Skills in Engineering Education and its challenges to the labour market

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Abstract: Since childhood, education is an essential element in shaping and building knowledge, wisdom and character. What the child absorbs in this knowledge shapes their interest in their attitudes and preferences, directly impacting their school career and, consequently, their professional career. More importantly, education directly impacts the skills each individual is equipped with and can use daily. Skills in the field of sustainability, for example, have become quite relevant nowadays as we need increasingly more technological solutions that have less impact on the environment. If students do not have these skills, then this will mean that professionals in the labor market will not have sufficient skills to respond to the needs of society, and consequently fail to meet national and governmental commitments to outlined goals. It therefore becomes important to understand students' needs for a more complete education adjusted to the needs of society, preparing these future professionals for an increasingly technological, demanding and competitive labor market. This study aims to provide an overview and approach to some findings within the scope of an educational project in STEAM learning and an ERASMUS + project related to education and sustainability.

Keywords: Education, Sustainability, Engineering.

1 Introduction

In the Encyclopedia Britannica, engineering is defined as "*the application of science to the optimum conversion of the resources of nature to the uses of humankind*". Engineers play a pivotal role in solving some of the most pressing global challenges, such as climate change, resource depletion, and environmental degradation. As this profession is so important for society, it is essential that existing professionals in the labor market are equipped with knowledge and techniques that allow them to respond to current dilemmas and problems, thus achieving solutions that allow for speeding up the development of society in an increasingly technological and complex world. Consequently, learning must adapt to current demands, thus promoting skills development in future engineers. Regarding learning, it is necessary to understand the stages of the process in order to structure the education that each professional should receive. It is meanwhile widely accepted that learning is a cyclic process. Therefore, it is proposed that the different stages of this cycle are [1]:

1. Get to know facts;
2. Learn about context;
3. Train procedures for automatic reactions;
4. Find rules behind procedures;
5. Find strategies for acting.

Even though the learning path is sometimes difficult and tumultuous, the result is positive, allowing the individual to evolve professionally and personally, gaining skills, developing new ways of thinking, particularly critical thinking, and increasing resilience. In this last aspect, one of the key points is leaving the comfort zone, the need to have crucial learning experiences and the relevance of motivation in the development of the transformation process until its completion [2]. Today's students face completing higher education as an opportunity to increase the probability of obtaining a better job, focusing on better performance in their academic career, that is, obtaining better grades in subjects. This focus resulted in neglecting the development of skills and competencies necessary to be better prepared for the labor market since grades alone no longer guarantee employability. What happens is that these gaps remain, causing these professionals to be inadequate in carrying out their professional activity [3]. There should be several skills in “baggage” that students should take with them from their academic journey. Most technical skills are cognitive, with other skills related to the affective domain. These are associated with resilience and will, such as carrying out tasks such as reading, researching, being prepared to deal with ambiguous questions and information, dealing with changes and knowing how to react to stress. All of these skills are essential for future engineers to be prepared for the labor market, yet each requires different learning methodologies and different ways of accessing them [4].

One factor has gained considerable importance in the education and skills that students should have: the sustainability. Opportunities are identified to incorporate sustainability competencies into study plans, highlighting the importance of connecting academic training with social and environmental reality through extracurricular activities. Despite the challenges identified, the existence of inspiring experiences that demonstrate the viability of integrating sustainability into university engineering education is highlighted. A multidisciplinary approach can be appropriate to introduce diverse perspectives of multiple disciplines and, therefore, can foster creativity and innovation in addressing the sustainability problems that can be approached from different angles. To face real-world challenges, interdisciplinary collaboration will be necessary. Exposure to diverse disciplines also helps the students deepen their understanding of the interconnected nature of sustainability issues [5]. By incorporating multidisciplinary perspectives and approaches into engineering education, institutions are preparing students to become future engineers who can effectively contribute to sustainable development and address the challenges outlined in the Sustainable Development Goals (SDGs). This holistic and collaborative approach helps students develop the skills, knowledge, and mindset needed to tackle complex sustainability issues in their engineering careers [6].

There is a need to address new engineering competencies and a corresponding gradual change in curriculum and pedagogy in engineering education. Regulations and standards requiring sustainable practices in engineering projects are being implemented in many countries. Incorporating sustainability knowledge into engineering programs helps to equip students with the skills to adhere to these policies and regulations [7]. Furthermore, industries from all backgrounds are realising how critical sustainability is to their operations, and they are looking for experts who can create creative, sustainable solutions. In summary, incorporating sustainability skills into engineering education programs is essential for producing graduates who are not only technically proficient but also capable of addressing the complex challenges facing society in an environmentally and socially responsible manner. Collaboration among different educational communities is critical in driving meaningful curriculum transformations in engineering education [8].

2 Skills in Engineering

Engineers are indispensable for advancing sustainable development due to their unique skill sets and knowledge. Outlining the range of competencies and knowledge related to engineering that are especially relevant to sustainable development will help to guarantee that institutions of higher education are fostering the development of these crucial skills. Technical and non-technical skills are the two main categories into which the overall skill requirements can be divided. Technical skills centre on conventional technical knowledge, such as computational techniques and technical problem-solving, whereas non-technical skills are a conglomeration of social and interpersonal abilities and character traits [9]. Concerning technical competencies, the literature proposes a wide variety of technical skills that engineers can apply to sustainable development. This range of skills can be broadly organized into technical skills which are taught in engineering programmes and then project management skills which are not specific to engineering but are technical.

2.1 Key Technical Skills

The are a range of technical skills that are taught across a variety of engineering fields. First and foremost, engineers are trained to design and analyse structures, systems, and processes in order to achieve a variety of goals, including sustainability standards. For example, waste minimization is a method that focuses on lowering the quantity of waste produced at the individual and societal levels, while eco-design is a strategy that lessens the environmental burden on products [10]. When creating sustainable goods, structures, and infrastructure, it is crucial to comprehend the characteristics, behaviour, and life cycle of materials. Engineers cited that some of the core skills required for their positions were specialised engineering skills like modelling skills, software proficiency, knowledge of Geographic Information Systems (GIS) and Information and

Communication Technology (ICT) [9]. Using modelling systems and other information, engineers learn how to analyse and interpret this data to inform decision-making and evaluate the performance of sustainable solutions.

Understanding of terms, concepts and methods associated with sustainable development, as well as the relevant laws, regulations, and standards, is frequently mentioned in the literature as important skills for engineering students to develop [9], [10].

Project Management

Global trends indicate that professional project management abilities are regarded as an essential skill for engineers. Researchers and project management instructors tend to emphasise on technical project management dimensions such as integrating and coordinating operations across several organisational functional lines while managing resources in terms of time, cost, and performance [11]. These planning and controlling elements of project management translate as skills in risk analysis, contracting, business finance, integrated cost/schedule control, performance measurement, and quality monitoring. Critical thinking and problem solving are other critical skills for sustainable development. Critical thinking is frequently referenced in the literature as a collection of abilities that assess the reliability, correctness, and value of information or claims of knowledge [12]. Problem solving for engineers is described as the capacity to recognize, formulate, and resolve engineering problems [13].

2.2 Soft Skills

Engineering education has traditionally placed a strong emphasis on ensuring that students acquire the necessary technical and computational competencies that are required for employment. However, the value of non-technical skills is growing in the workplace and HEIs. Engineers in the twenty-first century are expected to require a various abilities, including the capacity to integrate business and technical knowledge, think strategically, build teams, to communicate effectively, and to behave ethically [9].

Due to contextual changes such as an increase in project complexity, multicultural concerns, and the growth of work by virtual teams, there has been a growing emphasis on the importance of soft skills to better achieve project success [11]. Although there is no universally accepted definition of what constitutes a soft skill, they are often referred to by researchers using terms like employability skills, personal skills, transferable skills, non-cognitive, non-technical skills, and interpersonal skills [14]. Studies noted that it is particularly common for engineers to see an increase in the importance of soft skills like leadership and other related areas as their careers progress, with technical skills being more crucial in the beginning [9].

According to the findings of a recent survey conducted among Finnish graduates in the fields of water and environmental engineering, the vast majority of participants considered social skills (100%) as crucial to their professional lives, along with teamwork skills (95%), communication skills (94%), and leadership skills (74%) [15]. Among the most important abilities for engineers are good interpersonal skills and the capacity to work well with stakeholders. Engineers need to effectively engage with communities, policymakers, and industry partners in order to facilitate collaboration in the planning, design, and implementation of sustainability projects. Teamwork is also referenced frequently in the literature. The capacity to work in multidisciplinary teams is viewed as a very attractive trait for engineering students to possess [13]. It is emphasised that the attitudes of team members must be in place before the team can function effectively [10]. Regarding communication skills, studies claim that it's critical to be able to communicate sustainability concerns to partners both inside and outside the organisation in an engaging and effective way [16]. This includes being able to offer solutions for challenging problems that are connected to sustainability. Argumentative skills are also referenced as important in order to prepare engineering students for debates and defending positions on global sustainability issues [10].

2.3 Attitudes

Another category of non-technical skills includes attitudes, behaviours, and fundamental personality traits that support an individual's capacity to function both independently and collaboratively [11]. Ethical behaviour is considered important for engineers so that they have an understanding of the professional and ethical responsibility their position entails [13]. Other positive attributes include having an attitude toward one's own experiences that will enable one to reflect on and learn from them as well as being receptive to what others are trying to communicate [11]. In addition, having an understanding of the value of and aptitude for lifelong learning is also considered an important [13].

3 Sustainability in engineering education

Engineering plays a key role in growth and development all across economies, from transport infrastructures, public services and digital [17]. Sustainable agendas are focused on technological changes altering the provision of goods and services, preventing pollution and decreasing energy usage through systems changes, and developing innovative socio-technical system [18]. Using an SDG lens to view infrastructure investments can lead to significant progress towards achieving the SDGs [19]. Each of the 17 SDGs will require engineering solutions in some fashion [17], with several reports indicating that over 81% of the SDG targets are influenced specifically by infrastructure projects [19], [20].

The global challenges require engineering solutions for air quality, food security, clean water supplies, energy, and communication, in addition to mitigation efforts for natural disasters and climate change-induced environmental effects [17]. New technologies provide benefits globally and across sectors, such as low-cost and high-efficiency lighting systems, energy systems, and systems with reduced greenhouse gas emissions. The policy agendas surrounding Sustainable Development (SD) are focused on cross-cutting technological changes and processes, such as manufacturing, transportation, energy and construction [18]. Science, technology and engineering lie at the core of sustainable development by establishing factual bases, anticipating future challenges, and innovating solutions to sustainability challenges [17]. Even before the SDGs were agreed upon, engineering societies and collectivities, including the American Society of Civil Engineers (ASCE), Institute of Electrical and Electronics Engineers (IEEE), and American Association of Engineering Societies (AAES) made commitments towards integrating sustainable development into their code of ethics dating back to the early 2000s [21]. Even though engineers are a key occupational group for productivity improvements, they receive little focus in economic and social development policy discussions, as can be seen through the limited mention of 'engineering' in UN sustainable development policy. These mentions, for example in the UN's Achieving Sustainable Development and Promoting Development Cooperation conference in 2008 and in the 2030 Agenda refer to engineering's benefits only in terms of technology transfer to less-developed countries [17]. Organizational challenges also create limitations for incorporating the SDGs into engineering practice. The global nature of the SDGs means that their framework performs well at regional and national levels but struggles to be accessible at the local level where most infrastructure investments made. Beyond this, profitability has a significant impact on the decisions of engineers when identifying SDG goals and targets [19]. Conflicting research suggests varying levels of agency for engineers in the control over their capacity to incorporate sustainable ideologies into technology development, with some accounts revealing that corporate structures [22]. Reliance on traditionally-trained engineers for innovating the sustainable transition ignores the need and capacity for industry and individuals to change [18]. At the project management level, the hyper-granularity of the SDGs, targets and indicators has proven to create implementation and tracking challenges [19].

University initiatives also face roadblocks to aligning the SDGs with engineering. Sustainability challenges are difficult and cross-disciplinary with initiatives tending to be interdisciplinary [23]. Sustainability challenges need engineers capable of handling ill-defined, open-ended, transdisciplinary and complex socio-technical problems [17], [18]. The difficulty is that most faculty are neither multi nor trans-disciplinary and trans-disciplinary faculty are less likely to be approved by traditional departments [18].

4 Approach to engineering education through hands-on methodologies - a specific perspective

The development and structuring of new teaching methodologies can revolutionize the way teaching is implemented, innovating the way in which knowledge is passed on to students, differentiating the connection bridge between the teacher and the student, thus increasing the attention and interactivity of students. students by subject. By common sense, Engineering education is intrinsically linked to STEM learning, where science, technology, mathematics and engineering develop multidisciplinary links. One possibility of transforming STEM education is based on shifting the focus from acquiring passive knowledge, to a hands-on methodology, which represents a possibility of acquiring knowledge actively. This represents an opportunity to engage in extended, real-world projects promoting critical thinking and developing solutions to solve complex problems [24]. This is an example of the activity *Há Engenharia em Mim®*, from the

Ordem dos Engenheiros – Região Norte. This specific project promotes the activity of discovering Engineering, which aims to stimulate and (re)discover in teenagers the stimulation and practical sense of engineering, in a playful-pedagogical 'hands on' aspect, based on a STEAM learning tool. The Educational Project *Há Engenharia em mim®* proposes, within the framework of children and young people, to bring to school, particularly primary and secondary education, simple but fundamental engineering processes, gaining not only the interest and motivation of students in the exact sciences but also the development and expansion of their knowledge, aiming to observe, participate and contribute in a proactive way to issues of everyday life and coexistence. In this STEAM experience, with primary and secondary school students as its target audience, the interaction combines science, technology, engineering, arts and mathematics skills, aiming to encourage interest in mathematics and physics, as well as spark practical knowledge in engineering in young people. Through the construction of prototypes, combining abstract-logical reasoning with know-how. The provisional results are promising, and additional research should be carried out in order to strengthen the final conclusions obtained.

As previously mentioned, cooperation between entities becomes crucial. This educational project commits to the SDGs and the core premises of the 2030 agenda, thus receiving High Patronage from UNESCO. It also has the European Parliament as partner, under the Project entitled Europe is Engineering in my hands, being granted High Patronage for the activity, which counts on the implementation of this project in EPAS schools (European Parliament Ambassador Schools). The *Há Engenharia em Mim®* program was created with the aim of promoting Engineering in younger students, thus attracting future professionals to the national market, trying to reverse the negative trend of the lack of Engineers in the national panorama. Thus, the project received High Patronage from the Presidency of the Portuguese Republic. In the connection between academia and the profession, a partnership was established with EAFA - European Alliance for Apprenticeships, from the European Commission, which aims to stimulate learning and the introduction of students to the labor market.

Conclusion

Taking a perspective, the importance of multidisciplinary approaches to engineering education is determined. These approaches enable students to tackle complex issues and challenges, develop critical thinking skills, and appreciate different perspectives. They also emphasize the importance of key and non-key technical skills, focusing on sustainability in engineering education. Multidisciplinary approaches to engineering education are becoming increasingly important to equip engineers with the skills, knowledge, and mindset needed to tackle complex issues and challenges. These approaches emphasize critical thinking, collaboration, communication skills, and ethics. All the previously mentioned factors thus become relevant to prepare Engineers to become highly trained, multidisciplinary and competent professionals to face the challenges that society faces. The importance of updating teaching methodologies in order to develop critical skills in students is also highlighted, with the hands-on methodology gaining relevance due to the advantage of promoting the acquisition of knowledge in an active way and preparing for real-world projects, having the potential to the development of highly relevant partnerships for the dissemination and growth of educational projects.

For future work, it is suggested to deepen research regarding students' interest not only in Engineering, but in subjects such as science, technology and mathematics. Regarding the approach to STEM learning using hands-on methodologies, it is suggested to carry out actions with students at different stages of the school year, carrying out the respective scientific measurement before and after this action.

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