Materials & Manufacturing Methods selection in product design: Experiences in undergraduate programs

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Abstract: This paper presents the results of an exploratory analysis about the existence and nature of ‘materials and manufacturing methods’ contents into the curricula of product design undergraduate programs in Brazil. Materials selection has great impact on the manufacturing of products and can support more sustainable design. This study is the first phase of a research about the implications of choosing autochthonous materials and traditional manufacturing methods for design of local products and, consequently, adding value to local resource and its origin. The main case study was conducted in Brazil that is an immense country and owns vast natural resources. Moreover, Brazilian ancestry communities developed a lot of traditional manufacture methods. Neither native materials nor traditional manufacturing methods are presented for design students as alternative for adding value to local resources. Aiming at illustrate possible strategies for M&MM education, three innovative initiatives in Europe are presented.

Keywords: Design Education, Product Design, Promotion of local resources, Materials and manufacturing methods

1. Introduction

Over the last decades production systems have acted globally: A product can be designed at some place and be built in other one with abroad materials or foreign technologies; this same product still can be sold everywhere. However this situation is critical to emergent places. According to Santos (1999), this reality is devastating because large companies have no responsibilities with social or environment aspects; they just obtain profits until it attends.

Starting by this condition, the following question was addressed: How to add value to local resources and its origin by using local productive capacity to design local products?

Brazil is an immense country and owns vast natural resources. Moreover, ancestry communities developed a lot of traditional manufacture methods. However, traditional manufacturing methods
are not registered, and it exists a serious risk of they disappear. Rarely, large companies use traditional manufacturing methods and natural materials. Frequently, traditional manufacturing methods and natural resources are exploited by craft and usually results in low quality products. Emotional aspects of materials and manufacturing methods are not employed. Profits generated by massive production do not stay in territories of the materials or manufacturing processes. Design education almost ignores this type of source.

Beyond economic and social injuries, Schumacher (1979) defends that the concentration of economic supremacy and massive production had been also injuring environment. Braungart and McDonough (2013) advert that large industrial systems discharge amount toxic waste on air, soil and water; causes intoxication to people and natural systems; produce dangerous materials; produces unless waste; buries materials. These production systems can improve and develop several aspects of places: environmental, social and economical.

The productive capacity from places can boost several benefits to them. It is possible to say some materials or some manufacturing methods are connected with history and tradition of territories. The way things are made can say something about its people and its place. In the meantime, some natural matters (what gives origin to a material) grows up exclusively in specific regions, they are singularly transformed in material in specific regions. Moreover, traditional manufacturing methods or ancestry techniques used to build objects are current in the cultural history of societies. According to Albino (2012) crafts can be used as example: some territories can be represented by iconic elements from crafts skills developed by societies; some places still have their names associated to one of these crafts activities.

To understand relevant aspects and apply autochthonous materials and traditional manufacturing methods subject, we examined the design and materials study field. The decision making of a material or a manufacturing method for product design can be affected by several factors: technical characteristics; companies demand; aesthetical requirements. On most of cases, technical aspects and costs are decisive. However, other aspects are important for design too.

In 1986, professor Ezio Manzini presented the book “The material of invention” about materials and manufacturing processes as a “horizon of possibilities” for designers. Author explained technical features should not be principal criterion to select a material against an increasing number of new materials. Then, he realized reflections about cultural aspects of materials and it effects at users perception of products.

From then on, lots researchers investigate the role of sensorial, emotional and perception aspects of material and manufacturing methods. These aspects are called by experts “intangible meanings” since they are subjective (Jee and Kang, 2001; Sapuan, 2001; Ashby and Johnson, 2002, 2003; Ljungberg and Edwards, 2003; Hodgson and Harper, 2004; Rognoli and Levi, 2004; Lefteri, 2005; Zuo, 2005; van Kesteren, 2008; Karana, 2009).

Starting by “materials evoke meanings and elicit emotions” (Karana, 2009, p.23), some material or manufacturing method employed in local products can evoke emotions in users. Among others, intangible aspects of materials are relevant to this research because it is concerned with factor of local recognition.

Recognition of territory is an essential factor for adds value to its resources. Then, as Krucken (2009) arguments local qualities should be presented and exploited when gives value to local resources is expected. For author, local products can do this quality recognition.
Our research purpose is the one of offering contents for design education based on strategies for selection and application of autochthonous materials and traditional manufacture methods. It is expected that findings contribute to local product innovation and, consequently, to the promotion of resources of a territory. Thus, understanding the current context of teaching and learning about materials and manufacturing methods in Brazilian design programs is important.

This research topic is relevant because designers can acquire more conscious understanding about materials if it is observed by cultural perspective. Not only habits and beliefs build the material culture but also design and materials relationship. Once materials express and convey meanings during the use of product or influence the decision making of buyer, they can be used to add value in products.

The research project has 3 main phases. Similarly to a design project, it includes context analysis, research and project (in this case the results are strategies).

1. **Context analysis** - an exploratory study of Materials and Manufacturing Methods (M&MM) contents into the curricula of product design undergraduate courses (with an special focus on Brazil);

2. **Research / benchmarking** – identification of innovative Design Education strategies related to M&MM in the international arena, with particular emphasis in local resources and know-how;

3. **Strategies development** – the idea is to develop strategies for teaching M&MM that are suitable for megabiodiverse contexts, as Brazil.

This paper will focus on the first phase of the project and some initiatives regarding the second phase will be pointed out.

### 2. Methodology and methods

Two research methods have been chosen for the Phase 1: (a) Documents Review and (b) Survey. Documents analysis has been chosen because it presents the context based on classification and indexing of documents (Bardin, 1993). Additionally, survey gives the information that could not be collected by documents. Survey by questionnaires is an efficient method to collect information based on personal feelings and emotions (Shuman & Presser, 1996).

#### 2.1 Analysis of higher education curricula: documents review

According to e-MEC (2016), currently, Brazilian scenario of design education can be seen at table 1. We used the terms “design” and “industrial design” to search programs because these are the names used by institutions for design programs. In this phase, all qualification lines and fields of design were considered such as graphic design, fashion design, interior design and product design.

| Table 1. Number of Brazilian educational programs in design |
|-------------------------------------------------------------|
| 1 It is part of a Doctoral research in progress at Faculty of Architecture of University of Lisbon |
| 2 E-Mec is a database about education mananaged by Brazilian Ministry of Education |
In view of the large initial set, 30 public undergraduate courses in Design were selected. Public courses were chosen because they are, in general, larger in contact hours education, which means more disciplines or more embracing content. Equally, public courses documents are made available for consultation. Following, grades and educational plans of programs were examined to select those courses focused on product design once several institutions name Design programs that offer both qualifications in product design and graphic design. Our sample is presented on table 2.

Table 2. Our sample: Public undergraduate courses in Design in Brazil

| Type of program | Associate degree (Classroom lessons) | Associate degree (Massive Open Online Course) | Bachelor degree | Advanced formation (Classroom lessons) | Advanced formation (Massive Open Online Course) | Master degree | Doctoral degree |
|-----------------|-------------------------------------|---------------------------------------------|----------------|----------------------------------------|-----------------------------------------------|---------------|----------------|
| Total           | 442                                 | 10                                         | 247            | 105                                    | 14                                           | 17            | 11             |

Source: Elaborated by the author from data available at e-MEC, 2016

3 Associate degree offers a specialized and practical educational background in design. They are focused on developing skills related to a particular field as: interior design, graphic design, fashion design or product design. They are short programs dedicated to practice activities.

Bachelor programs offer an overall educational background in design. The current regulations from Ministry of Education (MEC, 2011) predicts that students should customize their specialization by choosing courses, mobility programs, advanced formation or graduate degrees. Though, curricula must contain subjects from fashion, industrial or visual design. Some universities still use Product Design or Graphic Design to name their bachelor programs. Despite of they offer overall background in design, they focus studios disciplines to one of these qualifications. Both Associate degree programs and Bachelor courses are undergraduate courses.

Advanced formation offers specialized courses in the design domains of fashion, industrial or visual. In this level, more particular contents are discussed. These programs are focused on professional requirements and are directed for market practices. This type of program is accessible in two ways: classroom lessons and Massive Open Online Course.

Masters and Doctoral degrees are focused on scientific research. From seventeen academic programs that offer Masters, eleven of them offer also Doctoral degrees. They discuss topics on fashion, industrial or visual design and its specificities.
Official curricula from those programs were mapped and interpreted to diagnose materials and manufacturing contents approaches. Once information about educational plans was collected concerning each course, a grid was created to identify the existence of curricular units about Materials and Manufacturing Methods on required hourly schedule. According to this analysis, the prevalence of Materials and Manufacturing Methods (M&MM) curricular units varies between zero to 11.4% of total curricular units, with average of 5.9%, and they mainly occur out second semester.

About the nature of the Teaching approaches, we can classify contents in four groups, as Table 3 shows:

| (1) Science of materials | (2) Classification and typology | (3) Manufacturing Methods | (4) Production systems |
|--------------------------|---------------------------------|---------------------------|-----------------------|
| Chemical, mechanical, thermic, electrical, physical and optical properties. Social and ecological responsibilities. | Ceramic and Glass, Natural, Metal and Composites. Individual characteristics and properties are strong worked in theoretical and practical approaches. | Basic operations for each type of materials group as extraction, transformation process, finishing, assembling, workmanship, models and prototypes. | Production sequence, terminologies, laws and regulations, documentation for production, production costs and constructive viability. |

Source: Elaborated by the author from data available at official curricula from programs, 2016.

As can be seen in Table 3, curricular units exclusively dedicated to M&MM mainly focus on technical aspects of building products. However, three programs must be highlighted because of one of contents present in curricula program. First, UEPA offers content about “main materials from local culture: organic and inorganic”. Second, UFMA offers content about “natural fibers from Maranhão” (Maranhão is the state where this University is located). And, finally, UNB offers content about “Brazilian industrial processes”. These contents about local materials and local manufacturing methods are very small in contact hours of education. Moreover, they belong to a curricular unit that approach materials and process in general.

2.2 Survey: Designers’ view

The aim of this study was to understand aspects of designers’ educational background by examining real contexts. Online questionnaire have been chosen because this method permits designers realize an individual thinking and self-evaluation without influences of other participants. There are 683 formal design studios in Brazil; sixteen percent is dedicated to product design (Minc, 2014). Thus, the sample was defined by convenience. Questionnaires were spread in associations, universities, social networks and professionals. At least 5 years of experience in product design was required. As a result, thirty-six designers answered the survey.
First question asked if they had some kind of educational background that supported their knowledge about materials and manufacturing processes. Figure 1 shows the designer’s answers.

![Figure 1. Brazilian designers’ educational background about material and manufacturing methods according their own classification](image)

On second question, thinking about their work practices they were requested to classify information obtained according different aspects: About theoretical information, 42.1% considers good; about useful content, 39.5% considers good; about quality of information, 26.3% considers very good. However: 26.3% considers poor the quantity of information; 26, 3% considers poor the technical contents; 44.1% considers poor immaterial contents; 42,3% considers fair contents about Brazilian native materials; 55.3% considers poor contents about Brazilian traditional manufacturing methods.

Third question requested they classify their understanding about local materials and traditional manufacturing methods from Brazil according following aspects: knowledge about Brazilian native materials, 42.1% considers fair; comprehension about native materials and their geographic regions origin, 55.3% considers poor; knowledge about Brazilian traditional manufacturing methods, 44,7% considers fair; comprehension about Brazilian traditional manufacturing methods and geographic regions where they are more abundant, 44,7% considers fair.

Fourth question asked if they were interested in an educational program about the issue: local materials and traditional manufacturing methods from Brazil. 86,8% of the answers were affirmative. And, finally, they suggest the best setup for an educational program about local materials and traditional manufacturing methods (in order of preference): a) short term courses (classroom lessons); b) Guided visit by specialist; c) Contents applied to Graduate Programs; d) Short-terms courses (Massive Open Online Course); e) Contents applied to Undergraduate Programs; f) Others: Summer courses, website search, isolated discipline, practical training, preferred do not to answer.

2.3 Some considerations about the results of Phase 1

Based on the gathering and interpretation of Brazilian design undergraduate curricula data, we listed relevant findings:
Average, curricular units dedicated to M&MM offers less than 6% of all course contact hours. It occurs specially from second to fifth semesters.

Associate degree offers curricular units more focused on specialized area that they are. For example, UFCA program offer curricular units on M&MM applied to design shoes course or design jewelry course. Even though IFSC program do not focus on a specialized area, this program offers M&MM according product design fields as commodities, furniture and packing.

Curricula approach especially technical aspects of materials and industrial processes as: Science of materials, Classification and typology, Manufacturing Methods and Production systems.

M&MM contents are still approached on design studios, when it is necessary.

Except UEPA, UFMA and UNB, other programs do not approach local materials or local manufacturing methods. Anyway, these programs approaches are short in class contact hour, variety and contents.

Based on Survey with designers, we listed relevant findings:

Most of interviewed designers learned about M&MM on undergraduate courses. Still, 32% of interviewed designers appealed to alternative courses as certificate courses, short-term courses, elective subjects, graduate degrees, trainee programs, individual learn by searching and technical visits to manufacturing places.

Considering M&MM in general, most of designers consider good their educational background in different aspects. But, it contrasts when they are asked about immaterial aspects, Brazilian native materials subject or Brazilian traditional manufacturing methods. At least 44,7% of questioned designers considers poor contents about immaterial aspects. At least 34, 2% of interviewed consider poor contents about Brazilian native materials subject. And, 55,3% of interviewed consider poor contents about Brazilian traditional manufacturing methods.

Even they are senior designers, they consider poor or fair their knowledge about Brazilian native materials or Brazilian traditional manufacturing methods.

Brazilian interviewed designers would like to learn about autochthonous materials and traditional manufacturing methods.

Most of interviewed designers suggest short-term courses with classrooms lessons, guided visits by specialist or graduate programs to approach this theme.

Grounded by presented study, we understand M&MM contents, in general, can be upgraded to product design requirements mainly about aesthetical qualities, immaterial appreciation, sustainability, health and security. These aspects – in addition to more technical aspects - have been researched on materials and design field.

The gap about the really relevant aspects of materials selection for design is present both on curricula mapping and designers’ survey. Specific about local M&MM contents, we understand that native materials and traditional manufacturing methods could be discussed on design education.

This issue is important in this context and on study field because: Brazil has a large and varied number of native resources; Traditional manufacturing methods in Brazil are varied, creative and original; Design can be used to improve local products; Brazilian designers are interested in local resources; using local resources contributes to sustainability; design is a recent activity in Brazil and it is increasing.
3. Innovative initiatives for M&MM education

The aim of Phase 2 is to map and examine Innovative initiatives for M&MM education. This phase is still in progress and we would like to point some interesting initiatives: a) the method/workshop “Material Driven Design”, b) the online training course “Design for material” and c) “Materialmente”: training model.

3.1 Method and workshop “Material Driven Design”

Material Driven Design (MDD) is a method developed by Karana et al. (2015) that aims to facilitate designing for material experiences. It is structured in 4 steps: (1) Understanding The Material: Technical and Experiential Characterization, (2) Creating Materials Experience Vision, (3) Manifesting Materials Experience Patterns and (4) Designing Material/Product Concepts.

![Figure 2. Material package used in workshop. Source: Karana et al. (2015)](image)

It was developed for a 2 days intensive workshop. The experiential and experimental dimension is one of the more innovative aspects of this initiative. This approach allows more involvement of participants.

3.2 Training Course “Design for Material”

It is a module of the “Design for Enterprises” training course, completely free and online (Fig. 3) for European SMEs, designers and intermediary organization by European Union⁴. This initiative is part of the Research Group MADEC⁵ that investigates Italian Culture of Materials Design.

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⁴ http://www.designforenterprises.eu/courses/materials-and-technologies/
⁵ http://www.madec.polimi.it/progetto/
The more interesting aspect of this initiative for our research is the format: the short course is available online, freely accessible, and can diffuse content on M&MM to other places beyond universities and to practitioners. The potential of increasing the awareness on materials selection in design projects is one of the main results that can be highlighted.

3.3 “Materialmente”: training model

“Materialmente” is part of a larger research about design as a strategic tool for the enhancement of cultural heritage and material culture coordinated by Bozolla et al. (2015). The research aims to delineate strategies to improve territory and increase value of the craftsmanship and of productive system involved. In the scope of research took place a “training model” (succession of seminars and workshops) directed to design students involved in the research.

Figure 3. Online course presentation: Materials for the project Design for Enterprises. Source: Ferrara (2016)

Figure 4. The Materialmente products collection. Source: Bozolla (2015)
The content is the most innovative aspect: the cultural heritage as a multidimensional value category that includes material culture by excellent skills of local craftsmanship.

4. Final considerations: opportunities

This study presented the results of an exploratory analysis about the existence and nature of M&MM contents into the curricula of product design undergraduate programs in Brazil. Considering Brazil as a megabiodiverse context, the insertion of contents about autochthonous materials and traditional manufacturing methods to design education could be an opportunity to adding value to local resources and products. Results pointed that this issue is not discussed on undergraduate courses, then we verified if designers would like to learn about this theme. Once designers presented their educational background about M&MM, they want to learn more about local M&MM, and they suggested setups for it; we investigated innovative initiatives for M&MM education.

The current challenge involves the understanding of strategies to add autochthonous materials and traditional manufacturing methods contents on designer formation. This study was concentrated on undergraduate courses gaps.

Some opportunities regarding content, focus and format/approach can be pointed out:

- **Content** – include knowledge on autochthonous materials and traditional manufacturing methods on design education and promote the use of them; include information that support the selection of more sustainable M&MM; show connections between the M&MM decisions and possible local development; present tools to evaluate local production system; discuss means to include produce community in the design process; include tools to search and indexing local materials to became easier next works.

- **Focus** – the selection of local M&MM can support local development, therefore is important to make designers and students aware of their potential role as a local ‘activator’ or agent for innovation.

- **Format/approach** – Local M&MM contents could be offered by specific short-term courses, as designers suggested. Therefore, they could attend professionals and students interested in these contents. It could be offered to all creative professionals interested in local development also artists, artisans, artificers, etc. Short contact hour on undergraduate course about M&MM in general indicates an opportunity to offer a specialized formation. Best medias, formats and approach should be analyzed.

References

Albino, C. (2012). Editoria: Design, artesanato & indústria. [Editoria: Design, crafts and industry]. Guimarães: Fundação da cidade de Guimarães.

Ashby, M.; Johnson, K. (2003). Materials and design: The art of materials selection. Oxford: Elsiever.

Bardin, L. (1993). Análise de conteúdo. [Content analysis]. Lisbon: Edições 70.

Bozolla, M.; De Giorgio, C.; Germak, C. (2015). Craftsmanship merchandise for cultural heritage: back home with a piece of history, territory and design. In: Proceedings of 11th European Academy of Design Conference. Sourbone University: Paris.

Braungart, M. & McDonough, W. (2013). Cradle to Cradle: criar e reciclar ilimitadamente. [Remaking the way we make things]. São Paulo: Gill.
Centro Brasil Design. (2014). Diagnóstico do design brasileiro. [Brazilian design diagnosis]. Findings report [online]. Brasília: ApexBrasil.

E-mec. (2016). Instituições de Educação Superior e Cursos Cadastrados. [Registered Educational programs and courses]. E-mec [online]. Avaible: http://emec.mec.gov.br. [Acessed: 17 july 2016]

Hodgson, S. B.; Harper, J. F. (2004). Effective use of materials in the design process more than a selection problem. In Proceedings of 2nd International engineering and product design education conference. Delft: TU-Delft.

Karana, E. (2009). Meaning of materials (PhD Thesis). Delft: Tu-Delft.

Karana, E.; Barati, B.; Rognoli, V.; van der Laan, A. (2015). Material Driven Design (MDD): A Method to Design for Material Experiences. In: International Journal of Design [Online] 9:2. Available: http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/2341.

Krucken, L. (2009). Design e território: valorização de identidades e produtos locais. [Design and territory: adding values to local identities and products]. São Paulo: Studio Nobel.

Lengberg, L., Edwards, K. (2003). Design, materials selection and marketing of successful products. In: Materials And Design Journal. London: Elsiever.

Likert, R. (1932). A Technique for the Measurement of Attitudes (Phd Thesis). New York: New York University.

Manzini, E. (1986). La materia dell’invenzione [The material of invention]. Milan: Arcadia Edizioni.

MEC. (2011). Referenciais curriculares nacionais para os cursos de bacharelado e licenciatura. [National curricular references for undergraduate and bachalor courses]. Curricular references [online]. Avaible: http://portal.mec.gov.br/consulta-publica/apresentacao. [Acessed: 17 july 2016]

Rognoli, V. (2004). The expressive-sensorial characterization of materials for design (PhD thesis). Milan: Politecnico di Milano.

van Kesteren, I. (2008). Selecting materials in product design (PhD thesis). Delft: Tu-Delft.

Santos, M. (2001). Por uma outra globalização: do pensamento único à consciência Universal (6th ed). [For another globalization: from specific knowlogde to universal conscience]. São Paulo: Record.

Sapuan, S. (2001). A Knowledge-Based System for Materials Selection in Mechanical Engineering Design. In: Materials and Design Journal. London: Elsiever.

Schumacher, E. (1979). O negócio é ser pequeno [Small is beaultiful]. Rio de Janeiro: Zahar.

Shuman, H. & Presser, S. (1996). Questions and answers in attitude surveys: Experiments on question form, wording, and context. California: SAGE.

Zuo, H. (2003). Sensory Interection with Materials in Product Design (Phd thesis). Southampton: Solent University.
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