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Student Researchers Breaking Barriers: Exploring How STEM Can Drive Education for Sustainability in UK Higher Education

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Abstract

Education for Sustainable Development (ESD) equips learners with the knowledge, skills, and attitudes needed to create a fair, inclusive, and sustainable future. In engineering education, the integration of Sustainability Development Goals (SDGs) is vital for preparing students with the quantitative and critical skills necessary for sustainable decision-making. Embedding ESD in STEM curricula not only addresses existing gaps but enhances the global and societal relevance of engineering education. Our research explored the challenges and opportunities of integrating ESD into taught postgraduate STEM programmes at two east London universities. Using a student-staff co-creation approach (Cook-Sather et al., 2014), we collaborated with interdisciplinary student researchers on a literature review of best practices and a mapping exercise examining SDG coverage across engineering modules. The project also identified pedagogical strategies that help students meaningfully engage with sustainability, highlighting effective ways for educators to connect STEM teaching with real-world social and environmental challenges.

1 Introduction

Over the past 15 years, policy and accreditation frameworks have increasingly promoted ESD in higher education – for example, the Quality Assurance Agency (QAA) issued guidance identifying sustainability learning outcomes and teaching approaches for all disciplines (QAA, 2021). Likewise, engineering accreditation standards (Engineering Council, 2020) now explicitly require programmes to address sustainability and societal impact. Beyond accreditation, the UK government has acknowledged the crucial role of higher education in its sustainability agenda. The Department for Education’s 2022 *Sustainability and Climate Change Strategy* sets out a national vision for the education sector to positively respond to climate change and inspire action on an international stage. By 2025, every institution is expected to nominate a sustainability lead and develop a climate action plan (DfE, 2023) to embed and promote sustainability into institutional decision-making.

As engineering educators in higher education, we share a commitment to better engage with sustainability through embedding SDGs in our teaching practices (UCL, 2024) to equip engineering students with the essential quantitative knowledge and skills crucial for achieving sustainable development (Al-Rawahy, 2013). Integrating ESD into STEM curricula not only addresses these shortcomings but also creates opportunities to enhance the societal impact and global relevance of engineering education (Zelinka and Amadei, 2017). Consequently, the SDGs should be prominently visible and prioritised by the university’s top management, with the institution’s mission and vision clearly reflecting a commitment to the SDGs (Ramirez-Mendoza, 2020).

1.1 The role of STEM in advancing ESD

The integration of ESD into STEM disciplines is fostering significant institutional momentum towards sustainability. Higher education institutions occupy a pivotal role in driving societal transformation due to their capacity to influence future professionals through targeted educational programmes. Universities possess unique opportunities and responsibilities as they act as “engines of societal transformation” capable of guiding society “towards sustainability through their educational programmes” (Kioupi and Voulvoulis, 2020). Thus, embedding ESD within STEM curricula not only shapes graduates' competencies and outlooks, but also positions universities as critical facilitators of sustainable societal transitions.

1.2 Embedding ESD in engineering: institutional momentum and persistent challenges

A recent survey of UK engineering curricula found that about half of the dedicated postgraduate sustainable engineering programmes include between 25% and 50% sustainability-focused content (Livada et al, 2023). However, the survey also found that traditional engineering MSc courses that incorporate sustainability tend to cover it more superficially (often only 10–25% of content). As opposed to holistically embedding sustainability throughout an entire STEM programme, several studies noted how ‘bolt-on’ approaches i.e. adding a single sustainability module to an otherwise standard STEM programme, were more commonly adopted (Willats et al., 2018).

Strachan et al. (2023) highlight how structural constraints within academic programmes can hinder the integration of sustainability-focused content, emphasising that a significant barrier to embedding ESD lies in the challenge of finding adequate space within existing curricula to incorporate such options. Universities and engineering faculties tend to be organised in disciplinary silos, with rigid curriculum requirements and professional accreditation standards that leave little room for cross-cutting themes (Strachan et al, 2024). In a similar vein, Willats et al. (2018) argue that shifting away from the traditional bolt-on approach and adopting more embedded practices enables students to engage more meaningfully with sustainability issues as part of their core learning. By integrating sustainability throughout the curriculum rather than treating it as an add-on, students are more likely to develop a deeper and more practical understanding of these global issues. Furthermore, engineering experts are typically excluded from high-level policymaking processes concerning the SDGs. As a result, the formulation of these goals has been shaped more by political consensus and partisan compromise than by academic consensus and rational deliberation among relevant multidisciplinary experts (Zelinka and Amadei, 2017). This top-down vs. bottom-up disconnect can impede progress; as observed by Sivapalan et al. (2016), it is “more common to identify the challenges than to report on successful solutions” in ESD integration efforts.

1.3 Innovative pedagogical strategies for embedding ESD in Engineering education

Pedagogical strategies are the methods and approaches STEM educators use to facilitate learning, engage students, and achieve desired learning outcomes, which can vary based on the subject, student needs, and curriculum goals. They stress the importance of embedding systems thinking comprehensively within curricula, arguing that sustainability skills are complex and require integrated, repeated practice and exposure, rather than isolated treatment. Additionally, students may struggle to appreciate the relevance of sustainability if it's presented separately from core disciplinary content, reducing their motivation to deeply engage with the topic. Consequently, several studies have proposed systematically upgrading curricula by incorporating a broader range of sustainability themes (e.g. ethics, socio-economic aspects) through innovative pedagogical strategies, as highlighted below.

1.3.1 Community-based learning and teaching (CBLT)

Rather than a bolt-on approach, literature suggests that universities adopt the integration of strategies such as Community-based learning and teaching (CBLT) that combines experiential learning processes directed towards community service with structured reflection and academic instruction (Martín-Sánchez et al., 2022). The stakes and relevance of students' work being tangible through community and industry-linked projects or 'live briefs' have proven effective. Delaney and Liu's study (2023) of UK postgraduate design programmes with strong sustainability integration relied on incorporating live industry sustainability projects. Similarly, semi-structured interviews with engineering academics also reported how students involved in CBLT projects become socially aware engineers with holistic perspective of the discipline and in turn, local communities gain the much-needed skillset to inspire and lead more community-based work to generate measurable impact (Shah et al., 2023). A study of the Aston University MSc programme by Doss and Poursharif (2023) highlighted that using real-world case studies was pivotal in allowing students to transfer theory to concrete problem-solving. Through the collaboration with Engineers without Borders UK, Aston University has embedded national and international engineering design challenges as credit-bearing assessments in the curriculum, which in turn reinforce students' ethical and professional responsibilities.

1.3.2 Interdisciplinary learning

Interdisciplinary learning is another effective strategy for embedding ESD in STEM, particularly in areas where technical and social issues intersect, such as the social impacts of technology or economic trade-offs in engineering. Traditional curricula seldom venture into those intersections. However, pedagogies that intentionally cross disciplinary boundaries such as interdisciplinary learning that engage with socio-scientific issues (SSI) can illuminate the connection of sustainability issues being interdisciplinary by nature (Hogan and O'Flaherty, 2021). This approach fosters "critical scientific literacy," which empowers learners to navigate the multiple perspectives presented in media and public debates through discourse-based pedagogies to practice negotiations of SSI and explore divergent perspectives on the issues surrounding sustainability. Lasker and Lovitt (2024) further demonstrate how integrating STEM with humanities through 'systems-level analysis' tasks helps students map how science interacts with societal systems, public policy, and environmental infrastructure — encouraging and challenging students to recognise their active role in climate change as meaningful global solutions cannot emerge when STEM disciplines operate in isolation.

2 Research Study: Examining the prevalence and alignment of SDGs within postgraduate modules across the engineering curricula of the two universities

To explore how STEM subjects contribute to addressing SDGs in higher education, we focused on engineering through two sub-questions: (RQ1) the challenges and opportunities in integrating ESD in engineering, and (RQ2) the most effective pedagogical strategies for helping students connect with traditionally inaccessible areas. We reviewed the prevalence and alignment of SDGs within postgraduate engineering modules at two universities, using these institutions as case studies to identify current practices. This focus on engineering reflects its interdisciplinary nature, bridging technical, social, and ethical dimensions essential for tackling complex global challenges.

2.1 Methodology

This study employed a mixed-methods approach to analyse the integration of SDGs and our methodological framework was structured into two key phases: SDG Mapping and Qualitative Analysis of Module Content. The SDG Mapping phase provided quantitative insights into how sustainability themes are currently embedded, while the qualitative analysis of module content helped uncover the pedagogical strategies used to engage students. A systematic keyword analysis of 108 module descriptions was conducted to assess the extent to which SDGs were embedded at the module level. Rather than comparing the two universities, we used them as case studies to explore trends and variations in SDG integration.

Keyword Search for SDGs: All engineering modules from both university campuses were identified. Module descriptions were analysed for alignment with SDGs using keywords like "sustainability," "climate," "resilience," and "equity." Relevant modules were tagged by associated SDG(s). Findings were recorded in a spreadsheet, categorised by university, faculty, and department, with multi-SDG modules noted and the extent of SDG integration explored. A qualitative content analysis of module descriptions was conducted to examine pedagogical approaches supporting student engagement with SDG themes. Using a two-stage process, we first mapped SDG integration across modules, then selected a sub-set for deeper analysis. This addressed RQ1 by highlighting challenges and inconsistencies in SDG coverage, and RQ2 by exploring teaching methods that help students connect with SDG themes, especially in less accessible areas of STEM.

3 Results

3.1 SDG Mapping

Figure 1: From an analysis of 108 engineering modules, the majority of modules covered a limited integration of SDGs, primarily one or two SDGs covering 68 modules combined (63% of the dataset), suggesting a narrow but focused approach to embedding sustainability themes. Modules extensively integrating 4 or 5 SDGs were notably scarce with less than 10 modules integrating four SDGs and 1 or 2 modules comprehensively address five SDGs. Given the 17 SDGs, even the most comprehensive modules only engaged with up to 29% of the available SDGs, a clear indication of limited interdisciplinary engagement with sustainability challenges. Furthermore, the presence of 8 modules with zero explicit SDG coverage highlights a clear gap in the curricula, suggesting missed opportunities to embed vital sustainability consideration. Figure 2: Across two institutions, the distribution of SDG integration within engineering modules revealed that the three most commonly incorporated SDGs — SDG 9, SDG 3 and SDG 4 — collectively account for 56.4% of all SDG mentions. SDG 9 alone represents 32.9%, highlighting a strong emphasis on industry engagement and innovation within curricula. SDG 3 (12.2%) and SDG 4 also feature prominently, reflecting a commitment to student well-being and educational quality.

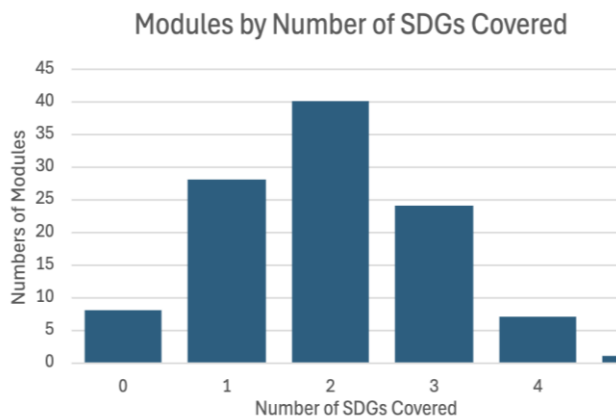


Figure 1: Modules by Number of SDGs covered across the two institutions.

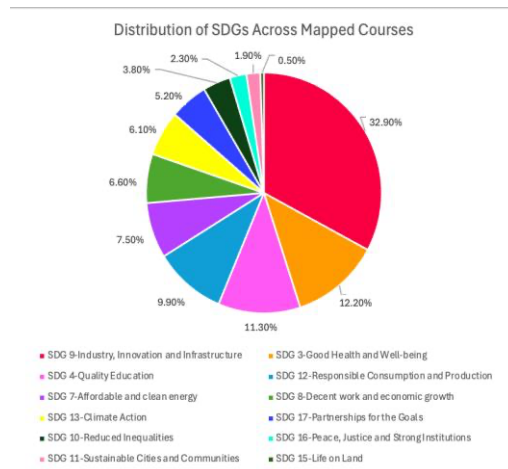


Figure 2: Distribution of SDGs across the mapped courses.

3.2 Qualitative Analysis of Pedagogical Approaches

We now discuss a smaller sub-set of modules to present findings linked to pedagogical approaches. When analysing modules from this perspective we looked deeper at where multiple SDGs were coded—particularly those where goals such as *Partnerships for the Goals* and *Reduced Inequalities* co-occurred with thematic areas like climate action or health. In the first institution, modules such as *Future Global Technologies for Disability and Development* and *Innovation for a Fairer World* exemplify pedagogical innovation through the integration of multiple SDGs—particularly SDG 10 (Reduced Inequalities), SDG 3, SDG 9 and SDG 17. These modules are characterised by active learning strategies, where students engage in real-world challenges through design tasks, technology audits, and critical analysis of global development frameworks. Interdisciplinary learning is a core design feature, with students drawing on insights from engineering, global health, disability studies, and social justice to understand how inclusive innovation can address complex, multi-layered issues. CBLT is embedded through partnerships with NGOs and social enterprises, giving students hands-on experience with community-centred approaches to design and development. These experiences are further enriched by a systems thinking pedagogy, encouraging students to explore how technological, economic, and sociopolitical systems intersect and impact marginalised populations globally. Through this integrated pedagogical model, students are empowered to co-produce socially responsible and context-sensitive solutions to sustainability and equity challenges.

In the second institution, several pedagogical strategies promoted SDG integration across health, climate, innovation, and equality. For example, the *Medical Ethics and Regulatory Affairs* module integrates systems thinking by teaching students to navigate complex legal and ethical frameworks governing bioengineering, encouraging them to evaluate innovation within broader societal contexts. Similarly, *Macromolecular Engineering* employs interdisciplinary learning design, linking engineering, materials science, and biotechnology to develop sustainable biomedical solutions, such as hydrogels and biofunctionalised materials. Modules like *Environment, Ethics and Economics in Engineering Design* embrace active learning and community-based approaches through real-world problem-solving that includes ethical cost-benefit analysis and stakeholder-informed decision-making, thereby fostering reflection on how engineering design intersects with environmental justice and equity (SDG 10, SDG 13, SDG 16). Finally, *Electrochemical Energy Storage Systems* highlights project-based learning and systems

thinking by requiring students to understand the lifecycle and economic impacts of energy systems like hydrogen fuel cells and batteries, nurturing holistic thinking essential for addressing climate action (SDG 7, SDG 9, SDG 13).

4 Discussion

The analysis of 108 engineering modules across two institutions, addressing RQ1, our study reveals both challenges and opportunities in integrating ESD within STEM disciplines — specifically within engineering. While this study focuses solely on the ‘E’ in STEM, it is notable that many of the modules examined were interdisciplinary in nature, incorporating links to health, education, and industry sectors. A key opportunity lies in the existing emphasis on SDG 9 which alone accounted for 32.9% of all SDG integration. This reflects a proactive alignment of engineering curricula with industry needs and infrastructural challenges, positioning students to engage with innovation and real-world problem-solving. Additionally, the presence of SDG 3 and SDG 4 in the top three most covered goals demonstrates a valuable, if somewhat unexpected, interdisciplinary commitment to well-being and education — suggesting an openness within engineering education to address broader societal outcomes alongside technical expertise. However, the data also reveals significant challenges. The majority of modules integrated only one or two SDGs, with just a handful addressing four or five — a narrow focus given the interconnected nature of sustainability challenges. Critically, SDGs directly related to environmental sustainability, such as SDG 13, SDG 7 and SDG 11 were underrepresented. This is particularly concerning given the core role engineers play in shaping built and environmental systems. Moreover, the presence 8 modules with no explicit SDG coverage indicates missed opportunities to embed vital sustainability considerations.

Overall, while interdisciplinary connections are emerging, engineering curricula appear to prioritise industry-facing goals over broader environmental and social sustainability challenges. The findings highlight an important opportunity to widen the scope of ESD integration within engineering, ensuring a more balanced, systemic, and future-facing approach to educating socially responsible engineers. For RQ2, the most effective pedagogical strategies were concentrated around four core, interdisciplinary and socially engaged approaches. Active learning methods, including problem- and project-based learning, enabled students to apply knowledge to real-world challenges. Interdisciplinary learning design encouraged connections across fields—linking engineering with social sciences to address complex sustainability problems. CBLT facilitated collaboration with external stakeholders, enhancing both academic and social learning. Finally, systems thinking approaches helped students understand the interconnected nature of environmental, social, and economic systems. Together, these strategies deepened personal connections to often inaccessible STEM topics and underscored the value of integrating intersecting SDGs to make engineering education more socially and environmentally responsive.

5 Conclusion

This study highlights both progress and ongoing challenges in embedding ESD within engineering education at UK universities. Focusing on postgraduate modules across two institutions, we found momentum in aligning curricula with SDGs, particularly in innovation, infrastructure, and well-being. However, integration remains selective, favouring industry-related goals over broader environmental and social priorities. Limited interdisciplinary engagement and uneven SDG coverage suggest missed

opportunities for preparing graduates to address complex sustainability challenges. Encouragingly, the use of active learning, interdisciplinary design, community-based projects, and systems thinking offers promising models. To fully realise the potential of engineering education in driving sustainable futures, universities must embed sustainability as a core theme, supported by curriculum reform, institutional leadership, industry partnerships, and inclusive student-staff co-creation.

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