, economical requirements, availability, and environmental issues in materials selection (See [1-4]). In product design, however, materials should not only fulfill technical requirements but also appeal to the user's senses and contribute to the intended meaning of a product. However, designers tend to invent their own ways (or just use their own intuitions) particularly in putting these concerns into practice in their material decisions (e.g. *selecting materials for emotional experience*), because there exists no common systematic approach for supporting designers in involving these concerns into their selection processes [5-12].
In design education, we encounter a similar problem that design students find it difficult to select materials based particularly on the technical requirements [13]. Therefore, materials selection is usually left to a very last phase of a design process. This paper is a part of a comprehensive research which focuses on developing a new method, [meaning driven materials selection], for selecting materials in product design. In this paper, the usefulness of this method for design education is tested with 140 Greek design students. In the next section, the rationale of the [meaning driven materials selection] is briefly explained. Afterwards, the conducted study is presented in Section 3. Section 4 consists of a comprehensive discussion on the results of this study.

2 MEANING DRIVEN MATERIALS SELECTION
Meanings of materials in this study refers to what we think about materials, what kind of values we attribute after the initial sensorial input in a particular context of use (e.g. feminine, masculine, modern, traditional, cozy, etc.) [14]. A meaning is not factually part of materials' physical entity or appearance (i.e. a material is not literally feminine or masculine). A meaning of a material is evoked by the interaction between product aspects (such as shape, function) and material properties, with respect to how and in which context it is used and who the user is [13,14]. Therefore, it is not possible to define simple design rules for a certain material- meaning relationship. Nevertheless, findings of a comprehensive research [13] showed that there are some patterns that identify how materials obtain their meanings. A material, for instance, may express *professionalism* when it is smooth and dark (coloured), when its used in an office environment and when certain technical properties are combined

for enhancing its function (e.g. combining strength and lightness). We assume that a designer who can understand these relationships (which we may call 'meaning evoking patterns') can more deliberately (or systematically) manipulate meaning creation in materials selection processes. In order to make designers capable of finding these patterns, a method should first familiarize designers with the key aspects (such as shape, user, manufacturing processes, etc.) that play an important role in attributing meanings to materials.

Following these concerns, a method for selecting materials in product design, [meaning driven materials selection], has been developed as a part of a PhD study at Delft University of Technology. The proposed method aims *(1) to show which aspects of design play an important role for certain meanings (such as sensorial properties, gender, culture, shape, etc.), and (3) to stimulate designers to find the relationships (or patterns) between these aspects and meanings.* For the two goals listed above, the method proposes to provide designers with a collection of material examples (as material samples or materials embodied in products) that have been selected by a number of individuals who think that each material example expresses a certain meaning. In this way, the intention is not to provide designers with explicit design rules but rather to encourage designers to make their own conclusions by analyzing the selected materials. After testing the usefulness of this method with junior and senior designers, in this study, the focus is converted to design education: can we use MDMS for teaching materials in design education?

3 A WORKSHOP FOR TESTING THE USEFULNESS OF MDMS IN DESIGN EDUCATION

Three main aims were defined to be achieved in this workshop: (1) to inform students about what kind of variables play an important role in the attribution of meanings to materials, (2) to show them the importance of understanding their target users, and (3) to inspire them for new ideas about materials. In order to achieve these aims, the first step was to generate data by making students select materials expressing certain meanings and evaluate their selections with their own words as well as with the sensorial scales. Four meanings were selected for this step: cozy, feminine, futuristic and strange (for more detailed information about the selected meanings, see [15]). The main motivation in selecting these meanings for the workshop was to attract the students' attention and consequently provide a high participation in the study. In addition, we assumed that the attribution of the meanings strange and feminine to materials, for instance, is affected more by shape and function than by the material properties alone [13]. On the other hand, the attribution of futuristic or cozy can be dominated more by the material properties. These meanings could be good examples to show the effects of other key variables (such as shape and function) in the attribution of meanings to materials.

3.1 A week before the workshop: TASK 1

Procedure

140 students were divided into four groups. The individuals of each group were asked to select a material which expresses the given meaning (cozy, feminine, futuristic or strange), and explain their selection. The task was given by the assistant of the course in Greece. The students sent their selections with their explanations to an e-mail address particularly created for the workshop (meaningsofmaterials@gmail.com). Once they sent their selections, they received an automatic reply consisting of a list of sensorial scales (Figure 1), which was developed by a number of studies [15]. The students were informed that their submission would not be completed, unless they sent their evaluations on the sensorial scales.

Results

29 cozy, 33 feminine, 35 futuristic and 33 strange materials were collected at the end the study (so in total 130 students sent their selections and explanations). However, students had difficulties in sending the results of the sensorial scales. There were 90 valid submissions (23 for cozy, 22 for feminine, 20 for futuristic and 25 for strange).

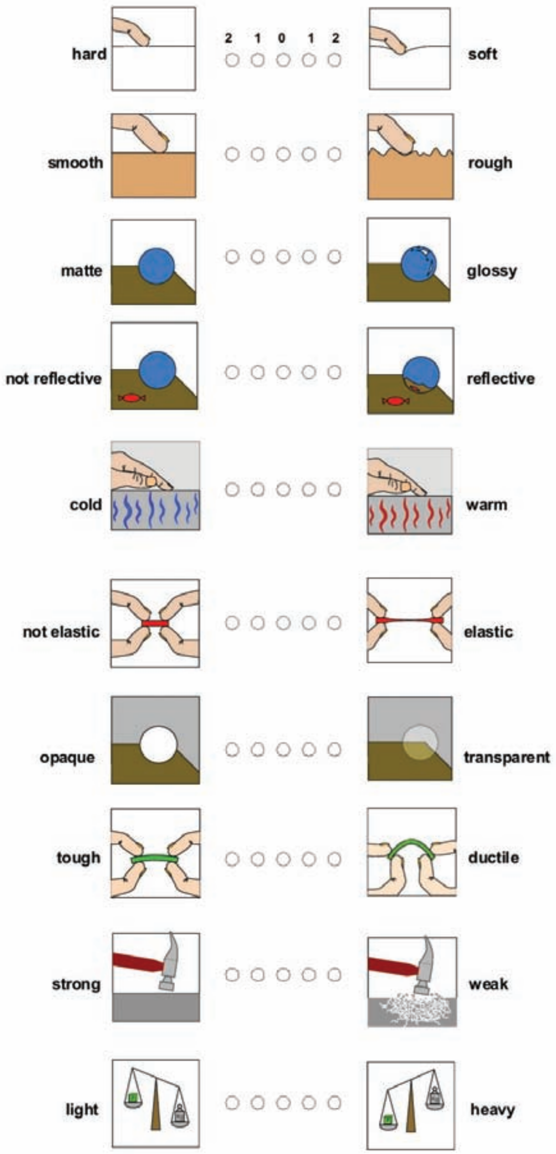

Figure 1. Sensorial scales used in the study

Cozy materials selected by 29 Greek students
The Greek students mainly focused on soft and warm materials such as plumage, polyurethane foam and cotton (Figure 2). Some students explained their cozy materials with the overall context in which the selected materials are used. For instance, a student explained how the soft and light material of an earphone provides comfort and pleasure in use (Figure 2_1E). Likewise, another student explained how the material of a bathtub expresses coziness because it offers relaxation, comfort and pleasure (Figure2_5B).
The sensorial scales filled by the students were analyzed statistically to see the most significant properties in attributing the meaning cozy to materials. A *One Sample t- test* was executed to compute the importance of the properties. The overall mean score for 10 items (M= 2. 8) was taken as the test value for the One Sample t-test. Bold items in Table 1 show the properties that received scores significantly above or below the overall mean score. As recognized from Chapter 8, the properties that received scores significantly below the overall mean score are presented with a minus sign (-) in the table. According to the findings, *Transparency* (1. 78) was significantly below (-) the overall mean, therefore *opaqueness* of a material would appear to be one of the most important properties in attributing the meaning cozy to materials. *Roughness* (2. 09), *glossiness* (2. 13) and *reflectiveness* (2. 13) were also rated significantly below the overall mean score, which shows that the cozy materials were significantly rated as *smooth, matte* and *non-reflective*. *Softness* (3. 91) and *warmness* (3. 48) and *ductility* (4. 04) were rated significantly above the overall mean score (i.e. the selected materials were commonly soft, warm and ductile).

Table 1. Results obtained from the sensorial scales for cozy materials

COZY:: Test Value = 2.8	t	df	Sig. (2-tailed)	Mean
soft-hard	3,237	22	,004	3,91
rough-smooth	-2,843	22	,009	2,09
glossy-matte	-2,560	22	,018	2,13
reflective-nonreflective	-2,560	22	,018	2,13
warm-cold	2,627	22	,015	3,48
elastic-not elastic	1,356	22	,189	3,22
transparent-opaque	-4,184	22	,000	1,78
ductile-tough	3,918	22	,001	4,04
weak-strong	1,050	22	,305	3,09
heavy-light	-1,855	22	,077	2,22

Feminine materials selected by 33 Greek students
Glossy and smooth materials dominated the Greek students' selections for the meaning feminine (Figure 3). Interestingly, eleven students selected 'diamond' as a feminine material. Two other students selected crystal and glass, and associated their selections with diamond (Figure 4_ 6B and 6E). Three students selected silk due to its soft, warm and smooth feeling.
The overall mean score for 10 sensorial scales (M= 2. 5) was taken as the test value for the One Sample t-test (Table 2). Table Y shows that *elasticity* (1. 77), *ductility* (1. 86) and *roughness* (1. 95) were significantly below (-) the overall mean (i.e. the selected materials were commonly not-elastic, tough and smooth). *Glossiness* (3. 68) and *reflectiveness* (3.50) of a material would appear to be two of the most important properties in attributing the meaning feminine to materials in this study.

Table 2. Results of the sensorial scales for feminine materials

FEMININE:: Test Value = 2.5	t	df	Sig. (2-tailed)	Mean
soft-hard	-1,490	21	,151	2,00
rough-smooth	-2,179	21	,041	1,95
glossy-matte	3,371	21	,003	3,68
reflective-nonreflective	3,420	21	,003	3,50
warm-cold	-1,264	21	,220	2,18
elastic-not elastic	-2,861	21	,009	1,77
transparent-opaque	,136	21	,893	2,55
ductile-tough	-2,096	21	,048	1,86
weak-strong	-,571	21	,574	2,32
heavy-light	,000	21	1,000	2,50

Futuristic materials selected by 35 Greek students

The Greek students mainly selected smooth, glossy and hard materials for the meaning futuristic (Figure 4). They often associated the properties strength, hardness and lightness with the futuristic design. Aerogel, which is a material with a very low density and weight and made by the drying of liquid gels of alumina, chromia, tin oxide or carbon, were selected by seven students as a futuristic material. Amorphous metals, Plexiglas (PMMA), inox, carbon fibers, carbon nanotubes, e-textiles were some other materials considered as futuristic by the Greek students.

Table 3 shows the overall evaluation of the sensorial scales (the overall mean score M= 2. 4). As followed in the table, *softness* (1. 70) and *roughness* (1. 70) were significantly below (-) the overall mean (i.e. the selected materials were commonly hard and smooth). *Glossiness* (3. 40) and *reflectiveness* (3.30) were significantly above the overall mean (i.e. the selected materials were commonly glossy and reflective).

Table 3. Results of the sensorial scales for futuristic materials

FUTURISTIC:: Test Value = 2.4	t	df	Sig. (2-tailed)	Mean
soft-hard	-3,621	19	,002	1,70
rough-smooth	-2,570	19	,019	1,70
glossy-matte	2,735	19	,013	3,40
reflective-nonreflective	3,000	19	,007	3,30
warm-cold	-,355	19	,727	2,30
elastic-not elastic	-,489	19	,630	2,25
transparent-opaque	,000	19	1,000	2,40
ductile-tough	-1,831	19	,083	1,95
weak-strong	-,882	19	,389	2,15
heavy-light	1,675	19	,110	2,95

Strange materials selected by 33 Greek students

The biggest variety of materials was obtained in this category (Figure 5). Stainless steel, polypropylene, ferrofluid, PMMA, aerogel, latex, bubinga (a type of wood), carbon fiber reinforced polymers, fiber glass, hardened leather and bones were some of the strange materials selected by the students.

Table 4 shows the overall evaluation of the sensorial scales (the overall mean score M= 2. 6). As followed in the table, there were only two scales which obtained significantly high (or low) scores in the overall evaluation of the strange materials: *glossiness* (3. 24) was significantly above the overall mean (i.e. the selected materials were commonly glossy) and *heaviness* (2. 00) was significantly below (-) the overall mean (i.e. the selected materials were commonly light).

Table 4. Results of the sensorial scales for strange materials

STRANGE:: Test Value = 2.6	t	df	Sig. (2-tailed)	Mean
soft-hard	-,241	24	,812	2,52
rough-smooth	-1,866	24	,074	2,16
glossy-matte	2,122	24	,044	3,24
reflective-nonreflective	-,679	24	,503	2,40
warm-cold	-1,095	24	,284	2,40
elastic-not elastic	,816	24	,423	2,88
transparent-opaque	,344	24	,734	2,72
ductile-tough	,603	24	,552	2,80
weak-strong	,136	24	,893	2,64
heavy-light	-2,384	24	,025	2,00

Overall Discussion: Task 1

In general, the students were able to select materials expressing the given meanings and explained their selections clearly. However, a few students (particularly for the category strange) focused on products more than materials and explained their selections accordingly (see the guitar and the car in Figure 5). It was surprising to see a number of similar materials selected for a particular category (such as aerogel for futuristic, or diamond for feminine). In informal discussions with the students, I understood that the main reason to select diamond as a feminine material was a recent TV commercial which had become popular with the motto 'diamonds are the best friends of women'. Almost all students who selected diamond as a feminine material had explained their selections by mentioning the same motto. Indeed, this finding is a very good example how the cultural and social contexts affect a meaning-material relationship. If we conducted the same study with Dutch students and asked them to select feminine materials, the selected materials would probably be different. Similar to the diamond example, I found out that the tutor of the materials and design course had mentioned aerogel very briefly in one of his lectures a few months ago. In this case, the students' background and expertise was effective in the selection of futuristic materials.

It was also interesting to find that seven properties were significantly effective in the attribution of the meaning cozy to materials. This result shows that the meaning evoking patterns for the coziness of a material is very apparent for the Greek students and it is very much related to certain sensorial properties of materials.

Figure 5. Strange materials selected by Greek students

On the other hand, in the selection of futuristic materials the main motive was the technical (or functional) superiority of a material. For the feminine materials, shape (such as the material of a flower like home audio), function (such as the material of a high-heeled shoe) and the certain sensorial properties of materials (such as glossiness and reflectiveness) played an important role. The strange materials had some unexpected properties which conflicted with the students' expectations from a particular material regarding its strength, weight, etc. (e.g. a material which looks very fragile but very durable and strong, or a material which looks very heavy, but very light in reality). Ludden [16], in her PhD thesis, explains this phenomenon with 'sensory incongruity' which occurs when, for example, an individual sees a product and forms an expectation about how it will feel, hear and smell on the basis of its visual properties and on his/her previous experiences. If this expectation is disconfirmed upon perception through a second sense (such as touch), the information from the two senses is incongruent. As a result, people experience surprise.

A handout and a poster consisting of the results obtained from Task 1 (including individual explanations, see Figure 6 for an example) were prepared to be used in Task 3. The results of the sensorial scales were presented graphically (see Figure 7).

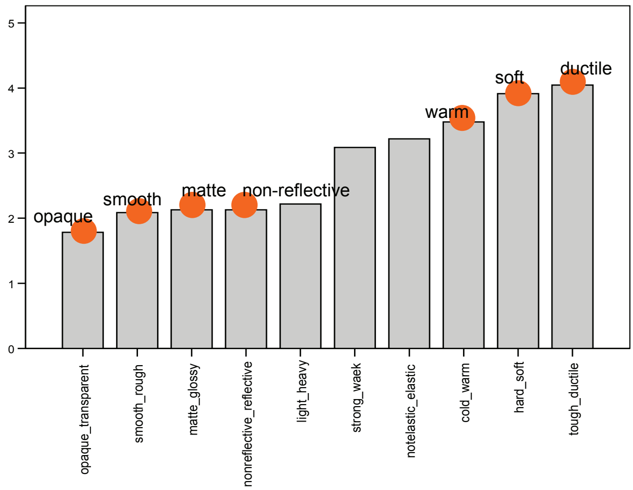

Figure 7. Example of a graph presented to students

3.2 1st Day of the workshop: TASK 2

The first day of the workshop started with the introduction lecture mainly focusing on the effects of materials on the design domain and on different societies. 130 students attended to the first day. We discussed the values of different materials in Greek culture and their differences from other cultures. Then the focus was converted to the materials selection in industrial design. We evaluated the existing materials selection sources with a number of examples from these sources. The students talked about their own selection processes, their needs and expectations from a materials selection source. The conclusion of this preliminary session was that the existing materials selection sources were very adequate for the technical materials selection. However, in order to be able to use these technical sources efficiently, the students first need to identify their objectives and constraints regarding technical and sensorial properties of materials. The question was 'how do we decide to use, for instance, a 'transparent, hard and smooth material' for our design?

Task 2 was ‘to design a sitting element’ (e.g. a chair, a stool, a sofa, an armchair, etc.) for Greek university students. The students were divided into four groups. Each group was given one of the meanings used in the first task. They were informed that their sitting element should express the given meaning. However, a particular emphasis should be put on the material decisions. The chair in Figure 8 was shown to students and explained that the chair looks strange mainly because of its structure. The legs of the chair look as if they are not able to carry a load. Therefore, the chair looks strange as it is meant to be a chair but cannot fulfill its utility function. In that sense, the chair was not a good example for the given task, because the material was not really contributing to the main idea/meaning tried to be achieved.

Figure 8. Example of a strange product

The students were told that they could make their own groups (max 3 students) for this task. They were asked to make sketches and select a final concept out of them. They were also asked to write the profile (the sensorial and technical properties) of the material(s) they selected and explain their selections. They were recommended to focus on these two questions during the brainstorming session:
- what kinds of materials (or material properties) can evoke the given meaning for the target group (Greek university students)?
- what are the other product aspects which can be effective in the creation of the given meaning?
They were allowed to make mock-ups to present the selected material(s) more efficiently. They were given two hours to complete the task.

Results: Task 2
After submitting their designs (mostly in sketches, only 1 mockup), the students were asked to explain the process. They mentioned that they had difficulties to find where to start, and how to integrate the materials selection into the whole design process. They had difficulty to find the relationships between the given meanings and the material properties (particularly for the meaning strange) as they were not to use to select materials in this way. In addition, they said that they hardly think about a target group’s approach about a particular material. Some of the students were not confident with their final material decisions.

TASK 3
After discussing the difficulties the students faced in the first task, the second part of the lectures started. This time the focus was on ‘how do materials obtain their meanings?’. The students were introduced the main idea behind the Meaning Driven Materials Selection. Before given the last task (Task 3) the results of the first task were presented to the students. They were very excited to see the overall evaluation of the task and what kinds of materials had been selected by the other students. The handouts consisting of the selected materials, individual explanations and the overall evaluations of the sensorial scales were delivered to the students; and the last task was given.

Task 3 was to go through the selected materials and try to understand the given meaning-material relationships for their target group (that is, for Greek university students). The main question of this task was: *when does this target group think that a material is cozy/feminine/futuristic/strange*? They were asked to try to find the links between different aspects of products and materials (i.e. finding out the meaning evoking patterns). On the basis of the identified patterns, they were asked to improve (or redesign) their sitting element which they submitted in the second task. The students were allowed to use 3D modeling/rendering programs in this task. They were asked to complete their submissions until the next morning (Second Day of the Workshop).

On the second day of the workshop, we made an exhibition with the submitted projects. The groups presented their designs and explained the materials they selected. In total, 37 projects were submitted on the second day of the workshop.

4 GENERAL DISCUSSION

The most important observations of the study were as follows:

(1) In general, the reactions of the students to the process were very positive. They enjoyed the meaning driven materials selection and found it very inspiring and useful to consider the materials experience in a very early phase of a design process. The selected materials and explanations helped them to identify their main constraints and objectives in terms of material properties as well as shape and use. They found the process particularly valuable to create ideas for combining different materials.

(2) Some students were very surprised to see that their own thoughts about a certain material-meaning relationship were completely different from the rest of the students. In this sense, they realized the value of understanding their target group's approach about materials and their values.

(3) Five groups found that their material decisions in Task 2 were comparable to the results obtained from Task 1. They mentioned that they felt more confident with their selections in Task 3, after seeing the results of Task 1.

(4) Task 3 encouraged many students to explore the most appropriate materials fulfilling the sensorial and technical requirements identified based on the result of Task 1. They used CES (Cambridge Engineering Selector) and some other online databases to find the materials with the identified properties. In addition, some materials selected in Task 1 were not very well-known for some students. A student, for instance, explained that "*I saw carbon fiber reinforced polymers selected by one of my friends in the first task. I liked the appearance of the material in the picture, but most importantly, according to the student's explanation, this material was very strong. I wanted to use it in my design. But I realized that I first need to know how strong and durable it was for making a sitting element.*" Therefore, the student made a further search about carbon fiber reinforced polymers and their applications. Likewise, another student read more about aerogel material in order to understand if she could use it to make a chair. Thus, the meaning driven materials selection stimulated students to explore other materials selection sources for detailed material information.

(5) One of the most important observations from the workshop was that the students were able to see the patterns for evoking the given meanings. They could see how certain aspects play a more crucial role than the others for each meaning. For the meaning feminine, for example, the students emphasized the value of shape-material combination. A group of students, who designed a feminine chair, tried several material combinations in order to find the best shape-material match expressing femininity. They mentioned that the results of the sensorial scales were very helpful to find the points to focus on. The students who designed for the meaning strange were able to detect what makes a material/product strange for Greek students. One of the students explained that "*if a material is very light but still can carry you very efficiently, you think that it is strange. Therefore, in my design, I looked for a very light but at the same time a very strong material which carries high load. Moreover, if the form also emphasizes its lightness, I guess you achieve to create a strange sitting element*". The student explained that she had been inspired by aerogel, which had been found strange by most of the students as it was very light but very strong, and by the form and structure of the polyurethane chair (Figure 5_4C). Similar to this example, another group designed a chair made of polypropylene but formed it in a way that the material looks very soft, like a cushion.

(6) The workshop encouraged students to think about multi-sensory design in their material decisions. They mentioned how their designs gratify senses in different ways. One group, for instance, designed a feminine armchair which was made of metal legs and polyurethane body covered with velvet. At first glance only the color of the chair (which was light purple) was connoting femininity, but not the form. However, the main idea of the armchair was that it was releasing a female perfume when someone sits on it. The group emphasized the importance of 'touch' and 'smell' in products for creating the meaning feminine (velvet was stimulating the sense of touch and odorous of the armchair was stimulating the sense of smell). In other words, the group was successful to convert the main idea by particularly focusing on the sensorial properties of materials. The group explained that they were inspired by the selected perfume bottles and the velvet armchair in Task 1.
(7) It was noticeable that every group was inspired by a different case(s) (results of Task 1). Albeit there were a number of diamonds selected in Task 1, only one group designed a feminine sitting element using diamond. Instead, some groups tried to create associations through glossy and transparent materials; and some of them focused on completely different cases. This showed that even though a particular material dominates the 'material collection', designers still find other cases to inspire, they weight up the consequences of their selection and think about other selected materials instead of sticking to the most dominant selection (e.g. the students used sateen, velvet, leather, Plexiglas, marble, silk and metal in their feminine sitting elements). One group who designed a strange armchair used paraffin wax (used for making candles). The material was not one of the collected strange materials. However, the group explained that "*we saw in some of the examples that using a well-known material in a completely different context can be found very strange, such as an armchair made of cork (Figure 5_3D) or a coffee table made of leather (Figure 5_6A)*".
(8) A negative point was observed during the workshop. Two groups (in total 6 students) tended to stick very strictly to the results of the sensorial scales. They felt obliged to focus on these results in their material decisions. After discussing the projects exhibited on the second day, they realized that they did not have to use the results of the scales. The main idea aimed to be conveyed through the scales was to help students (designers) to identify the meaning evoking patterns regarding their target group. They understood that the intention was not to offer them 'definite' solutions for a particular material-meaning relationship, but to help them in identifying their constraints and objectives by taking their target groups' approach into account.

5 CONCLUSION

This workshop was an important attempt to test the usefulness of *meaning driven materials selection* in design education. We saw that the principle of 'meaning driven materials selection' can be adapted within design education and can complement the teaching of technical based selection. We also saw that the proposed method of meaning driven materials selection did not only enhance the abilities for quick and appropriate materials decisions but also increase the creativity of students. It was a pleasant surprise to see that the students were also more encouraged to search about the technical properties of materials and find new materials or new application techniques for their designs. We expect that the implementation of this method in design curriculum will enhance students' interest towards materials and their applications and make them consider materials at very early phases of their design processes.

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