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Asking the engineering educators: prevalence of SDGs in the engineering curriculum & analysing accreditation requirements

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Abstract

This paper presents findings from a global survey of engineering educators (n=22) across five continents, examining the integration of Sustainable Development Goals (SDGs) in engineering education. Despite the limited sample size, consistent response patterns reveal significant trends in sustainability education implementation. SDGs 6, 7, 9 and 11 were the most prominent SDGs identified as being relevant to the engineering discipline. All respondents identified at least one SDG as being relevant to their teaching content; however, the actual coverage rate of SDGs – defined as the ratio of SDGs that educators say they explicitly identify in their teaching to SDGs that they identify as being relevant to the taught content – averages below 40%. Survey respondents cited a packed curriculum and accreditation requirements as the main reasons for the low coverage of SDGs. To explore how educators' concerns of a crowded curriculum can be reconciled with accreditation requirements, a comparative Bloom's Taxonomy analysis of sustainability-related undergraduate learning outcomes mandated by five major engineering accreditation bodies from around the world was undertaken. Although there are differences in the learning outcomes prescribed by the different accreditation bodies, an overarching emphasis on sustainability as the foundational pillar to engineering design and problem-solving is evident.

1 Introduction

The imperative to integrate sustainability into engineering education has gained significant traction over the last two decades (Thürer et al. 2018). As the world faces increasingly complex socio-environmental challenges, the role of engineers in developing sustainable solutions through systems thinking has become paramount (Byrne et al. 2013). This has ramifications for engineering education – it is not about equipping future engineers with just technical expertise but the knowledge, skills, and attitudes necessary to address global challenges effectively, which draws on a wider pool of capabilities related to problem-solving (Guerra and Holgaard 2016).

Global sustainability initiatives, such as the United Nations Sustainable Development Goals (SDGs), have helped drive the transformation towards embedding sustainability in higher education. The SDGs, adopted by all United Nations Member States in 2015, provide a comprehensive framework for addressing global challenges, including poverty, inequality, climate change, environmental degradation, and peace and justice. These 17 interconnected goals have been widely recognized as relevant to engineering practice and consequently, there has been growing interest in how these goals can be effectively integrated into engineering curricula (Sánchez-Carracedo et al. 2021; Beagon et al. 2023). In this endeavour, several frameworks and pedagogical approaches to embed sustainability in engineering education have been published (Ramirez-Mendoza et al. 2020; Narong 2024). Despite these developments, the implementation of sustainability in engineering education remains inconsistent and faces numerous challenges. Engineering education has been quoted to ‘struggle to foster learning characteristics with integrated sustainability education’ (Gutierrez-Bucheli, Kidman, and Reid 2022) and inconsistencies in the emphasis of sustainability in accreditation documentation pose an additional challenge (UCL Centre for Engineering Education 2024).

Hence, questions remain about the extent to which sustainability is genuinely embedded in engineering curricula globally, specifically on how educators are using the SDGs as part of their teaching practice and navigating the demand of accreditation requirements. To address this knowledge gap, a global survey of engineering educators across five continents was conducted to examine current practices, challenges, and perspectives on integrating sustainability through the SDGs into engineering education. This paper presents the findings of this survey, with particular emphasis on the implementation gap between recognized relevance of SDGs and actual teaching practice, and perceived barriers to integration. Additionally, accreditation requirements from multiple accreditation bodies are analysed through the lens of Bloom's Taxonomy to explore how sustainability learning outcomes might be more effectively aligned with curriculum development.

2 Methodology

The engineering educators' survey data presented in this study was collected online using the JISC Online Surveys platform. The link to the survey requesting educators to complete the survey was sent by email by the corresponding author. The survey was designed to take between 5-10 minutes to complete and respondents could complete the survey anonymously by skipping any number of questions that they did not wish to answer. Analysis of the resulting data was performed on Microsoft Excel.

For the analysis of sustainability-related learning outcomes in accreditation documentation, curation was done through a manual text analysis of graduate learning outcomes specified by five engineering accreditation organizations worldwide. Learning outcomes were deemed to be related to sustainability either if there was an explicit reference to ‘sustainability’ or ‘sustainable development’, or if multiple dimensions of sustainability were referred to within a learning outcome – for example, consideration of economic, environmental and societal factors. Bloom’s taxonomy (Anderson and Krathwohl 2001; Bloom et al. 1956) was used to classify the action verbs at three levels of cognition in the following hierarchical order: awareness or recognition of, understanding and evaluation, design and develop.

3 Results and Discussion

A total of 22 responses were received for the global engineering educator survey. Figure 1 shows the demographic of the survey respondents. Responses were received from educators in 11 different countries with the United States and the United Kingdom accounting for 23% and 18% of the total responses, respectively. There is a disproportionate representation of the Global North in the survey demographic with only 24% of the respondents being affiliated to institutions in the Global South (South Africa, India and Trinidad & Tobago). One-half of the survey respondents declared their core expertise to be in chemical engineering. The other main disciplines self-reported by the respondents were civil, electrical, environmental and mechanical engineering (Figure 1).

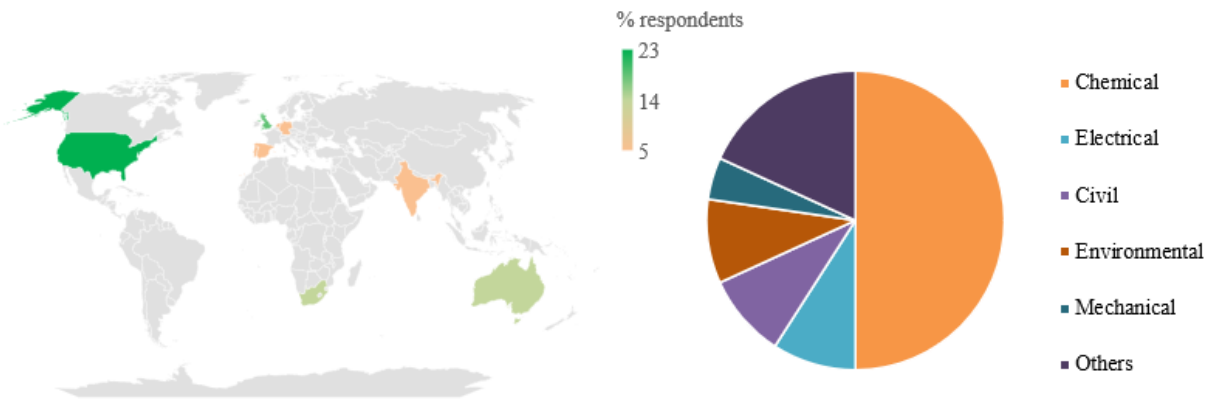


Figure 1: Survey respondents demographic – Country of affiliated educational institution (left) and main engineering discipline of expertise (right).

The respondents were asked to select the SDGs that had a strong fit or overlap with their core engineering discipline as well as the SDGs that were specifically related to the content of their current teaching material. The polar area chart shows a high degree of similarity in the educators’ responses for both these questions (Figure 2). The most prominent SDGs identified as being central to the engineering discipline were SDG 7 (Affordable and clean energy) and SDG 6 (Clean Water and Sanitation), selected by 77% and 68% of respondents respectively. This was followed by SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable cities and communities), both at 64%. These same SDGs were also top of the list for

their relevance to current teaching material, although SDG 7 had the highest difference across the two questions – 59% of respondents selected the SDG as being related to the content of their teaching material in comparison to 77% who said it was a strong fit with their engineering discipline. These findings align well with the most prevalent SDGs identified in the (UCL Centre for Engineering Education 2024) report, although SDG 13 did not receive as much traction from this survey’s respondents (Figure 2). Meanwhile, SDGs 1 (No poverty), 5 (Gender equality), 10 (Reduced inequalities), 16 (Peace, justice and strong institutions) and 17 (Partnerships for the goals) were the least selected SDGs, polling less than 10% on both questions (Figure 2).

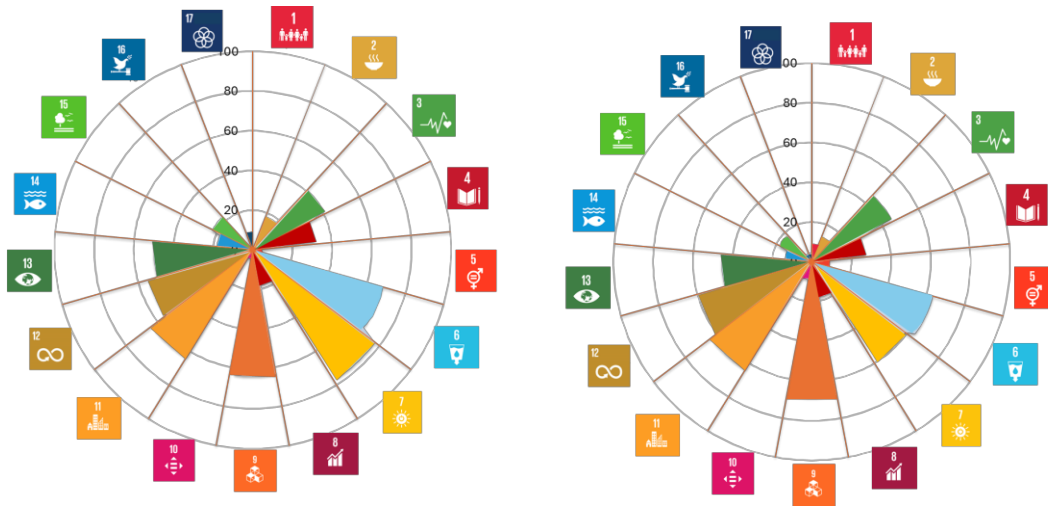


Figure 2: Polar area charts of UNSDGs identified by survey respondents (%) as being related to their engineering discipline (left) and related to the content of their teaching material (right).

While all survey respondents identified at least one SDG as being relevant to their teaching material (Figure 2 right), the average ‘coverage’ of SDGs in their actual teaching practice – defined as the ratio of SDGs that educators say they explicitly identify in their teaching to SDGs that they self-identify as being relevant to the taught content – was 37%. Although this average coverage being on the lower side is worth introspection on its own, the coverage data also revealed a strong bipolarity; nearly 32% of the respondents declared not identifying any of the SDGs as part of their teaching practice, while 18% declare identifying all the relevant SDGs – translating in 50% of the respondents falling at either extreme (Figure 3 upper left).

Performing the same coverage analysis for each SDG shows that although only a small fraction of educators identify SDGs 5, 10, 16 and 17 as being relevant to their teaching material, these educators do explicitly identify them in their teaching practice, resulting in these SDGs falling in the (0.8,1] coverage bracket in Figure 3. On the other hand, SDGs 6 and 11, which were both identified by 64% of respondents as being relevant to their teaching content (Figure 2), have the lowest coverage in the (0,0.2] range (Figure 3). Taken together, these findings show that most SDGs are not explicitly referred to within the engineering curriculum; the SDGs with a stronger socio-economic focus are only emphasized by a small fraction of the surveyed educators, while the SDGs with a greater techno-environmental focus – although acknowledged as being relevant by most respondents – are embedded as part of the taught material only by a minority. The only exception to this overarching trend appears to be SDG 7, which scores highly on both the relevance (Figure 2) and coverage (Figure 3) metrics. The right panel of Figure 3 plots the percentage of educators

declaring an SDG as being relevant to the engineering discipline versus the percentage who believe the SDG needs greater attention in the student curriculum. Notwithstanding the relatively high coverage of SDG 7, educators still call for its greater emphasis in the taught curriculum. It features alongside SDGs 11 and 12 – the two other SDGs identified by >25% of the survey respondents as needing more attention (Figure 3). While these two SDGs are characterized by a high relevance metric, unlike SDG 7, they currently have an inferior educator self-declared coverage (Figure 3).

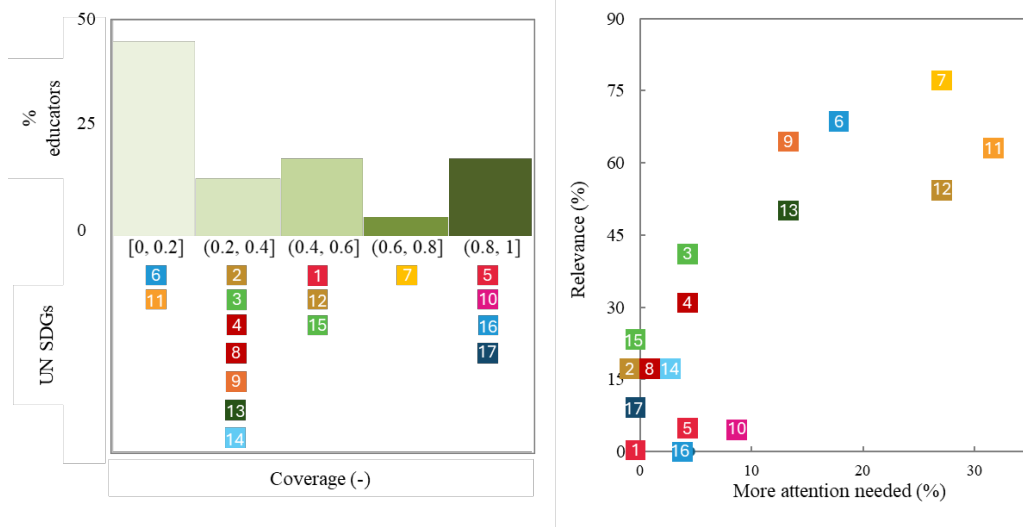


Figure 3: Histogram of respondents’ self-declared average coverage of SDGs (upper left), coverage of specific SDGs (lower left) and scatter plot of SDGs identified by % respondents as being relevant to their discipline versus % respondents calling for its greater attention in the student curriculum (right).

Educators refer to leveraging case studies and project-based learning as the most prominent methods to engage students in learning about sustainability in engineering. The challenges that survey respondents identify in incorporating sustainability into the engineering curriculum fall under the following main themes (in order of mentions): (i) packed curriculum and accreditation requirements (ii) lack of resources and time constraints (iii) lack of interest among students and staff and (iv) student exposure to social sciences. Several open-access resources, such as the (Engineering Professors’ Council 2024) Sustainability Toolkit, have been published to help engineering educators embed sustainability in their teaching. More engagement with these resources can be particularly useful for staff, especially when a better understanding of accreditation requirements can be surfaced.

A careful analysis of accreditation requirements can serve as an enabler of integrating sustainability in engineering education. To this end, Table 1 curates the sustainability-related undergraduate learning outcomes mentioned in the documentation of five accreditation bodies from around the world: Accreditation Board for Engineering and Technology (ABET), European Network for Accreditation of Engineering Education (ENAE), Engineering Council United Kingdom (ECUK), Engineering Council of South Africa (ECSA) and India’s National Board of Accreditation (NBA). The overarching similarities of the listed learning outcomes can be surfaced by leveraging Bloom’s Taxonomy to classify the expected levels of cognitive competence. At the lowest level, an awareness or recognition of ‘ethical and professional responsibilities’ and importance of ‘non-technical’ constraints, including societal, environmental and industrial considerations is needed. This serves as the foundational basis for engineers to be able to

‘understand’ and ‘evaluate’ the ‘impact of engineering solutions’ from a broad multifaceted perspective (Table 1). At the highest end of cognitive competence is the ability to ‘design’ and ‘develop’ processes and solutions to meet a ‘combination of desired needs’ that consider ‘global, cultural, social, environmental, political, ethical and economic factors’ (Table 1). The ability to analyse ‘impact of engineering solutions’ emphasizes the ‘end-of-pipe’ or mitigation approaches to sustainability, while at the same time, placing sustainable development at the forefront of engineering design should enable a greater balance of ‘beginning-of-pipe’ or adaptation approaches to sustainability in the curriculum. Notwithstanding the differences in the as-stated learning outcomes, the accreditation guidance appears to unanimously prompt engineering educators to use sustainability, in a holistic sense (techno-environmental as well as socio-economic), as the central theme to engineering design and problem-solving.

Table 1: Sustainability-related undergraduate learning outcomes as specified in the accreditation documentation of various global accreditation bodies.

Accreditation body	Student learning outcome
ABET, United States	<p>apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors</p> <p>recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts</p>
ENAAEE, Europe	<p>recognise the importance of non-technical – societal, health and safety, environmental, economic and industrial – constraints</p> <p>develop and design complex products (devices, artefacts, etc.), processes and systems in their field of study to meet established requirements, that can include an awareness of non-technical – societal, health and safety, environmental, economic and industrial – considerations</p> <p>awareness of non-technical – societal, health and safety, environmental, economic and industrial – implications of engineering practice</p> <p>inform judgements that include reflection on relevant social and ethical issues</p>
ECUK, United Kingdom	<p>design solutions for complex problems that meet a combination of societal, user, business and customer needs as appropriate. This will involve consideration of applicable health and safety, diversity, inclusion, cultural, societal, environmental and commercial matters, codes of practice and industry standards.</p> <p>evaluate the environmental and societal impact of solutions to complex problems and minimise adverse impacts</p>
ECSA, South Africa	<p>critical awareness of the impact of engineering activity on the social, industrial and physical environment.</p>

NBA, India	design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
	understand the impact of engineering solutions in a global, economic, environmental, and societal context

4 Conclusions

Although the SDGs are set to expire in five years' time, there is still much ground to cover in terms of how sustainable development and specifically the SDGs are integrated into engineering education. While the published literature in this domain has seen several advancements ranging from frameworks to toolkits, their adoption as part of engineering teaching practice is not widespread. Notwithstanding the small sample size of the survey results discussed in this paper, the integration of SDGs in the engineering curriculum reveals a leaky pipeline. Firstly, when it comes to educator-identified relevance of SDGs to engineering disciplines, the SDGs with a stronger techno-environmental focus receive significantly much more traction compared to the SDGs with a socio-economic focus. This might suggest a potentially myopic perspective on the impact of engineering on the global society. Secondly, the average coverage of relevant SDGs within the taught curriculum is again a relatively small fraction. Hence, there are two considerable losses along the SDGs adoption pipeline – at the stage of educator-identified relevance and subsequently when explicitly referring to SDGs in their teaching material.

A packed curriculum and accreditation requirements are cited as the main barriers against integrating sustainability in engineering curriculum. By undertaking a Bloom's taxonomy analysis of sustainability-related learning outcomes curated from multiple global engineering accreditation bodies, the clear emphasis of a multifaceted and holistic definition of sustainability, encompassing social, environmental and economic considerations among others, in engineering design and problem-solving is surfaced. Although accreditation bodies can do better in taking a more unified and stronger approach in mandating sustainability, the existing requirements should still prompt engineering educators to adopt sustainability as a central pillar to curriculum design and delivery.

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