Engineering Education and its Current (Un)suitability in Addressing Sustainable Development Goals

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Abstract

This paper assesses the current approaches to engineering education, focusing on the integration of Education for Sustainable Development (ESD) to address Sustainable Development Goals (SDGs). Utilising a case study methodology within engineering higher education institutions (HEIs) in South India, the research involves mapping the current curriculum against SDGs, quantitative assessment of student performance in control and experimental groups, and qualitative interviews with academics. Findings indicate a notable underemphasis on the Social and Economic sustainability pillars. Interviews reveal a lack of SDG knowledge among academics, who questioned its relevance to engineering. Despite this scepticism, quantitative results demonstrate increased student comprehension in the experimental group. The study emphasises the need for the evolution of current engineering higher education (HE) approaches, providing insights for policymakers and institutions to revise curricula and teaching practices, empowering students and academics to address contemporary and future sustainability challenges.

Engineering education has traditionally been associated with technical skills, problem-solving abilities, and innovation. However, acknowledging the challenges of the 21st century, there is a growing recognition of the need to redefine the goals of engineering education to address broader societal challenges, including climate change and its impacts, depleting resources, increasing conflicts, gender inequity and sustainable development (SD) at large (Bakthavatchaalam et al., 2019, 2020; Shulla et al., 2020; UNESCO, 2019; UNESCO-ICEE, 2021).

The importance of engineering education and its curriculum in creating learners with 21st-century skills and a sustainable future is paramount (Lamere et al., 2021). Such a curriculum would empower students to responsibly design and manufacture products and processes that are more energy and resource efficient. More importantly, it would make them agents of change who can evaluate the long-term impacts of their professional practice (Kolmos, 2021; Leicht et al., 2018).

However, HEIs in developing countries, especially the private institutions, which form the mass of newly founded institutions, are reported to be mostly concerned with the students' scores and employability. Looking at Indian HEIs, even though there is a huge increase in their number (AISHE, 2019; UGC, 2018), a focus on research, SD, social responsibility, social justice, inclusivity etc., is reportedly lacking (Bakthavatchaalam, 2018; Varghese et al., 2023). Despite the necessity of the education paths to prepare students for real-world challenges, sustainability is frequently overlooked, especially in engineering, where applications are expected to be the focus, thus requiring a change in the approach to curriculum development and pedagogical practices.

Designing a curriculum with SD would require institutional and academic commitment and understanding of the importance of ESD by various stakeholders (Longhurst & Gough, 2021). There are several issues associated with changing engineering curriculum, including staff and management inertia, lack of facilities and incentives, staff knowledge of SD, policy and institutional support, emphasis on the traditional curriculum, industry expectations, assessment challenges and socio-cultural factors (Filho et al., 2018; Leifler & Dahlin, 2020).

Current methods of ESD implementation include project works, sustainability challenges, classroom discussions, stand-alone sustainability modules, or induction programs (Daub et al., 2020; Fogg-Rogers et al., 2021; Leifler & Dahlin, 2020; Molderez & Fonseca, 2018; Wamsler, 2020). Quite a few studies have examined ways to get students and teachers interested in adding sustainability skills to curricula (Cebrian et al., 2015; Mulder et al., 2015). They investigate factors motivating students to think about long-term perspectives and sustainability issues and how teachers can make students aware of SD. Project-Based Learning is also increasingly used as a method for integrating ESD in engineering.

Evaluating the effectiveness of ESD integration in engineering education is crucial. This research explores if the current engineering curriculum and pedagogical methods, aimed at integrating ESD, are suited to creating responsible agents of change among students and academics. The study focuses on assessing a specific micro-curriculum designed for ESD integration. Additionally, it explores academics' perspectives on ESD and presents the findings of an SDG mapping within the existing curriculum. By addressing these aspects, the research aims to provide insights into the overall suitability and impact of ESD integration in the engineering education landscape.

Methodology

The research gathered data from three sources: curriculum analysis, academic insights, and student assessments. Initially, the curriculum and its delivery were mapped with the SDGs based on the academics' input. Qualitative data from semi-structured interviews with academics underwent content analysis for evaluation. Quantitative data aimed to evaluate the impact of ESD pedagogy on students' interest and performance, comparing it with the traditional pedagogical approach. The author developed ESD lectures, bridging engineering topics (Flow Equations in Fluid Mechanics, Gas Laws in Thermodynamics, and Efficiency Equations) with SDGs, demonstrating practical applications.

The target population comprised third-year engineering students (n=120), who were divided randomly into control and experimental groups (n=60 each). Both groups attended a series of three lectures, with the control group attending their regular lectures and the experimental group attending the modified ESD lecture. Two types of quantitative data were collected: a controlled class test measuring the students' understanding of the topics and a questionnaire assessing their awareness, responsibility, and potential sustainability contributions. The analysis utilised T-tests, factor analysis, and means.

Results and Discussion

The audit of curriculum mapping (Table 1) within Mechanical and related engineering programs revealed a notable lack of emphasis on the Social and Economic dimensions of sustainability. Particularly, SDG16, SDG17, SDG1 and SDG5 were significantly neglected. SDG16, focusing on concepts like 'Peacebuilding', was particularly absent, as it was perceived as too subjective and distant from the core objectives of Engineering Education, which traditionally emphasised objectivity through Mathematics. While concepts like 'Engineering Ethics' were discussed, they often relied on historical case studies, leaving little room for addressing broader SDG objectives. UNESCO (2024) comments on the need for HE as a tool to develop peacebuilding skills and employ emerging technologies such as AI ethically and responsibly. They further provide curriculum-related changes for such an integration.

On the other hand, SDG9, SDG12, SDG13, and SDG7 were more readily integrated into the curriculum, as they aligned closely with engineering principles. For most of the academics, environmental sustainability was synonymous with SD, whereas the social and the economic sustainability were not addressed.

Table 1. Mapping of the SDGs in the Curriculum

Sustainable Development Goals (SDG)		Frequency of addressing in modules
1	No Poverty	1
2	Zero Hunger	1
3	Good Health and Well-being	2
4	Quality Education	7
5	Gender Equality	5
6	Clean Water and Sanitation	2
7	Affordable and Clean Energy	7
8	Decent Work and Economic Growth	2
9	Industry, Innovation, and Infrastructure	13
10	Reduced Inequality	3
11	Sustainable Cities and Communities	6
12	Responsible Consumption and Production	9
13	Climate Action	8
14	Life Below Water	1
15	Life on Land	3
16	Peace, Justice, and Strong Institutions	0
17	Partnerships for the Goals	0

Data source: Author.

Looking at the qualitative data, it was evident that while the academics were familiar with SD and the 17 colourful goals, their understanding of SDGs lacked depth. They were unaware of the interconnections and sub-divisions within SDGs, and the practical links to their disciplines. Despite being experts in their respective subject areas, the academics lacked knowledge of SDGs and how to integrate them with the engineering and technology subjects they taught.

The interviews showed that academics were sceptical about the value of ESD in the engineering curriculum and commented that it was 'extra-curricular' and might not directly influence students' employability – for which their grades were considered more important.

"The management does not question if SDGs are taught, they focus only on the students' pass percentage and grades. These would influence the institutional ranking".

- (Experienced academic/ Head of the Department)

Furthermore, academics expressed a lack of understanding in linking SDGs with subject matter, leading to feelings of alienation and reluctance to incorporate them into the curriculum. The interviews revealed a lack of clarity on what they meant by ESD and its importance in engineering. Academics were sceptical about whether embedding ESD in the programme would create any changes for the students. The results showed significant epistemic dissonance of the academics regarding SD. There was a view that if a concept lacks quantifiability and objectivity, it falls outside engineering, as it contradicts the traditional emphasis on equations and mathematical rigour. It culminated with an academic commenting:

"These [SDGs] *are not engineering. Where are the equations, simulations, drawings?"*

- (Experienced academic)

These findings align with Wint (2022), who comments that the existing engineering culture and curriculum discourage alternative thinking, leaving students feeling powerless to instigate meaningful changes. This scepticism and resistance within academia underscore the challenges of integrating sustainability perspectives into the engineering education paradigm.

There were also comments showing that some of the academics accepted SDGs reluctantly, as the funding bodies request them. Yet, how much of this is translated into their pedagogical practice needs investigation.

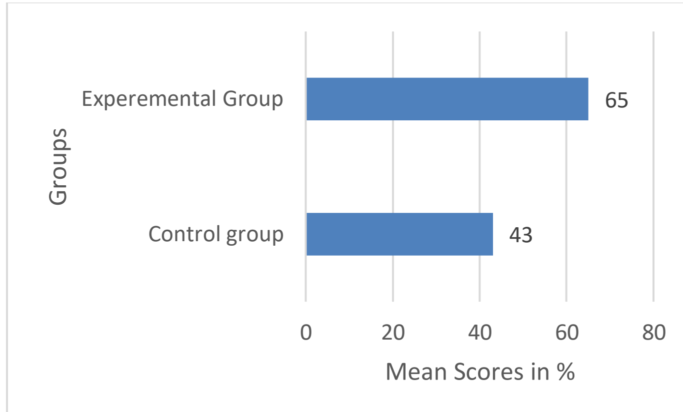
Encouragingly, two of the new academics underscored the importance of ESD and highlighted its importance in creating responsible engineering practitioners. There were also comments on the need to empirically evaluate the effectiveness of ESD on the students' grades and their perceptions of engineering.

"Integrating SDG into the curriculum is very important, this is the 'why' we do engineering."

- (Early-career academic)

The quantitative data collected from the experimental and control groups were used to assess the effectiveness of ESD integration into the curriculum. The experimental group that had ESD-integrated pedagogy scored 22% higher in the controlled class test (Figure 1). This showed ESD having a positive influence on grade attainment, which the institutions comment as being essential for employability. This test was designed by academics and involved mathematical calculations and reasoning. This was done to address the academics and the management's concerns on how effective ESD is in increasing students' grades.

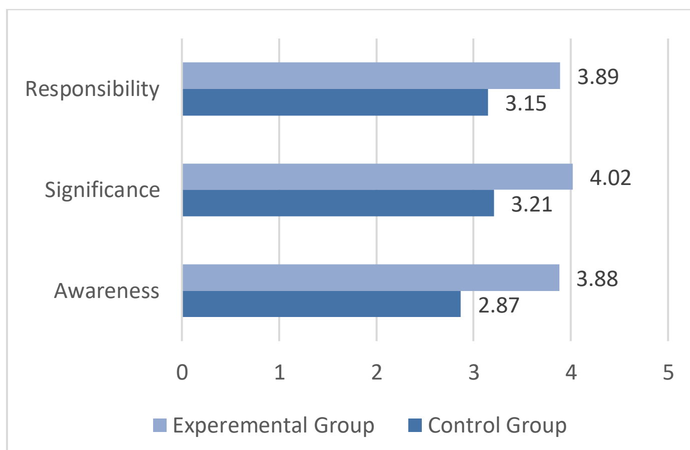
Figure 1. Mean Test Scores (%) of Students



Data source: Author.

The questionnaire results showed a contrast between the two groups (Figure 2), with the experimental group showing an increased awareness, responsibility and wanting to make significant efforts towards sustainability, compared to the control group.

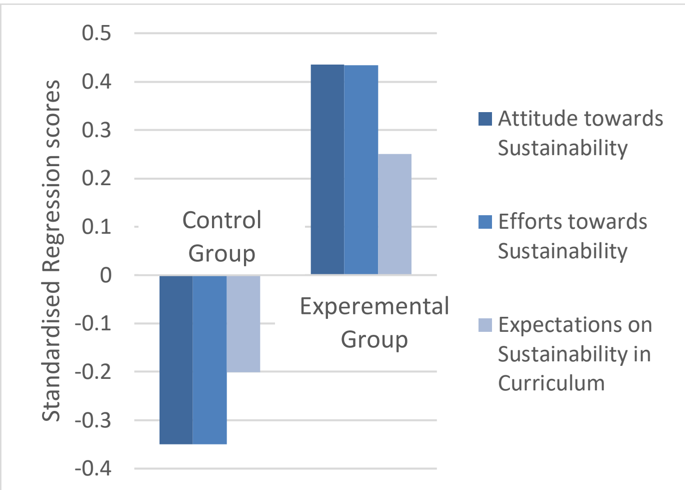
Figure 2. Between group averages



Data source: Author.

Factor Analysis revealed three dimensions: Students' attitude towards sustainability, their potential efforts towards sustainability and the expectations from their lecturers and curriculum. The mean plot of the standardised regression scores (Figure 3) revealed the advantages and effectiveness of integrating ESD integration. The findings indicate a tangible improvement in students' attitudes and efforts towards sustainability within the experimental group, underscoring the positive impact of ESD in engineering education. Additionally, it showed that ESD increased expectations among students for further discussions on sustainability topics within the academic context. This observation underscores the growing relevance and interest among students in engaging in sustainability themes in their educational journey.

Figure 3. Plot of the mean standardised regression scores of the groups



Data source: Author.

Policy recommendations

The findings advocate for ESD integration in engineering education. Addressing the ESD implementation involves considerations at various levels, including policy, institutional, academic and pedagogical levels.

At the policy and institutional levels, a comprehensive approach is essential, driven by the growing demand for ESD from both students and employers. This approach requires measures by accreditation bodies to formulate explicit policies guiding curriculum development to address SD in engineering education.

On the academic front, there is a need for a significant shift in the attitudes of academics toward ESD in teaching and research. There were instances when research on engineering pedagogy or ESD was seen as secondary to traditional 'hardcore' engineering research. The resistance to change in teaching is often attributed to a lack of ESD skills. Organising workshops and training sessions, creating a recognition and incentives programme, and collaborative research approaches can contribute to fostering a change in attitude.

While there were pockets of excellence in embedding ESD, these efforts were often isolated, with a minority of academics actively engaged, aligning with Pritchard et al. (2018). To enhance these efforts, greater coordination among academics and the formulation of explicit policies for curriculum development are essential steps.

At the pedagogical level, rather than teaching ESD in isolation or as a part of specific subjects, the paper recommends its integration across the curriculum by bridging ESD with the technical content, and by providing opportunities for the learners to actively construct these bridges. This could be done by shifting towards learner-centred, experiential, and reflective learning approaches aligning with UNESCO (2022) and Teixeira and Crawford (2022). The research underscores the need for a departure from traditional pedagogical methods to make ESD more engaging and action-driven, in line with contemporary educational paradigms.

Limitations and future work

The limited diversity and sample size in this study restrict its generalisability. Caution is needed when applying qualitative data beyond the study's scope. While HEIs can use this research as a framework, conducting individual curriculum audits is crucial for tailored policies. Future research should explore integrating 'Social Justice' and 'Peacebuilding' skills within the engineering curriculum and their relationship with SD. Longitudinal studies could be conducted to assess the lasting impact of SDG integration into engineering education. This could span diverse engineering disciplines, comparing results and evaluating the effectiveness of faculty training, multi-modal pedagogies, and interdisciplinary learning.

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