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# Engineering Skills And Competences For A More Sustainable World

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## Abstract

In 2015, the member states of the United Nations agreed that the ideal vision of the world should be achieved by 2030. Halfway through the efforts to reach that vision, and considering the environmental issues we are surrounded by, the need for Higher Education to further incorporate sustainability topics into the curriculum is noticeable.

This paper presents the outcomes of the research through which we aim to make an impact on Higher Education institutions and the ways they are educating and raising awareness on sustainability-related topics. It presents an analysis of the data collected through a survey and focus groups, organised with the students from 63 technical universities all across Europe, in total counting 226 responses. The paper points out the relevance of engineering education on environmental sustainability in

today's rapidly changing, modern world. It also identifies the sustainability-related topics that should be incorporated into the curriculum. Further, it points out different engineering skills and competences needed for a more sustainable world and the ways in which they can be obtained. Some of the skills highlighted as the most important ones are: communication, time management and critical thinking.

The results show a critical imbalance between the practical and theoretical parts of engineering education. It reflects on the possibilities of implementing modern teaching and learning methods, in order to create a more sustainable mindset in engineering, thus making the learning process more engaging and accessible.

## 1. INTRODUCTION

Our planet is facing massive economic, social and environmental challenges that we can no longer ignore *(*SDG compass, n.d*.).* Over 130 countries strive for net-zero carbon emissions by 2050. Technological innovations will be essential in the backend to ensure global leaders reach this goal. However, in the frontend, there is a strong demand for society to relearn how to live on this planet sustainably as the climate rapidly changes - and education is a key enabler of this transition *(*BCG 2022).

Over the years, Education for Sustainable Development has gained international recognition as an integral element of quality education and a key enabler for sustainable development (UN, n.d.). It utilises action-oriented, innovative pedagogy to transform society into a more sustainable one (Giannini S, 2020). Education plays a crucial role in developing climate literacy, which is essential for driving behavioural change and collective action. Early studies suggest that young people who become climate literate can educate their families, creating a multiplier effect in their communities (Lawson et al, 2019). However, it is important to acknowledge the limitations of Higher Education's role in sustainability (Sterling S, 2021). While some organisations and individuals have been working on the intersection of education and economic, environmental, and social topics, education has not been widely recognized as a solution to sustainability issues.

We identify three primary objectives where education and sustainable development intersect, with education serving as a powerful driver of change:

Objective 1: Assess the current state of the Engineering Education on Sustainable Development (EESD) in Europe and identify relevant sustainable-related topics that addressed in Higher Education;
Objective 2: Define the key engineering skills for sustainable development that can be acquired through Higher Education and explore effective ways of obtaining them;
Objective 3: Determine the methods through which sustainability can be integrated into the curriculum and examine approaches for embedding sustainability principles .

## 2. METHODOLOGY

The methodological approach of this study was based on the initial quantitative analysis of gathered data, while the final conclusions were drawn using a combination of quantitative and qualitative data. The data were collected through a literature review, which helped establish the theoretical background. Additionally, a survey was conducted to gather qualitative data, and focus groups were organised to further support the development of the final conclusions. The target group consisted of students from technological universities in Europe. The total population of the study comprised 226 students from 63 technical universities in Europe, during the period from November 2022 to February 2023.

All participants of the research were asked about their perception of the current state of EESD and how to bridge the gap between the expected and actual outcomes provided by EESD to students. The research results are presented throughout the paper using various graphs that are relevant to the showcased dataset within each section. For a more in-depth analysis to identify logical correlations, the PowerBI software was utilised. The main dimensions used for analysis were age group, gender, and the participants' graduate status.

Lastly, it is important to emphasise the need for a critical mindset when interpreting the results, considering the benchmark and the average number of students per university that participated in this research. In conclusion, further steps regarding this aspect will be addressed.

## 3. RESULTS AND DISCUSSION

### *3.1. Current state of the EESD*

Nowadays, more countries say education on sustainable development is reflected in their educational system. However, EESD is often narrowly interpreted, focusing primarily on topical issues rather than adopting a holistic approach that promotes a fundamental behavioural shift towards sustainable development. Higher Education Institutions worldwide are recognising the significance of engineering in addressing the sustainability challenges of the 21st century. As a result, there is growing contemplation of integrating sustainable development principles into engineering curricula, in line with accreditation guidelines (Edmond P. et al., 2010).

Table 1 showcases the state of the sustainable topics tackled in the studies in technical Universities in Europe, with the total percentages given for ratings 1 to 5:

| Topic | 1 - Not at all | 2 | 3 | 4 | 5 - In depth | 4 & 5 |
|---|---|---|---|---|---|---|
| The UN Sustainable Development Goals | 23% | 17% | 29% | 21% | 10% | **32%** |
| Climate change | 12% | 13% | 27% | 30% | 18% | **48%** |
| Product lifecycle | 14% | 14% | 27% | 34% | 11% | **46%** |
| Design for sustainability | 21% | 31% | 22% | 17% | 9% | **26%** |
| Impact assessment | 26% | 24% | 24% | 18% | 8% | **26%** |
| Sustainable energy production & management | 18% | 14% | 30% | 24% | 14% | **38%** |

*Table 1. Percentages of coverage of sustainability-related topics in studies, on a scale 1-5*

According to the data presented in Table 1, technical universities in Europe have main focus on the following sustainability issues: climate change, product lifecycle, and sustainable energy production/management. The table reveals the distribution of grades (specifically, grades 4 and 5) assigned to these topics, with percentages of 48%, 46%, and 38% respectively. Out of all the topics, climate change is the only one which was graded with higher grades by undergraduate students. [17]

The data indicate that the topics currently included in curricula align with the "top sustainability trends" in the global market, such as recycling, reduction of food waste, improved transport and infrastructure, and sustainable materials (McKay B, 2023).

However, the United Nations has raised the question of whether it is necessary to include social and economic aspects in EESD, in addition to the environmental pillar of sustainable development (UNESCO, 2020, chap. 1). The extent to which these topics are addressed in universities is highly dependent on the development state of countries and their "sustainable mindset." Considering the principles outlined in Agenda 2030 and SDGs, which emphasise the need for collective action towards building a better future, it can be concluded that quantifying the extent of the positive impact achieved is challenging due to significant discrepancies between countries in their attention to sustainability matters. This question also extends to EESD.

The **main recommendation,** therefore, is for Higher Education to shift towards a holistic approach that encompasses sustainable development. This entails fostering a more sustainable mindset among students, raising their awareness of the impact their actions have on the world around them through sustainability literacy. To achieve this, educators, educational institutions, and governments need to commit to implementing action-oriented curricula, rather than solely being conveyors of information, and provide appropriate training for teachers.

### *3.2. Engineering Skills for a more sustainable world*

To follow a sustainable development path, it is crucial to undergo a fundamental and transformative shift in thinking, values, and actions for everyone. Multiple studies emphasise that future generations of engineers will not only drive technical innovation but also play a leading role in addressing various social issues (Desha and Hargroves Citation, 2014). They are key actors who can incorporate sustainability into their solutions and transform our current technologies into greener alternatives. This raises important questions: **What** skills and competencies should engineers possess? **How** and **where** can these skills be acquired? Should sustainable-related topics be integrated into engineering curricula, and if so, how?

The literature reveals that future engineers will require a broad range of sustainability competencies and skills to support the SDGs. However, different stakeholders, including students, employers, and academics, may define these key competencies for sustainable development differently (Beagon U. 2022).

According to the presented data on Fig. 1, the majority of respondents indicated that the most relevant competencies for engineers are: critical thinking, sustainable mindset, creativity and innovation, problem-solving, and ability to work in a team, respectively. It is worth noting that there is a slight preference for these top five skills among female respondents, as indicated by their higher ratings of 4 or 5 on the scale. [17]

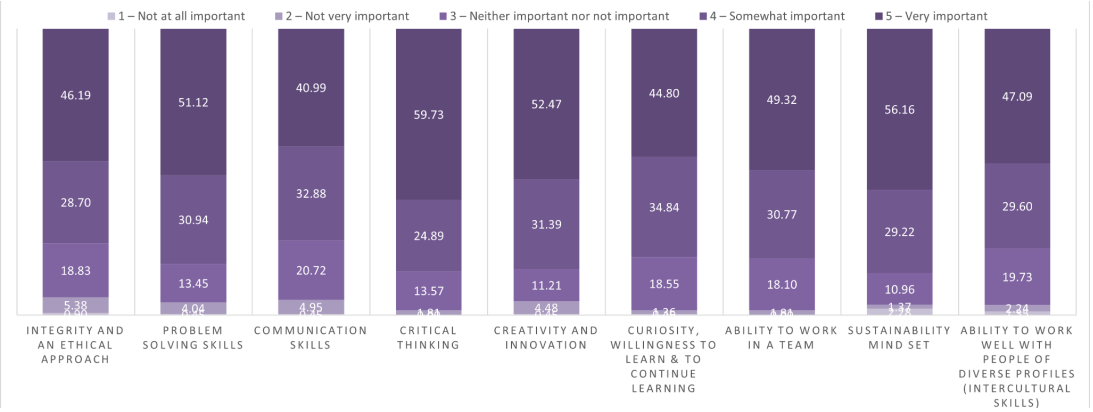


*Fig. 1. Histogram showing the perceived importance of the following skills for addressing sustainable development, on a scale 1-5*

If we compare the results with the research conducted by the United Nations in 2017 (UNESCO, 2017, pp. 54-56), we can observe that the competencies mentioned align with the "key competences for sustainability" listed in that study. However, these do not replace specific skills required for successful action in specific situations and contexts.Instead, they encompass and have a broader focus (Rychen, 2003).

Based on these findings, it can be concluded that through EESD, engineers in today's society should possess the following abilities:

- Question norms, practices, and opinions, and reflect on their own values, perceptions, and actions, as well as those of society;
- Be self-driven and operate responsibly, considering how everyday actions can contribute to building a sustainable future;
- Use imagination, creativity, and innovation to develop products and services that maintain and enhance the quality of the environment and the community, while also meeting financial objectives;
- Apply diverse problem-solving frameworks to address complex sustainability issues and develop viable, inclusive, and equitable solution options that promote sustainable development;
- Learn from and collaborate with others, understanding and respecting their needs, perspectives, and actions, and facilitating collaborative and participatory problem-solving.

These competencies should enable individuals to establish connections between the different SDGs, allowing them to comprehend the "big picture" of the 2030 Agenda for Sustainable Development. The extent to which these competencies can be acquired through Higher Education varies depending on the structure of curricula in different universities.

The **main recommendation** is for Higher Education institutions to prioritise two critical areas. Firstly, they should focus on providing lifelong education opportunities for current workers. Secondly, institutions should establish a strong foundation for students who will become leaders in the development of future technologies,

equipping them with the necessary knowledge and skills. In addition to technical skills, it is essential to foster green skills that centre around teamwork, resilience to navigate ambiguity, problem-solving, and creative thinking. To facilitate a smooth transition towards a sustainable economy, it is imperative for leaders in education, government, and industry to align educational programs and training institutions, ensuring the provision of essential skills.

### *3.3. Learning methods and techniques for EESD*

Until now, little is known about the quality of EESD programmes, the extent of their implementation and their effectiveness in generating the desired changes in learning attainments - knowledge, competencies, values, and behaviours (A. Leicht et al. 2018, chap. 2).

There are multiple activities, learning and teaching methods that can contribute to the development of sustainable skills and mindset. Fig. 2 showcases some of them that students recognised as the most impactful ones, with an average grade from 1 to 5.

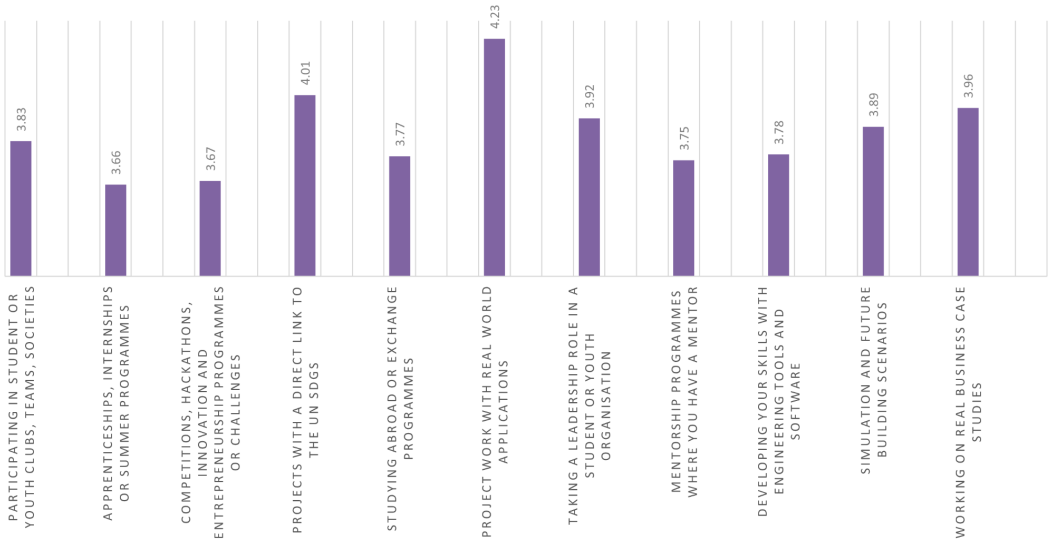


*Fig. 2: Impact of different learning methods according to students, on a scale 1-5*

The results indicate that the top 5 activities supporting development of crucial skills during studies are as follows:

- Project work with real-world implementation;
- Projects with direct link to the UN SDGs;
- Working on real business case studies;
- Taking a leadership role in a student or youth organisation;
- Simulations and future building scenarios.

Both undergraduate and postgraduate students share a similar opinion on the impact of these activities on skill development, with graduated students slightly favouring the top activities. In terms of gender, there is a slightly higher preference for the top activities among females. Undergraduate students emphasise the importance of skill development through software usage, competition participation, and internships. [17]

These learning techniques prioritise practical implementation of knowledge rather than pure theory, fostering student engagement and challenging them to find sustainable solutions. However, it is important to acknowledge the need for a theoretical background in understanding the topic.

By combining these techniques, students can learn to analyse the bigger picture, recognize environmental limits and finite resources, understand the impact of engineering projects on communities, and more. Therefore, a **key recommendation** is to carefully plan courses and approach the learning process at universities, striking a balance between theory and practice, and providing opportunities to address real problems. Lastly, it is important to recognize that ESD should not only develop skills and competencies but also contribute to lifelong learning and initiate a shift in everyday behaviour and attitudes towards a more sustainable world.

### *3.4. Embedding sustainability in the curriculum*

The need for education about the environment and sustainable development has been recognized since the Stockholm conference in 1972. Over the years, extensive discussions have taken place regarding the integration of sustainable development into academic curricula. However, there is now a growing interest in developing and integrating sustainable development into curricula at all academic levels (Lozano F.J, Lozano R., 2013, pp. 136-146).

Higher Engineering Education, with its strong traditions, faces the challenge of transitioning to more innovative curricula based on active and cooperative learning. Embracing this challenge is essential to enhance EESD.

Sustainability is currently addressed in various ways within Higher Education. Examples shared during the focus group include:

- Standalone modules dedicated to making processes, such as manufacturing, more environmentally friendly;
- Specific courses on sustainability and sustainable technologies, offered as either compulsory or elective subjects;
- Projects focused on the SDGs and related issues.

The effectiveness of these approaches depends on several factors, including the competencies and interest of teachers/lecturers in sustainable development, the structure of courses, and the overall mindset and awareness of sustainable development topics in different countries, cultures, and universities.

In the field of EESD, three key pedagogical approaches are commonly employed: learner-centred pedagogy, action-oriented learning, and transformative learning (UNESCO, 2017, pp. 54-56).

Embedding sustainability within the curriculum can be challenging, but there are

several **recommendations** to consider. The curriculum should aim to develop students' sustainability literacy and foster the development of sustainable skills. This can be achieved by incorporating diverse activities, such as project works with real-world implementation and direct links to the SDGs. Additionally, promoting extracurricular activities outside of the university that contribute to sustainable skills development is beneficial. Higher Education institutions should also provide support for educators to enhance their sustainability knowledge and education, and work towards creating an overall sustainable-oriented environment.

## 4. SUMMARY

As we reach the halfway point of the implementation period for the SDGs, there is still a need to determine how education should be adapted to effectively address the significant economic, social, and environmental challenges we face. The examination of the current state of EESD reveals variations between nations in their strategies and level of commitment towards addressing sustainability concerns.

While the data gathered and analysed in this research is limited and cannot be generalised on a larger scale, the insights provided align with previous studies conducted. The **key takeaways** on accelerating sustainable literacy for behaviour change and collective action are as follows:

1. Higher Education institutions should reshape the curriculum to contribute to the development of sustainable skills and foster a more sustainable mindset;
2. The activities included in the curriculum should support the practical implementation of the knowledge;
3. Educators, Higher Education institutions, industry and governments must commit to creating interdisciplinary action-oriented curricula;
4. Higher Education institutions should provide support to educators in implementing innovative teaching methods;
5. Students need to continue advocating for the necessary changes, and hold decision makers accountable.

In conclusion, the process of identifying all the essential and critical areas for sustainable education is complex and extensive. Therefore, there is an urgent need for the academic community to respond in an agile manner. Rather than seeking the perfect solution through extensive benchmarking, it is crucial to take action towards a more sustainable future. While curriculum adjustments may seem tempting to address educational deficiencies, the issue extends beyond curricular coverage. It also involves curriculum implementation and the design of effective learning environments.

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