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The application of ergonomic knowledge by undergraduate product design students: FAULisbon as a case study

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Abstract

In a period of significant change when contemporary society has demonstrated to be more conscious about the principle of accessibility, being no longer focused on accommodating people with disabilities, the current challenge involves the enhancement of inclusive design development. Design education and training has a primary role on the formation of this new mentality, providing the adequate professional skills and instilling in students the knowledge about human limitations and capacities for product design project support. So this paper, as part of a PhD research focused on product design curricula adequacy to business challenges, aims to underline the importance of teaching ergonomics to designers. It is the second part of a specific study about the presence of human factors and ergonomics (HFE) contents in the academic curricula of industrial/product design in Portugal. Using FAULisbon as a case study of a Portuguese institution, we examined the current varying HFE knowledge of undergraduate students in Design in a twofold perspective: the one of the students themselves and the one resulting from the examination of their project solutions. The results underline the relevance of three aspects: a) the HFE principles should be earlier transmitted in the education process; b) the contact and learning of tools and methods of HFE shouldn’t be taught and practiced in an isolated way, instead they should be articulated with the design studio course; and c) this approach should be more practical than theoretical. This way, students could be more conscious about inclusivity and usability of products and spaces, with the focus on a user centered approach. In the future, this will allow them to respond with more social sustainable projects, increasing the chances of being more prepared and adjusted to the market and its demands.

Keywords: Design Education; Product Design; Human Factors and Ergonomics; Inclusivity and Usability;

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1. Introduction

During the last years, humanity has shown to be more aware to inclusivity and usability of products and spaces [1]. According to Paul Hawken et al. [2], this awareness is related to the new industrial system model. It is based on a mindset transition to social and ecological restoration which seeks the economic prosperity. It set of new values includes, among other things, the human welfare [2]. Thus, the current challenge is to optimize human well-being and overall system performance [3], through the principles of accessibility [4, 5].

Education and training has a primary role to provide and instill in students the application of knowledge about human limitations and capacities in the fluid project practice [6]. According to Zapata [7], new ways to design and produce, through an inclusive and sustainable design development, can be facilitated by the establishment of a methodological relationship between ergonomics and design.

The early incorporation of ergonomics theory, principles, data and methods [3], in all phases of design project [8], can have clear impacts on the quality of the proposed design solutions, adding value to the final product [5, 9, 10]. It could prevent the need of making corrections in the project afterwards, in order to adapt it to the user [7, 8].

That led to the increase of the ergonomics’ importance in design area, being integrated in design education curricula. However, there is still a gap between design teaching-learning process and other subjects that correspond to the factors to be considered in the design process, namely HFE [11]. Both subjects should work together and in an integrated manner from the beginning of the project. One can complement each other through their common interests, objectives and procedures, focusing in the comfort, usability, efficiency and safety [12, 13].

So, considering this, Van der Linden [6] works in order to reduce the mismatch between the two areas and to facilitate the consciousness about its aims, limitations and advantages. He proposed “a new conception for the teaching of ergonomics for the design, that it unfolds in four points: i) elaboration of the teaching program tailored to the needs of the course; ii) adjusting the language used in teaching ergonomics; iii) incorporation of principles of design to the teaching of ergonomics; and iv) integrating linguistics analysis and design analysis to ergonomics analysis”.

Van der Linden [6] believes that the first step to motivate students is to adapt the curricula of the course to their needs, through a prevision of constrains and concerns of the main planning issues that students will face in their academic career. Furthermore [14] emphasizes the absolute need to consider HFE in design education.

This also leads to fundamental questions on which we must engage to understand: What design students think about what is being taught and learned in terms of ergonomics? Are they aware to the relevance of HFE during the design development process? How is this reflected in their own projects?

2. Theoretical Framework

This paper is part of a specific study about the presence of human factors and ergonomics contents in Portuguese Design Higher Education System. It stems from another paper [15] which aimed to identify the given importance of teaching HFE in the development of design projects, to keep up the consciousness about inclusivity and usability of products and spaces. That paper presented data that was gathered and interpreted regarding the specific area of industrial/product design of both undergraduate and master curricula. The analysis of that data showed that the contact and learning of tools and methods of HFE that students had occurred late in the formation process the contents were mostly displayed as theoretical and isolated issues, and rarely linked with the design studio course [15]. In methodological terms, this current paper presents the empirical part of the research. It is focused on the undergraduation curricula and aims to underline that actually it exists a perceived mismatch between courses that have visible consequences.

2.1. The case study

The Faculty of Architecture from University of Lisbon (FAULisbon) is one of the 22 from the 29 the Portuguese institutions of higher education which offer HFE courses in its undergraduation curricula [15].

This institution was chosen as the case study because is where the authors work, making simple the contact with teaching-learning process and its results.
FAULisbon’ design undergraduation degree program was created and implemented by Daciano da Costa in 1991 [12] and, over the last years, his program has been reviewed and updated according to Bologne process and market demands.

2.2. Curriculum background

Nowadays, FAULisbon undergraduate plan just offers one HFE course, during its 3rd semester. This course, publicly claimed as compulsory in a theoretic-practical approach, is called ‘Ergonomia’ and accounts for 3,5 ECTS (1,85%) from the 180 ECTS (100%) of the degree plan.

From few years until now, ‘Ergonomia’ is no longer part of design studio course, as well as ‘Tecnologias do Design I’ (a technology component of design studio). Now, these courses no longer operate in an integrated way but in an autonomous way.

‘Ergonomia’ course “should provide students with the theoretical and practical need information tools that allow the understanding of design problems within ergonomics, including the individual, the environment, the tasks they have to perform as well as their limitations and expectations” [16]. Its programmatic contents are published as “(1) introduction to ergonomics: theory and design applications; (2) anthropometrics in ergonomics; and (3) ergonomics evaluation of products and/or systems” [16].

During the same 3rd semester, the existing design studio course is called ‘Design III’. It is one of the primordial courses of the undergraduate plan, also compulsory and taught in a theoretic-practical approach. It accounts for 12,5 ECTS (6,95%) of the degree and proposes a “thematic approach to real-world cases of human needs in different habitable environments”. That requires a coordinated approach with ‘Ergonomia’.

2.3. The briefing

One of the authors of this paper taught ‘Design III’ more than once, applying the same project briefing twice.

The ‘Design III’ project work should “focuses on the current social and economic context in terms of equipment for housing” [16], identifying and highlighting the technical productive factors involved in ceramics traditional industries.

Thus, her briefing proposes the development of a family of three pieces in faience. Students could define the specific context of use (i.e. for kitchen, for bathroom or for balcony). They just had to design for the scale of the hand and to be sure that one of their pieces had the ability to pour liquids. Those requirements needed to get support on the ergonomic knowledge, to guarantee the user safety, efficiency and comfort. This means that students should be able to apply the competencies to be acquired in ‘Ergonomia’.

3. Method

Aiming to answer the questions initially mentioned, this paper focuses on the experience one of the authors had while teaching Design III One could verify that the majority of students on their 3rd semester (which means in the middle of the undergraduate plan) were not still aware of the importance of ergonomics. Moreover they were not aware how to apply ergonomic consideration within their designs, making the same mistakes each year.

Thus, the research was undertaken in two stages:

- Stage 1: a group of 25 portuguese students was inquired through an online survey, applied in 2015.
- Stage 2: some design solutions were analyzed in order to typify the students’ difficulties and faults.

Those methods were used to assess two perspectives: the one of the students themselves and the one resulting from the examination of their project outcomes.

The results contribute to identify discrepancies between what students say they do and what they really do.
3.1. The perspective of the students

The class of ‘Design III’ had 41 students, 25 are Portuguese and 16 are foreign.

This international group comprises students who were participating in exchange programs, coming from different institutions all over the world and having different backgrounds. Therefore and because one cannot control their previously acquired knowledge they were not included in the sample of the survey. So, this study was focused on the Portuguese group with their background education from FAULisbon.

In this first stage, participants were asked to complete an online survey that was applied to apprehend their perspective on the importance of ergonomics within design program, its training and their application of its knowledge in project development.

From the inquired group (25), 24 completed the survey.

The questionnaire was composed by six closed questions:

- Is ergonomics an important consideration in the design process?
- When did you felt ‘awake’ to the HFE issues?
- Should ergonomics course be early integrated in the design training process?
- What kind of approach is mainly made by ergonomics course?
- In ergonomics course, how are the exercises mostly developed?
- Do you consider that ergonomics and design studio courses are articulated?
- In project development, which of the following usability principles do you take into consideration?

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER OPTIONS</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is ergonomics an important consideration in the design process?</td>
<td>Yes</td>
<td>24 100,00%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0 0%</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>0 0%</td>
</tr>
<tr>
<td>When do you felt ‘awake’ to the HFE issues?</td>
<td>1st semester</td>
<td>4 16,67%</td>
</tr>
<tr>
<td></td>
<td>2nd semester</td>
<td>4 16,67%</td>
</tr>
<tr>
<td></td>
<td>3rd semester</td>
<td>13 54,17%</td>
</tr>
<tr>
<td></td>
<td>4th semester</td>
<td>3 12,50%</td>
</tr>
<tr>
<td>Should ergonomics course be early integrated in the design training process?</td>
<td>Yes</td>
<td>21 87,50%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>3 12,50%</td>
</tr>
<tr>
<td>What kind of approach is mainly made by ergonomics course?</td>
<td>Theoretical</td>
<td>20 83,33%</td>
</tr>
<tr>
<td></td>
<td>Theoretic-practical</td>
<td>4 16,67%</td>
</tr>
<tr>
<td></td>
<td>Practical</td>
<td>0 0%</td>
</tr>
<tr>
<td>In ergonomics course, how are the exercises mostly developed?</td>
<td>Individually</td>
<td>15 62,50%</td>
</tr>
<tr>
<td></td>
<td>In group</td>
<td>9 37,50%</td>
</tr>
<tr>
<td>Do you consider that ergonomics and design studio courses are articulated?</td>
<td>Nothing</td>
<td>10 41,67%</td>
</tr>
<tr>
<td></td>
<td>Little bit</td>
<td>12 50,00%</td>
</tr>
<tr>
<td></td>
<td>Very</td>
<td>2 8,33%</td>
</tr>
<tr>
<td></td>
<td>Totally</td>
<td>0 0%</td>
</tr>
<tr>
<td>In project development, which of the following usability principles do you take into consideration?</td>
<td>Safety</td>
<td>Never 0 0%</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>11 45,83%</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>13 54,17%</td>
</tr>
<tr>
<td></td>
<td>Efficiency</td>
<td>Never 0 0%</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>2 8,33%</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>22 91,67%</td>
</tr>
<tr>
<td></td>
<td>Comfort</td>
<td>Never 0 0%</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>6 25,00%</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>18 75,00%</td>
</tr>
</tbody>
</table>

As shown in Table 1, all students (100%) regarded ergonomics as an important consideration in the design process. But, despite that, 54,17% of them affirm that they awaked to HFE only during the 3rd semester and the majority states that HFE should be anticipated in the design training process (87,50%).
Even being a theoretic-practical course, the majority of students consider that the ergonomics course approach is mainly theoretical (83.33%) and the exercises are mostly developed individually (62.50%).

They claim that ergonomics and design studio courses are ‘nothing’ (41.67%) or badly (50%) articulated, considering that they should be really integrated.

Students could demonstrate to be more conscious about the principles of accessibility, which involves the enhancement of inclusive design development, which can be reflected on the quality of the proposed solutions, adding value to the final product. Thus, they were inquired about three of those principles- safety, efficiency and comfort – and if they were taken into consideration during the design project. The majority assumed to be ‘sometimes’ (45.83%) and ‘always’ (54.17%) concerned with safety; to be ‘sometimes’ (8.33%) or ‘always’ (91.67%) concerned with efficiency and to be ‘sometimes’ (25%) or ‘always’ (75%) preoccupied with comfort.

3.2. Results from the examination of students’ design solutions

The task proposed on ‘Design III’ briefing involves the application of ergonomics’ fundamentals to improve designs’ function at the level of the hand scale and instant gestures.

As previously noted, one of the briefing requirements was to design at least one piece able to pour liquids.

According to Antony Quinn [17], the development of a teapot in ceramics is almost the pinnacle of learning to work with clay. A functional and ergonomic teapot has to hold hot fluid while protecting the hand from heat, promoting a good comfort when lifting.

Nonetheless, teacher experienced that a large number of students decided to design a pot. This type of product includes some functional details, subjected to their own set of rules, which ensure they work correctly [17]. Those elements have different configurations to help the designer in the shape development.

So, the four chosen design samples are all (tea or coffee) pots, typify the students’ difficulties and faults.

Fig. 1. (a) first model; (b) second model; (c) third model; (d) forth model.

Looking in depth at the various stages in a successful project, the transition from the sketching to design development is one of the most difficult stages of the design process. In ceramics design process it is primordial to bridge it, through model making, technical drawing, and prototype construction in workshop. It is not simple, because ceramic design is almost always concerned with design for function [17].

To make it successfully, the main challenge is to apply the correct anthropometric data during the design development, which will condition the usability of the piece. This often results in some problems concerning dimensioning and shapes [17, 18]. The shape is influenced by the line, height and width. Some aspects such as the weight, stability and texture [18] may compromise the user safety, efficiency and comfort.

This analysis of the student’s designs was conducted to inspect current problems to be overcome during the design process development. According to Quinn and Fagundes [17, 19], to design a successful teapot we should respect some specificities, such as:

- The handle should be generously sturdy (good strong thickness);
- The handle should have an internal space of more than 40 mm;
- The handle has to be positioned for the successful pouring (the most comfortable to lift and pour is an over-handle, common on eastern teapots, because it supports the hand in a better pivot position; strangely, the conventional western handle position, at the rear of the body parallel to spout, is probably the least comfortable);
• The spout has to be long enough to balance the handle and pour higher than the capacity of the body (the volume of it is calculated from the tip of the spout if it is below the lid);
• The spout must have sufficient opening for air intake (if the part is closed or has cap) and fluid outflow;
• For the last drop non-spills, it is suggested that the spout follows the shape of an S and ending in C;
• The lid must lock in place and stay there when the pot is tipped forwards to pour (should build an eyelash in the tooth socket cannon);
• Build tooth inside the lid to ensure that the lid will keep its position. The gap between the lid and the body should be approximately 1.5 mm each side, being this known as shuffle (it ensures the lid will fit after glazing and shrinkage);

Developing a teapot in ceramics requires four main construction stages: the body, the spout, the handle and the lid. Each element is made individually and assembled over a couple of days. It can take at least ten days or a month in the workshop [17, 19].

So, based on these guidelines, the set of teapots generated were classified using a scale ranging from 1 (very bad) to 5 (excellent). It was consider as criteria the technical and structural competences of the object, from a user center approach, its security and the comfort it proportionate to users. As it can be seen in Table 2, the teapot A is not so big, what means that is also not very heavy. On the other hand, it is quite difficult to clean. Its main problems are related with the handle and spout proportions facing the body and the tooth on the lid. It is not visible on these images but the existing tooth is on the wrong side (it was made on the bottom part of the lid), needing some finger to press it during the pouring of liquids.

The teapot B doesn’t have a handle in ceramics but in cork. The fascination students display with their creative conceptual models interferes with their functional judgments. For example, to clean it is necessary to take the band out. Otherwise, the teapot won’t be correctly cleaned. This object is also a bit large. Just someone with a big hand can use it. Someone with a little hand can have some problems to transport it when it is full of liquids. The major problem is the spout form. It is very little to the body volume, locking the air intake to pouring liquids normally.

Teapot C has a big lid. It interferes with the weight of the piece. When it is full of liquids, it is quite difficult to transport, especially because the handle is not in the right position – it should be higher. Its spout has the shape of an S making it easy the pouring and not dripping.

Teapot D hasn’t an ergonomic handle. It is quite small (less than 40 mm) and it is not comfortable to the fingers when you use the teapot full of liquids.

In fact it is fundamental that they go to the workshop first to test the models thus facilitating the process of eliminating errors since this is rather difficult to be detected in drawings.

<table>
<thead>
<tr>
<th>GUIDELINES</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withstand high temperature</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Transport (weight; volume)</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Cleanability (surface; edges; texture)</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Adaptability to hand (40 mm)</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Sturdy handle (good strong thickness)</td>
<td>5</td>
<td>-</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Handle form is adequate to pot volume</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Spout form is adequate to pot volume</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Spout is able to pour liquids</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>No spills the last drop</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Lid locks in place when the pot is tipped forwards</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
4. Discussion and results

This paper discusses the importance of teaching ergonomics to designers. It describes an academic experience centered on the application of ergonomics knowledge by design undergraduate students. In order to review the presence of HFE in design curricula, the design undergraduate program at Faculty of Architecture from University of Lisbon was used as the context for this study.

One of the methodology’s key elements is that students, on their second year of studies, are not yet awake to the advantage of using of HFE principles since the beginning of the process. They are more concerned with aesthetics than with functionality (the creative model overlaps the interpretation of ergonomic data) [20].

The experience in teaching allowed us to verify that students only reflect on ergonomic issues after prototyping their designs. Although the teacher tries to guarantee the incorporation of ergonomics, the students just care about fundamentals of ergonomics when they perceive their own faults, trying to use their own products. Some of them do not make models before going to workshop, going directly to trial in clay on the wheel. It fails.

So, this specific study underlines that the ergonomic knowledge is not being integrated by students in their design.

If both courses, design and ergonomics were lectured at the same time that would have a positive impact since students would probably apply their ergonomic knowledge directly; On the other end if ‘Ergonomia’ course was anticipated in terms of degree plan students would be able to apply this knowledge in a more consistent way along their program.

This mismatch between courses has consequences, such as: waste of time since it is necessary to correct and adjust every design (assuming that students have a regular presence in class). This means that teachers of design studio courses, every semester, have to do an extra effort to integrate ergonomic contents by themselves.

A better understanding of usability factors, with the user satisfaction in mind, as key drivers of the design development, is of critical importance in product design field.

The main purpose of this study is to demonstrate that if HFE principles were earlier transmitted in the design education process, taught and practiced in an articulated way with the design studio course, students could respond with more social sustainable projects.

Future investigation in this area could build upon this work by creating small exercises to bridge knowledge between the courses of ergonomics and design studio. The identification of best practices is not within the scope of this study.

We believe that the co- construction of knowledge, through collaborative practices and a better dialogue between the various stakeholders, will allow students them to respond with more social sustainable projects, increasing the chances of being more prepared and adjusted to the market and its demands.

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A special thanks to our students. Without their collaboration, this study would not be possible.

References