Development of vocations in engineering in secondary education in Portugal

Paulo Silva*

CIETI - Centre of Innovation on Engineering and Industrial Technology/IPP-ISEP, School of Engineering, R. Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal, 1190053@isep.ipp.pt

Alicia Holgado

(…)

Carlos Felgueiras

CIETI - Centre of Innovation on Engineering and Industrial Technology/IPP-ISEP, School of Engineering, R. Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal, mcf@isep.ipp.pt, https://orcid.org/0000-0002-4202-5551

Education is essential to prepare future professionals, preparing them for the labor market, by providing knowledge and practical experiences. The model that trains these professionals becomes crucial for professionals to adapt to the current needs of this market, which in itself is competitive and dynamic, so it is always in constant change of priorities and needs. It is undeniable that environmental and sustainability issues have become essential aspects in the performance of any business at a global level. Particularly, the concern with sustainability becomes evident in the field of civil engineering, due to the need of optimization of use of resources (raw materials, energy and water), that can have a huge impact on the environment, resulting both from reduction of consumption of resources, and pollutants emissions. Therefore, the MSc courses should have two levels of education on sustainability: at the multidisciplinary level, Higher Education schools should offer courses specifically dedicated to sustainable development and sustainability should be analysed globally; at the disciplinary level, each course should include the basic related concerns with sustainability issues. This work surveys civil engineering courses in Portugal and analyzes how subjects related to SDGs are directly or indirectly present in the respective curricula.

Keywords:

1. Introduction

The 21st Century Engineer deals constantly with challenges and uncertainty, incomplete data and competing/conflicting demands from clients, governments, environmental groups, and society in general. It requires skills in human relations and technical competence (Mills and Treagust, 2003). With so many demanding requirements, qualities, and skills, how can the education system captivate the engineers of tomorrow? Learning is by no means a simple or a linear process. It is a complex human experience that must be exciting and enjoyable (Kapranos, 2015). It is with these assumptions that students should prepare for a university path in Engineering. That in this career they will stimulate and acquire new skills, knowledge, ingenuity, achieving the much-desired right result after so many failed attempts and that it will not always be easy, often tiring, but that they will be part of something bigger: professionals of a elite of technicians who serve and respond to the needs and issues of society.
A decade ago, Bodogna, Fromm and Ernst proclaimed that engineering education's primary goals should be to develop, in as individualized a way as possible, in each student the following capabilities: Integrative capability, analysis capability, Innovation and synthesis capability and contextual understanding capability (Shuman et al., 2002). And how can they acquire these skills? Through Education, theoretical and practical. But what is the exact definition of Education? In fact we can equate even more questions about Education, such as "Is education, as should be,a fundamental human right"? "Is the most expressive and correct way to gain knowledge and acquire the right skills for my future"? "Is it the development of the ability to argue and practice critical thinking"? Or "Is it a ticket to the economies and markets of the 21st century"? Perhaps education not only stimulates the development of intellectual capacity, but also provides economic benefits for the students as well as the greater society and therefore the main goal of a university should be the education and preparation for global citizenship (Kapranos, 2015).

There are indicators that engineering degrees are experiencing a decrease in number of students, as well as a discrepancy between female and male students. This is a fact that should be cause for concern since society needs solutions and answers to the many dilemmas and challenges it faces not only today, but those that are yet to come. In the case of Portugal, and consulting Portuguese statistical data, despite the fact that the number of Engineering students has registered an increase towards the highest number of students enrolled in Engineering courses since 1995, we conclude that the relationship between the number of students enrolled in Engineering courses Engineering and the total number of vacancies made available in higher education shows the lowest value ever recorded and with a negative trend since 2012.The reasons may be based in a loss of motivation among students to begin a difficult career, in spite of great expectations Jobs proposed from the society (Blázquez and Castro, 2011). Dropout is also a complex phenomenon of concern in the context of university education, which can have several reasons. Although there are many researches on the study success of students, the focus on

study success policies and their effectiveness is rare, showing that the data available is diverse in terms of availability, data collection methods, definitions, and usage (European commission, 2015).

One of the obstacles to the interest and success in attending Engineering courses, especially in underperforming schools that represent students with economic difficulties and minorities, is their lack of awareness of academic and career options available to them in STEM fields (Enriquez et al., 2018). One approach to solving the problem is the increase of pre-college engineering programs, exposing high school students to engineering content and practices (Salzman and Lafayette, 2020). Engineering is a hands-on profession where doing is key. Prior to the existence of engineering schools, engineering was taught in an apprenticeship program modeled in part after the British apprenticeship system, where engineers had to design, analyze, and build their own creations— learning by doing (Watson and Science, 2020). So why not take Engineering to those who haven't experienced it yet?

From a scientific and educational point of view, stimulating and implementing definitions of Engineering in secondary school students may encounter several obstacles, so it is imperative to adapt the complexity and methodology of the themes to the knowledge already acquired by these students (Enriquez et al., 2017). It is crucial and urgent that an answer be given to this problem, since it is believed that the application of science and engineering-based education is able improve the quality of human resources to face the challenges of the next century (Performance and Reading, 2009).

2. Working hypothesis and principal objectives sought

Considering that the tendency of pre-university students to choose careers in Engineering is negative and appears to be getting worse, this thesis project will investigate the current national landscape of Engineering, trying to find out what the interest is, and how to entice pre-university students into careers in Engineering and the probability that they apply for a vacancy in higher education in an Engineering course. In the present study, other variables are extremely relevant, since they present significant variations at the national level in terms of gender and the geographic location of students before entering higher education.

The objective of this study is to define a proposal for intervention in Portuguese secondary schools, at a national level, to analyze the perception of students by engineering and the impact on which they choose engineering careers, as well as to analyze possible variations or anomalies within the study population.

Considering the problematic, the main goal of this work aims to study the following Research Questions (RQ):

- RQ1: What is the students' perception about the current status of the Engineering career?

- RQ2: What is the interest of high school students about the career of Engineer?

- RQ3: Why do pre-university students not choose Engineering?

- RQ4: How to attract students to Engineering?

3. Methodology to be used

Educational research consists of applying the scientific method to the educational problems study, with the goa lof explaining, predictiong and/or controlling educational phenomena (Gay, Mills, & Airasian, 2011). Through the scientific method, scientists seek knowledge away from personal perceptions and beliefs. This is achieved by the empirical verification of ideas through a procedure open to public inspection. The reliability of the data obtained will depend on objective observation (Gilberto, 2022). In order to counteract the negative tendency of students to enroll in engineering courses, actions related to Education and Engineering should be taken, focusing on activities that involve more hands-on learning, ,efficient use of computers and its software, better textbooks that contain realistic examples and a more efficient and simplified communication with students (Baruh, 2015).

To conduct this research work, we will be using a mixed methods approach, colleting or analysing data from the quantitative and qualitative approaches (Creswell, 2007). There is a diverse range of techniques employed on these approaches, each adapted to the problem to be answered. However, it is advisable that the researcher dedicates time and resources interacting with the students who will be studied, and the data collection must be extensive and drawn from multiple sources such as direct or participant observations, interviews, questionnaires, archival records, physical artefacts and audio-visual materials (Williams, 2007).

The samples that will be used are students from the target courses where the didactical implementations will take place. The present research work outlined the objective of covering schools in all regions of Portugal, including the island of Madeira and the Azores Archipelago. This methodology will make it possible to obtain various data on possible differences between schools in the interior or coast, public and private education, within large metropolitan areas or remote areas, and the mismatch between the gender of students in these groups. Establishing partnerships with public and private entities defines a strategy that, by expanding contacts, makes it easier

to obtain data, disseminate information and facilitate contact with groups of individuals from different geographical areas.

After defining and fine-tuning the strategies and methodologies, the first activity – two classes per institution - will take place during the entire school year, in order to reach the largest number of Portuguese educational institutions. The data obtained to answer the research questions (RQ) is summarized in the table 1.

Table 1: Quantitative and qualitative data to answer the Research Questions.

	Collected Data	RQ1	RQ2	RQ3	RQ4
Quantitative data	Attendance in activities (quantity and distribution over time)	x	x	x	x
	Interest in the proposed recreational activities (quantity and distribution over time)	x	x	x	x
	Participation and conclusion in short courses of Engineering – number of accesses and distribution over time	x	x		x
	Students final grades in short courses of Engineering		x		x
	Students grades per component/task in short courses of Engineering		x		x
	Participation and/or delivery of proposed tasks (in due time)	x	x	x	x
Qualitative data	Short courses of Engineering – contents accessed, participation in forums		x		
	Students questionnaire	x	x	x	
	Interviews and/or informal comments	x	x	x	x
	Types of assessment tools and its distribution along the semester		x	x	x
	Time used in giving feedback and type of feedback given to each assessment task	x		x	x

The planning and streamlining of processes is represented in the following flow chart, represented in figure 1.

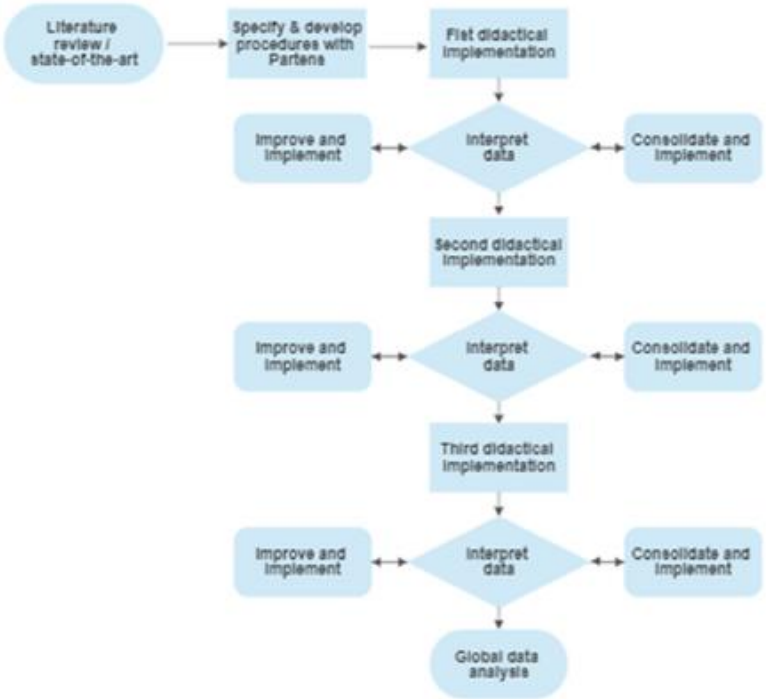


Figure 2: Planning and streamlining of processes for the study.

Finally, for the data analysis it will be used the statistical tool SPSS (Statistical Package for Social Sciences). It will be done a qualitative and quantitative cross analysis, considering the various study variables defined and mentioned above.

4. Material means and resources available.

For the literature review phase, all databases made available by both the University of Salamanca and the Polytechnic of Porto – School of Engineering will be used. According to the partnership with Portuguese Order of Engineers, the data will be made available, complying with the General Data Protection Regulation (GDPR).

All resources available at CIETI-LABORIS (Centro de Investigação em Engenharia e Tecnologia Industrial – Núcleo de Investigação em Sistemas de Testes) Research Group, are available for the research work and can be used in the different phases of the research.

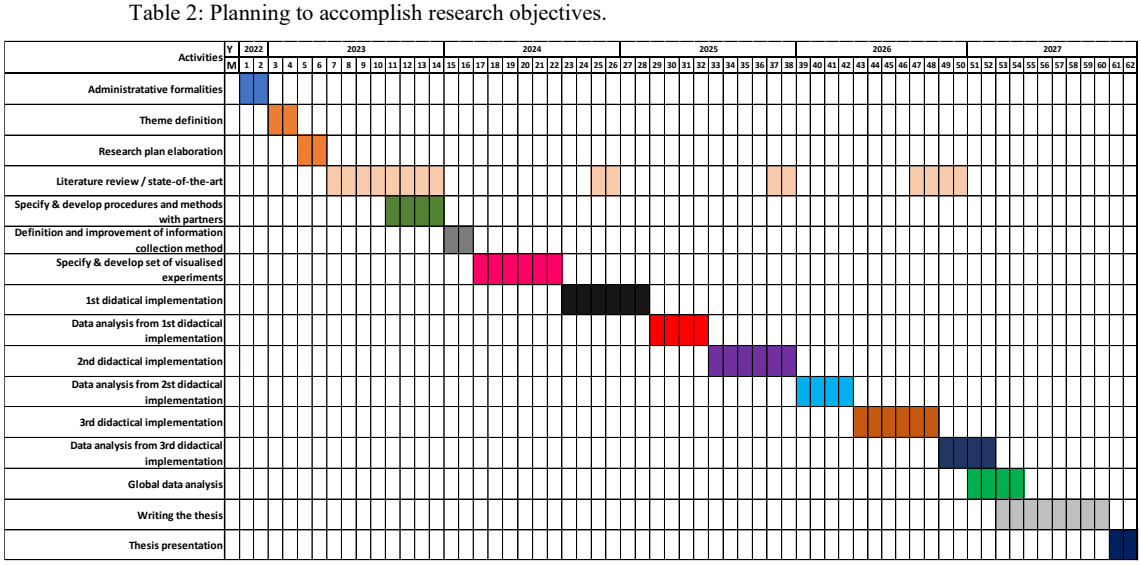
Some resources will be made available by the Portuguese Order of Engineers, according to its initiative and program "There is Engineering in me".

Most of the required data will be provided through Moodle platform, Interviews and questionnaires. For data analysis, we will use the statistical tool SPSS (Statistical Package for Social Sciences).

5. Timing schedule over five years

This research is expected to be completed in five years as the registration in this PhD Program is part-time. Thus, the activities developed to fulfil the research objectives are scheduled for a period of 5 years, as shown in the table 2.

Table 2: Planning to accomplish research objectives.



Over this 5-year period, it is intended to disseminate the results obtained in each research phase, namely:

- Participation in activities fostered by the PhD Education in the Knowledge Society Program.
- Participation (with submission and paper presentation) in the future Editions of Technological Ecosystems for Enhancing Multiculturality Conferences (TEEM).

Acknowledgements

This work was financially supported by Base Funding – UIDB/04730/2020 of Center for Innovation in Engineering and Industrial Technology, Portugal, CIETI – funded by national funds through the FCT/MCTES (PIDDAC), Portugal; LA/P/0045/2020 (ALiCE) and UIDB/00511/2020 - UIDP/00511/2020 (LEPABE) funded by national funds through FCT/MCTES (PIDDAC).

References

1. Baruh H. A Need for Change in Engineering Education 2015.
2. Blázquez M, Castro M. Are Engineering Students Decreasing? A Spanish Case Study 2011. https://doi.org/10.1109/EDUCON.2011.5773144.
3. Creswell JW. Research Design: Qualitative, Quantitative and Mixed Methods Approaches, 4th Edition. SAGE. J Bus Econ Res Vol 5, Number 3 2007.
4. Enriquez A, Langhoff N, Chen C, Teh K. Developing a Summer Research Internship Program for Underrepresented Community College Engineering Students

Developing a Summer Research Internship Program for Underrepresented Community College Engineering Students 2017. https://doi.org/10.18260/1-2--28134.
5. Enriquez AG, Langhoff N, Dunmire EN, Rebold T, E WPP. Strategies for Developing, Expanding, and Strengthening Community College Engineering Transfer Programs Strategies for Developing, Expanding, and Strengthening Community College Engineering Transfer Programs 2018.
6. European commission. Dropout and Completion in Higher Education in Europe. 2015. https://doi.org/10.2766/826962.
7.Gilberto J. Science and Scientific Method 2022. https://doi.org/10.21275/SR22412084104.
8. Kapranos P. Teaching and Learning in Engineering Education - Are we moving with the times? 2015:2–10. https://doi.org/10.1016/j.sbspro.2013.10.707.
9. Gay, L., Mills, G. E., & Airasian, P. W. (2011). Educational Research: Competencies for Analysis and Applications, 10th Edition. Pearson.
10. Mills JE, Treagust D. Engineering Education, is Problem-Based or Project-Based Learning the Answer? 2003
11. Performance S, Reading IN. PISA 2009 Results : What Students Know and Can Do. vol. I. 2009.
12. Salzman N, Lafayette W. Pre-College Engineering Participation Among First-Year Engineering Students Pre-College Engineering Participation Among First-Year Engineering Stu- dents 2020. https://doi.org/10.18260/1-2--22925.
13. Shuman LJ, Atman CJ, Eschenbach EA, Evans D, Felder RM. The future of Engineering Education 2002.
14. Watson TJ, Science A. The Role of the Laboratory in 2020. https://doi.org/10.1002/j.2168-9830.2005.tb00833.x.
15. Williams C. Research Methods - Journal of Business & Economic Research, Volume 5, Number 3. 2007;5:65–72.