

## OVERVIEW OF DESIGN TEACHING ON ENGINEERING COURSES: A COMPARATIVE STUDY BETWEEN BRAZIL AND PORTUGAL

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### Abstract

This paper presents an overview of design teaching in the undergraduate engineering courses at the main institutions of higher education in Brazil and Portugal. In order to carry out the comparative study, the curricula of the main engineering courses in Brazil and Portugal were used. The aim of the research is to first analyze how the design, as a disciplinary content, is being introduced in the engineering courses in both countries. In a second moment, a comparative analysis will be made between the information collected in Brazil and in Portugal in order to register how this conjugation is occurring and whether there is some similarity or not in the way of design approach in the engineering courses in each country. As a result, it is discussed how the design can collaborate with the interdisciplinarity between these areas and contribute with the formation of the new competences of the engineer.

**Keywords:** *Education, design, engineering, Brazil, Portugal.*

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### 1. Introduction

Education is the object of study, concern, focus, strategy and discussion in all the nations of the globe and reflects the intense changes the world has witnessed in the last decades of the 20<sup>th</sup> century, beginning with the two great wars, then the expansion of capitalism and the cultural and economic globalization in the 21<sup>st</sup> century. According to UNESCO (2010), engineering deserves our attention, its contribution to development must be fully acknowledged, being vital the full measurement of engineering's capacity to make a difference in the developing world. If engineering's role is more visible and better understood, more people would be attracted to it as a career. Now and in the years to come, it is fundamental to ensure that motivated young women and men concerned about problems in the developing world continue to enter the field in enough numbers.

The performance of engineering professionals is closely associated with the improvement of products and processes, optimization and innovation of production management models and Research & Development (R&D) efforts of the companies. The conditions of the engineering education occupy, therefore, a central place in the discussions involving the formulation and implementation of strategies for industrial development. They are part of the range of challenges that countries must face to sustain productivity gains and to strengthen their competitive positions in the dynamic knowledge-based economy of the world. The economic growth should be accompanied by a qualitative and quantitative improvement of employment and greater social cohesion. This demands a change in higher education system, promoting interdisciplinarity, stimulating entrepreneurship, emphasizing the cultural and social involvement of universities. This is propelled by strategic government investment in engineering education as an incubator for the technology-based entrepreneurial talent that will drive national economic growth (Brasil, 2019; Confederação Nacional da Indústria [CNI], 2018; Cordeiro et al, 2008, Heitor et al, 2004).

### 2. Scenario of engineering education in Brazil

Portuguese and Brazilian relations have lasted more than five centuries. Having as a backdrop the Atlantic, the two "brothers" countries are physically and symbolically united, by territory, history, culture, language and regional spaces in which they are inserted. Some points of convergence and singularities are evidenced, as well as the strong distinction regarding the amplitude of difficulties, since in Brazil these are extended by their territorial dimension, socioeconomic inequalities and regional diversities (Almeida, 2008).

Engineering education in Brazil had its beginning in 1699, with Dom Pedro II, King of Portugal at the time, and the creation of the first class of Fortification, for the training of military engineers. The fundamental landmark for higher education was the coming of the Portuguese royal family to Brazil in 1808, a fact that allowed the creation of several institutions, some of them offering higher education courses. The beginning of the formal education of engineering in Brazil was with the Royal Military Academy in 1810, replacing the Royal Academy of Artillery, Fortification and Drawing, installed in 1792, in Rio de Janeiro. In 1874, the army left the formation of engineers for civil institutions, when the first engineering school was borne: The Polytechnic School of Largo de São Francisco. Throughout the 19<sup>th</sup> century, several educational establishments for higher level vocational training emerged, even though they were isolated and in specific contexts, without having a university system, such as the Polytechnic School of São Paulo in 1893. The first university of the federal government of Brazil, the current Federal University of Rio de Janeiro (UFRJ), was created in 1920. And in 1934, through the political perspective of a liberal-democratic regime, with a different model, the University of São Paulo was created by the São Paulo government. Since 1950 there was a significant growth in the number of courses of engineering, with the great expansion occurred from the second half of the 90's. This is coincident with the edition of the new "Law of Guidelines and Bases of National Education" (1996), when the growth of engineering courses has reached an annual average of 96 new courses per year, mainly in the private sector (Cordeiro et al, 2008).

From 2010 to 2014, due mainly to the performance of the country in terms of infrastructures expansion, a significant growth was registered, both in terms of the offers (expansion of the number of courses), and applications for engineering courses (Brasil, 2019; CNI, 2018). After this period, these numbers started to decrease due to the recent economic, political and social crisis installed in the country. For each 1,000 candidates in engineering selection processes, only 175 were admitted and only 95 concluded their courses, suggesting a kind of "funnel" (CNI, 2018). In 2018, 6,106 engineering courses were registered in the E-MEC system, operating in 1,176 distinct institutions, including private and public. In addition to the numerical expansion, there was also a great growth of qualifications or areas of coverage of the engineering courses. Today there are already 60, considering the first denomination of the courses (civil, electrical, mechanics, etc.) and more than 250 when is considered the second denomination or emphasis (civil construction, electrical power, automobile mechanics, etc.). Between 2001 and 2018, there was, therefore, a total growth of 692% in the number of engineering courses (Brasil, 2019).

Brazil faces some difficulties to compete in the international market. According to the Global Innovation Index (IGI), the country lost 22 positions in the ranking between 2011 and 2017, which stood at 69<sup>o</sup> place among the 128 countries evaluated. In 2014, while Portugal had about 16 engineers for each 10,000 inhabitants, Brazil recorded only 4.8 engineers for the same inhabitants (Brasil, 2019).

### 3. Scenario of engineering education in Portugal

The teaching of engineering in Portugal was originated in the Nautical Class, created in 1765. The Royal Academy of Fortification, Artillery and Drawing, created in 1790, is considered the first modern school of Portuguese engineering and one of the first in the world. In the 20<sup>th</sup> century, with the implantation of the Republic in 1910, the teaching of engineering started for the first time to be held at the university, when the Polytechnic Academy of Porto, created in 1837, and predominantly military (although it also included civil engineering), replaced the School of Nautical. Integrated in the new University of Porto, created in 1911, with its courses of engineering, is in the genesis of the current Faculty of Engineering of that university (Azevedo, 2013). The foundation of Instituto Superior Técnico (1911) and the transformation of the Polytechnic Academy of Porto into Technical Faculty (1915), were considered decisive milestones in the technical context, since they would play a fundamental role in consolidating the social recognition of knowledge (Heitor et al, 2004).

In 1970, the Polytechnic Institutes were integrated into the higher education system, attributing the bachelor's degree (Academia de Engenharia de Portugal [AEP], 2006). Since 1972, new university engineering courses have been created in Coimbra, Porto, Braga, Aveiro, Lisbon and some other localities, strengthened by the European integration. The law of bases of the educational system integrated the higher institutes of engineering in Polytechnic education in 1988 (AEP, 2006, Heitor et al, 2004). Currently, the teaching of engineering is carried out in universities (oriented to the research and creation of scientific and cultural knowledge) and polytechnic institutes (oriented to the applied research and creation of the knowledge of professional nature), both public and private (Azevedo, 2013), which integrate an intrinsically rich and diversified institutional system.

Considering the area of education and training represented by Engineering, Manufacturing and Construction, currently Portugal has 319 courses in 94 institutions and organic units of education, including the graduation and integrated masters, in 12 specialties (Ordem dos Engenheiros, 2015). These specialties are subdivided in 72 different qualifications or areas of coverage of the engineering, in a total of 1010 cycles of study, that offered in 2018, 11,615 places, occupied by 10,805 selected students through the 3 stages of admission. Regarding the number of students, there was an increase of almost 9% in the total number of

graduates in higher education in engineering (from 14,412 in 2010 to 16,105 in 2017), which opposes to the decrease of 12.4% in the total number of students enrolled in this area (from 88,644 in 2010 to 78,830 in 2018) (DGES, 2019).

The Bologna Process has triggered an impressive set of reforms (AEP, 2006; Heitor et al, 2004). Signed in 1999, is an intergovernmental cooperation of 48 European countries in the field of higher education that guides the collective effort on how to improve the internationalization of higher education (European Commission, n.d.). Furthermore, there is still the Erasmus+, the European Union's programme to support education, training, youth and sport in Europe, providing opportunities for Europeans to study, train, and gain experience abroad (European Commission, n.d.).

While Brazil occupies the 40<sup>th</sup> place, Portugal is classified as the 25<sup>th</sup> best higher education system in the world in the U21 Rankings of National Higher Education Systems 2019, developed by "Universitas 21", a reference network that aggregates universities research in several countries (Universitas 21, 2019).

#### 4. Comparative study between Brazil and Portugal

Despite the visible growth of admissions in engineering, the productive sector has encountered difficulties to recruit skilled workers to act on the frontier of knowledge of engineering, which, in addition to the technique, requires that its professionals have mastery of skills as leadership, work in group, planning, strategic management and learning autonomously. These competencies, known as "soft skills", combine solid technical training with a more humanistic and entrepreneurial formation (Brasil, 2019). Proposals for modernizing engineering courses should consider international trends and specific aspects of the reality of each country, with more multidisciplinary, systemic and consistent visions. All these aspects should be aligned with the needs of society, especially in relation to sustainability issues, future-bearing areas (e.g. Nanobiotechnology) and new generation of production 4.0 industry (e.g. advanced automation, big data, artificial intelligence, design, etc.). In international experiences, the curricula focused on the development of competencies and the adoption of more practice-oriented teaching methodologies, such as the PBL – Project Based Learning, are good examples of modernization (CNI, 2018). Engineering knowledge has always been system-based knowledge where engineers are working with the phenomena of black boxes in their design. The new challenge is not to work with the black boxes, but to do work within a collaborative intercultural and interdisciplinary team (UNESCO, 2010).

Design projects that have been used as vehicles to motivate and integrate learning and cornerstone project-based courses, are also seen to enhance students' motivation and their attraction to engineering. So, what does the word "design" mean in an engineering context? Why is this complex, fascinating subject so hard to teach? Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints (Dym, 2005). Design, interdisciplinary by nature, is a strategic problem-solving process that drives innovation, builds the business success and leads to better quality of life through innovative products, systems, services and experiences (World Design Organization [WDO], 2019).

Design can help and, through its tools and methodologies, show new paths inspired not only in new technologies, but also in human needs, adding new values that are perceived by consumers and viable to implement. By its holistic and integrative character, the design has become more valued and coined with the term "Design Thinking" establishing the correspondence between human needs (desirability) and the technical resources available (feasibility) considering the practical constraints of the business (viability) (Brown, 2009).

The design insertion format in engineering courses can be done in a variety of ways: as a programmatic content addressed within a discipline, as a regular compulsory subject, as an elective or optional subject, as an extension course, as a specialization or minor and, even, as a content linked to an integrated project. And there are two important aspects to introducing product design to engineering students at undergraduate level: "when" and "how" the subject of design is taught (Sathikh, 2018). When means that it could be introduced at the freshman year, making design a core subject at the very early stages of study, where the subject maybe introduced too early to be effective or as an elective, at the senior year, as a follow up to what students learn in the freshman year, maybe too late to bring some real effect. How is about the method and means that it can be taught not only with a principal focus based on the aesthetic but also upon usability, sustainability and design for manufacture (built on the framework of studio-based learning) (Mills; Treagust, 2003-04).

The aim of the research was to analyze how the design, as a subject content, is being introduced in the engineering courses in both countries. The curricula and teaching plans of Mechanical Engineering courses in important educational institutions in Brazil and Portugal were considered and selected among the best evaluated in 2018/2019, according to Quacquarelli Symonds [QS] World University Rankings by Subject 2019: Engineering – Mechanical, Aeronautical & Manufacturing and the University Ranking of Folha de São Paulo (RUF 2018) – Mechanical Engineering.

Table 1. Design subjects inserted in engineering courses in Brazil and Portugal (adapted by the authors, 2019).

BRAZIL	<b>POLL-USP: Polytechnic School, University of São Paulo, public (São Paulo/SP, Brazil) #51-100 (QS); #1 (RUF)</b>	
	Applied Design Project I (Interdepartmental Disciplines of the Polytechnic School)	optional, 150h, semiannual, 6 credits
	Applied design Project II (Interdepartmental Disciplines of the Polytechnic School)	optional, 150h, semiannual, 6 credits
	<b>UNICAMP: Faculty of Mechanical Engineering, Campinas State University, public (Campinas/SP, Brazil) #101-150 (QS); #2 (RUF)</b>	
	iPhone Application Development and Design (Integrated courses program)	online, external course
	<b>PUC-RIO: Pontifical Catholic University of Rio de Janeiro, private (Rio de Janeiro/RJ, Brazil) #601-650 (QS); #14 (RUF)</b>	
	---nothing was found---	
	<b>EEM-IMT: Engineering School, Mauá Institute of Technology, private (São Caetano do Sul/SP, Brazil) #18 (RUF)</b>	
	Design Thinking (Minor of Design and Innovation)	elective, 80h, semiannual
	Strategic Design and Innovation (Minor of Design and Innovation)	elective, 40h, semiannual
	Interior Design (PAE - Projects and Special Activities)	elective, 40h, semiannual
	Development of Accessory and Application of Surface Design (PAE - Projects and Special Activities)	elective, 40h, semiannual
	<b>INSPER: Institute of Education and Research, private (São Paulo/SP, Brazil) #140 (RUF)</b>	
Software Design	1st period, 80h, semiannual	
Nature of Design	1st period, 80h, semiannual	
Application Co-Design	2nd period, 80h, semiannual	
Design for Manufacturing	3rd period, 80h, semiannual	
Product-Service System Design	elective, 80h, semiannual	
Design Thinking	elective, 80h, semiannual	
PORTUGAL	<b>FEUP: Faculty of Engineering, University of Porto, public (Porto, Portugal) #101-150 (QS WUR By Subject Ranking)</b>	
	Integrated Product Design	5th period, 6 credits
	<b>ULisboa: Higher Technical Institute, University of Lisbon, public (Lisbon, Portugal) #101-150 (QS WUR By Subject Ranking)</b>	
	Product Development and Entrepreneurship	optional, 5th period, 6 credits, semiannual
	<b>UC: Mechanical Engineering Department, University of Coimbra, public (Coimbra, Portugal) #151-200 (QS WUR By Subject Ranking)</b>	
	---nothing was found---	
<b>UA: Mechanical Engineering Department, University of Aveiro, public (Aveiro, Portugal) #251-300 (QS WUR By Subject Ranking)</b>		
Eco-design and Eco-efficiency (Sciences and Engineering of the Environment)	5th period, 6 credits	
<b>ISEP: Higher Institute of Engineering of Porto, Polytechnic of Porto, public (Porto, Portugal)</b>		
---nothing was found---		

According to the collected data (Table 1), it can be observed that, in general, design as a subject is being inserted in mechanical engineering courses more prominently in Brazil, with the occurrence of 13 disciplines, comparing to Portugal, with the discreet occurrence of only 3 cases. In the majority (77%) they are being offered as elective or optional, taken usually at the end of the course, in the last (5<sup>th</sup>) period. Other important observation is about the addressed content, where most of them are about project and product/service development.

Although this study was limited to a small sample, restricted to some institutions in Brazil and Portugal, have emerged during the research other schools in Europe that also offer design subjects in the mechanical engineering curriculum, such as: University of Cambridge, England (Structural Design, Product Design, Engineering Design, Integrated Design Project); Delft University of Technology, Netherlands (Machine Design Project); Politecnico di Milano, Italy (Machine Design); among others.

## 5. Final considerations

Design education represents both serious challenges and glorious opportunities (Dym, 2005). Design is still a complement to the engineer's training, and not a basic requirement; it is a start, but it still has a long way to go. In this scenario, design can act and show new paths, through its tools and methodologies, inspired in human needs, not only in new technologies, but also in adding new values that are perceived by consumers and are viable to implement. Design can then be considered as an interdisciplinary content factor that, when applied in design practice, can contribute to the development of innovative products, enrich the training of the engineer and be a relevant agent in the innovation of higher education.

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