REFLECTIONS ON AN EDUCATION FOR SUSTAINABLE DEVELOPMENT MAPPING EXERCISE

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ABSTRACT
In recent years, there has been an increased call for Higher Education Institutions (HEIs) to integrate Education for Sustainable Development (ESD) into their curricula. This paper is comprised of a literature review alongside an empirical study at the University of Strathclyde, assessing how undergraduate and postgraduate programmes within the Department of Design, Manufacturing and Engineering Management (DMEM) align with relevant UNESCO's core competencies, Sustainable Development Goals (SDGs), and Teaching and Learning Methods. To ensure that engineering students are well-prepared to meet the demands of the modern industry, there is a need for engineering design education to keep pace to industry demands with the increase in sustainable legislation requirements. The collaborative mapping exercise within the University of Strathclyde provides other HEIs insight into the implementation and execution of an ESD toolkit and will allow them to more effectively embed sustainable practice within design and engineering education.

Keywords: Education for Sustainable Development (ESD), Sustainable Development Goal (SDG), engineering education

1 INTRODUCTION
Universities play a vital role in addressing the challenges of sustainability, with the integration of SDGs in HEIs being crucial. This is demonstrated in the 2017 UNESCO report "*Education for Sustainable Development Goals: learning objectives*". However, it has been argued that this report may be biased towards specific fields of education, such as humanities courses, in which value-based themes like cultural understandings, philosophy, and ethics are addressed (Sánchez-Carracedo et al., 2021). This natural alignment allows for smoother integration of ESD within the humanities curricula and the active pedagogies, such as seminars, aid this further. In contrast, engineering content is often focused on technical knowledge with emphasis on the understanding of mathematics and science. This is traditionally taught using passive, lecture-based teaching methods, making the integration of ESD more challenging due to the rigid structure that leaves little room for active learning methods. Given the education sector's responsibility to promote sustainable practices (Caeiro et al., 2020), it is important that ESD is embedded equally across all disciplines. A case study at University of Strathclyde demonstrates how mapping exercises can provide both qualitative and quantitative data highlighting challenges and opportunities for more effective integration of ESD within design and engineering education.

2 LITERATURE REVIEW
HEIs are key social institutions that can aid sustainable development and help to achieve the SDGs (Prieto-Jiménez et al., 2021) through embedding the social, economic and environmental pillars of sustainability throughout their curricula (Zelinka & Amadei, 2017). Engineering education often fails to address the social dimensions of sustainability such as self-awareness, culture and ethics and this has been linked to engineering students displaying more resistance in value-based subjects (Gutierrez-Bucheli et al., 2022). To address this resistance, it has been argued that there is need for a paradigm shift within engineering curricula, including reflection on different pedagogical approaches and the need for students to understand their own values and motivational drivers (Giangrande et al., 2019). Through the implementation of ESD and the active learning journey that it encompasses, HEIs can begin to embrace this shift.

2.1 Pedagogical Approaches

A combination of holistic and pluralistic teaching methods is recommended when integrating ESD into curricula (Pauw *et al.*, 2015). Holism ensures sustainability is taught in an interconnected way, while pluralism allows diverse perspectives to be explored. In addition, action-oriented ESD further enhances student learning through "real-world" collaborations, making sustainability education more dynamic, engaging and impactful. Project-based learning (PBL) is one method of action-oriented ESD that allows students to develop essential skills such as leadership, teamwork, interdisciplinary thinking, and community engagement (Sinakou et al., 2019). PBL is particularly prevalent in design courses, where students can work on design briefs given by external organisations in which they must apply their technical knowledge in industry.

2.2 Tangible Impact of ESD

Through learning collaboratively, sharing insights, and building on each other's experiences, educators benefit from the integration of ESD through the development of their teaching practices (Strachan et al., 2021). This encourages academics to deepen their understanding of sustainability (Cebrián, 2017). Transformative methods such as PBL, are the core pedagogical methods that will enable action to be made through ESD. This is due to the emphasis on a human-centred perspective, taking feelings, conflicts, and even spirituality into account (Alam, 2022). It has also been seen that sustainability projects within HEIs have a positive impact on education and operations within the institution as well as academic performance (Cebrián, 2017). Due to the differences in pedagogical methods when integrating ESD into a curriculum, it is no surprise that grade attainment may be affected. For example, an experimental study in Southern India gathered quantitative data from two groups of students. A control group was taught using traditional methods whilst another experimental group was taught using the pedagogical methods that ESD calls for. Both groups were given the same assessment in which mathematical calculations and justifications were examined. The results demonstrated that students in the ESD-integrated group performed on average 22% better than the control group. This highlights a measurable improvement in academic performance which can be directly linked to the inclusion of ESD (Bakthavatchaalam, 2024). In addition to the paradigm shift occurring within engineering education, there is also a wider societal shift which can be seen in the employment sector. Employers increasingly expect candidates to possess sustainable development skills when applying for graduate positions (Grierson & Munro, 2018). ESD has been seen to increase students' employability (Huang et al., 2020). This shift may be attributed to the higher competencies demonstrated by students who have engaged with ESD such as systems-thinking, strategic management, interpersonal skills, interdisciplinary collaboration, and action-oriented problem-solving (Gutierrez-Bucheli et al., 2022). There is a growing recognition from employers that skills gained from ESD are appealing for future candidates (Grierson & Munro, 2018) and further highlights the importance of integrating it into HEIs.

2.3 Barriers to Effective Implementation

One potential barrier in the implementation of action-oriented ESD is external factors such as stakeholder values or organisational practices (Gutierrez-Bucheli *et al.*, 2022). An example of this could be protocol measures such as ethics checks in HEIs when collaborating with external organisations as part of a PBL activity. It has also been argued that holism and pluralism encourage students to have an 'anthropocentric' perspective on sustainability issues due to the stronger focus on the economic and social pillars of sustainability and not the environmental pillar. However, there is a lack of empirical data to support this argument (Pauw *et al.*, 2015) and furthermore, the use of both holism and pluralism in ESD, challenges Gutierrez- Bucheli's concerns regarding the resistance for value-based in engineering students.

2.4 The need for Structured Implementation Strategies

To address these challenges, structured toolkits can provide clear guidance for ESD implementation. A well-designed toolkit can offer educators a systematic approach to embedding sustainability education within curricula, ensuring consistency and effectiveness. By mapping the status of ESD within a curriculum as well as mapping the methods used for teaching and learning, institutions can identify gaps and implement improvements. Ultimately, the use of a structured toolkits can support HEIs in delivering transformative, action-oriented ESD whilst also providing both students and educators with the necessary skills and knowledge to drive sustainable change (Prieto-Jiménez et al., 2021).

3 MAPPING EXERCISE

3.1 Methodology

The University of Strathclyde is working to further embed Education for Sustainable Development (ESD) into its curricula, supported by a module mapping toolkit developed by the University's Centre for Sustainable Development. The Department of Design, Manufacturing and Engineering Management (DMEM) was among the first to trial this initiative, with 29 staff members evaluating 88 modules. The process involved distributing the toolkit with guidance, gathering qualitative feedback through one-to-one meetings, collecting and analysing quantitative data to assess alignment with UNESCO's core competencies, SDGs, and teaching methods, reflecting on the toolkit's effectiveness, and presenting findings in a staff roundtable to discuss future improvements to ESD implementation.

3.2 Implementation of Mapping Toolkit

The 88 modules that were mapped encompassed both undergraduate and postgraduate courses, covering a wide range of academic levels. Each module reflected the specific learning objectives, content scope, and assessment methods designed to meet the intended educational outcomes for its respective level. A simplified version of the toolkit is demonstrated in Figure 1. The first section of the toolkit gathered general data for each of the modules such as the module name, module leader, channels of teaching and academic level. This demonstrated whether there was any connection to how well ESD was being implemented and the fundamental teaching details. The next section outlined the UNESCO core competencies: Social and Commercial Awareness, Effective Communication, Resilience and Resourcefulness, Purpose and Values Driven, Creative and Integrated Problem Solving, Collaboration, Strategic Thinking, Systems Thinking, Future Thinking, Critical Thinking and Self-Awareness. Then it outlined the 17 SDGs and finally teaching and learning methods: Case Studies, Stimulus Activities, Experiential Projects, Simulation Activities, Problem-Based Learning, Participatory Learning, Debate or Discussion, Field-Based Activities, Community Engagement, Small Group Tutorial, Lab Practical, Flipped Classroom and Vertically-Integrated Projects.

The module leaders then assessed the relevance of each item to their module by selecting one of the following options from a drop-down menu:

1. Not used
2. Somewhat used
3. Extensively used

	UNESCO Core Comptencies			Sustainable Development Goals			Teaching & Learning Methods		
Module Name	Social & Commercial Awareness	Collaboration	Self-awareness	SDG 1: No poverty	SDG 2: Zero hunger	SDG 3: Good health and wellbeing	Case studies	Work-based learning	Problem-Based-Learning (PBL)
Design 1	1 - Somewhat used	0 - Not used		0 - Not used	0 - Not used	0 - Not used	1 - Somewhat used	0 - Not used	2 - Extensively used
Integrating Studies 1	1 - Somewhat used	2 - Extensive		0 - Not used	0 - Not used	1 - Somewhat used	0 - Not used	2 - Extensively used	2 - Extensively used
Technology Concepts	0 - Not used	0 - Not used		0 - Not used	0 - Not used	0 - Not used	0 - Not used	2 - Extensively used	0 - Not used
Design 2	1 - Somewhat used	2 - Extensive		1 - Somewhat used	1 - Somewhat used	1 - Somewhat used	1 - Somewhat used	0 - Not used	2 - Extensively used
Design Prototyping	1 - Somewhat used	0 - Not used		0 - Not used	0 - Not used	1 - Somewhat used	1 - Somewhat used	2 - Extensively used	1 - Somewhat used
Integrating Studies 2	1 - Somewhat used	2 - Extensively used	0 - Not used	1 - Somewhat used	0 - Not used	0 - Not used	1 - Somewhat used	2 - Extensively used	1 - Somewhat used
Design Emotion and Experience	2 - Extensively used	0 - Not used	2 - Extensively used	0 - Not used	0 - Not used	0 - Not used	1 - Somewhat used	2 - Extensively used	1 - Somewhat used

Collaboration vs Collaborative
Shared by ESD and Entrepreneurship skillsets - To learn from, understand and respect the needs, perspectives and actions others, including peers and external stakeholders; deal with group conflicts; encourage inclusion, participation and team cohesion.

Figure 1. Snapshot of ESD Mapping Toolkit

The data was collected using the Excel spreadsheet provided by the University's Centre for Sustainable Development, and automated charts were generated from this dataset. Each rating reflected specific criteria set out in the toolkit, offering a standardised approach to evaluating Education for Sustainable Development (ESD) integration. The toolkit provided a high-level, instant visual heatmap designed to demonstrate how the department currently integrates ESD across its curricula. Initially, the heatmap appeared predominantly red, suggesting a widespread lack of ESD integration throughout the department. However, upon further analysis, it became clear that this visual representation was largely misleading, due to a misalignment between the language and categories used in the toolkit and the actual nature of the modules taught within DMEM. This discrepancy highlighted the importance of contextual interpretation when using standardised tools for curriculum mapping.

4 REFLECTIONS OF TOOLKIT MAPPING

As this was the departments first practical engagement with the toolkit, we were unsure how suitable it would be for the specific needs of a DMEM programme. The facilitation team have reflected on the implementation experience and have a series of practical insights.

4.1 Balancing Coverage, Precision, and Interpretation

Within DMEM there are several modules that deliver through PBL, and this is a critical way in which design and engineering students engage with sustainability issues in a meaningful and applied manner. However, due to their diverse and often bespoke nature, such projects are not easily quantifiable within a toolkit that aims to give a high-level overview of a module. Understandably, the module leaders were unable to recite every student project and to which SDG it may or may not relate to. This resulted in some modules misrepresenting the extent of the integration of SDG engagement. Another limitation was identified within the staff roundtable discussions, in which academics felt as though the toolkit didn't accurately represent the depth of learning and engagement of SDG's and competencies within modules. This presents difficulty in understanding how knowledge builds over the course of the students' academic learning journey. From the automated results of the tool kit, it is difficult to assess whether students are developing a meaningful understanding or just surface-level exposure. As shown in Figure 2, the terminology used throughout the toolkit, such as 'somewhat used', was subjective, leading to inconsistencies in interpretation.

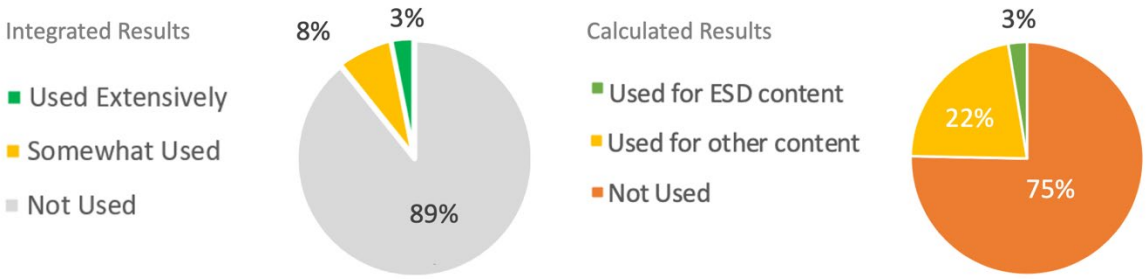

Figure 2. SDG Generated Results

The data suggested that the DMEM department only addressed 11% of the SDGs throughout their modules, however when the analysing this using more applicable terminology for DMEM courses, 25% the SDGs were shown to be addressed. This highlights the need for broader terminology within ESD toolkits as it can generate misleading results. When calculating our own data from the toolkit, we broadened the terminology to "other content" to capture project based learning and other applications of ESD within design and engineering. We found that there was a need for categorisation to formally account for SDG engagement within project work. Revised terminology would ensure that sustainability-focused student research and project-based modules are properly recorded and recognised, offering a more comprehensive evaluation of ESD integration. In parallel the facilitation team aim to conduct further studies to understand how the depth of learning and engagement can be suitably captured.

4.2 Perceptions of SDG Integration in Teaching

An aspect requiring deeper analysis is the potential discrepancy between student and academic understanding of SDG integration and sustainability competencies. While module leaders and tutors may assume that sustainability principles are well-integrated within their teaching, students may not always recognise these connections. A comparative analysis of perceptions between these two groups could reveal significant differences in how sustainability education is understood, valued, and applied. Identifying these gaps could inform strategies to improve communication, curriculum design, and pedagogical approaches to ensure that ESD is both effectively delivered and clearly understood by students. This has been recognised by the facilitation team and will form part of the ongoing research.
The level of understanding among academic staff regarding core competencies and the SDGs may have influenced the accuracy of reported sustainability integration within programmes. If faculty members have varying levels of familiarity with these concepts, there is a risk of misreporting or misinterpreting the extent to which sustainability is embedded in their teaching. The process of engaging with the toolkit

provided staff with an opportunity to critically reflect on their modules and consider ways to enhance their alignment with sustainability principles, different learning methods or the UNESCO core competencies. The reflection identified gaps in ESD integration and opened the exploration of new pedagogical approaches they could take that could better equip students with the skills and knowledge needed to address sustainability challenges. This highlights the need for targeted professional development initiatives to enhance staff awareness and understanding of sustainability competencies. Providing training, standardised criteria, and resources on SDG integration could improve both the accuracy of reporting and the overall effectiveness of sustainability education. By ensuring that educators have a strong grasp of ESD principles, institutions can better align their teaching with global sustainability goals and enhance student learning outcomes.

5 CONCLUSIONS

This paper sets out to explore and articulate the learnings from the mapping of ESD within a design, manufacturing and engineering management programme. Beyond its immediate findings, this study demonstrates the value of curriculum mapping as a reflective exercise, providing meaningful insights for both tutors and programme managers. By continuously refining teaching methodologies and assessment practices, institutions can bridge the gap between theoretical knowledge and practical application, better equipping students to address sustainability challenges in their future careers. While this study was limited to the implementation of mapping across only the DMEM programme of modules, it nonetheless provides insights that can be taken forward when the mapping is rolled out across the faculty. Further research could explore how students apply SDG-related knowledge and competencies throughout their academic journey. Ultimately, if higher education aims to produce graduates who are ready to thrive in the evolving landscape of modern industry and capable of driving sustainable change; then embedding, evaluating, and evolving ESD practices must remain an ongoing institutional priority.

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