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Integrating Sustainability and Entrepreneurship Education for SDG Solutions

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ABSTRACT

CONTEXT

The increasing complexity of global challenges, as outlined in the United Nations Sustainable Development Goals (UN SDGs), necessitates graduates with competencies that extend beyond traditional disciplinary boundaries. Entrepreneurship education, with its emphasis on skills like creativity, adaptability, and socioeconomic acuity, offers a valuable complement to sustainability education. In recent years, the integration of sustainability principles with entrepreneurial skills, often referred to as "sustainable entrepreneurship," has garnered attention as a means to equip graduates with the innovative problem-solving capabilities required to address the ambitious goals set out in the SDGs.

PURPOSE

This paper explores the existing literature on integrating sustainability and entrepreneurship education, particularly in engineering. It examines the approaches and challenges associated with teaching sustainable entrepreneurship and seeks to answer the research questions RQ1: *What are effective approaches for teaching and learning for sustainable entrepreneurship?* and RQ2: *How can these be embedded into engineering education?*

METHODOLOGY

A desktop literature review was conducted to gather existing research on teaching and learning for sustainable entrepreneurship in engineering education. The review identified effective approaches, pedagogical strategies, and best practices for integrating sustainability and entrepreneurship education. These findings inform the analysis of a case study subject "Entrepreneurship for Sustainability (MULT30024)".

OUTCOMES

The review highlighted a general lack of research into entrepreneurship and sustainability education. However, the research we did find identified that active learning and real-world-oriented learning approaches should be present in subjects integrating these topics. The case study identified several additional learning approaches, which reinforced and improved upon this.

CONCLUSIONS

Integrating disciplinary knowledge, industry and community interaction, and developing entrepreneurial concepts aligned with the UN SDGs is recommended as a valuable approach to teaching and learning sustainable entrepreneurship in engineering education. Future research should focus on empirical testing of the pedagogical approaches discussed, assessing their long-term impacts on student outcomes, and exploring the dynamics of interdisciplinary teamwork in educational settings.

KEYWORDS
Sustainable entrepreneurship, project-based learning, interdisciplinary collaboration.

Introduction

The United Nations' Sustainable Development Goals (UN SDGs) for 2030 demand a critical reflection on how we prepare students for their future careers. Engineers, as emphasised by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and others, will play a pivotal role in advancing these goals and achieving sustainable development (Gutierrez-Bucheli et al., 2022; Desha, 2019). However, meeting this challenge requires graduates with more than just technical capability; it calls for rethinking the meaning of 'being an engineer' and the engineering education required to produce graduates who are equipped with interdisciplinary competencies, a sense of ethical and social responsibility, and the individual qualities required to enact change (Gutierrez-Bucheli et al., 2022).

Against this backdrop, sustainable entrepreneurship (SE) has been identified as a promising avenue for addressing these educational demands. Having gained prominence in higher education over the last decade (Naderi, Monavvarifard, & Salehi, 2022), SE encourages the creation of solutions to sustainability challenges through an entrepreneurial lens (Planck et al., 2024). An SE approach can promote capabilities such as the ability to think beyond disciplinary boundaries and tackle the challenges of the SDGs with creativity, adaptability, and a keen sense of responsibility for global sustainability.

While sustainability and entrepreneurship have traditionally been incorporated into engineering education as distinct elements, a more integrated SE approach aligns well with the goal of preparing engineering students for complex, global challenges.

This paper explores the existing literature on integrating SE skills and knowledge into education, with a particular focus on engineering education. We examine the approaches and challenges associated with teaching SE and identify successful pedagogical strategies to reflect on two core research questions RQ1: *What are effective approaches for teaching and learning sustainable entrepreneurship?* RQ2: *How can these be embedded into engineering education?*

Sustainability and entrepreneurship in engineering education

In an engineering education context, teaching sustainability requires an integrated approach that recognises the socio-technical nature of the profession (Desha et al., 2019). This means incorporating the triple bottom line – considering not only technical feasibility but also the social, environmental and economic consequences of design decisions (Gutierrez-Bucheli et al., 2022). As such, imparting an appreciation for complex systems and the needs and perspectives of the diverse stakeholders impacted by our decisions becomes necessary. By possessing a strong foundation in sustainability knowledge alongside deep technical capability, engineers can create solutions that contribute to the UN SDGs in innovative, impactful and ethical ways.

The definition of engineering entrepreneurship remains a work in progress, lacking clear consensus in the literature (Huang-Saad et al., 2020). In this paper, we eschew a more traditional view of engineering entrepreneurship that focuses on fostering "entrepreneurial intent", i.e. the desire to launch a new venture (Huang-Saad et al., 2018). Instead, we advocate for equipping future engineers with the competencies and mindsets that will empower them to act entrepreneurially within various contexts (Larsen, 2022). This notion of "acting entrepreneurially" encompasses the ability to develop a deep understanding of problems from various perspectives, identify and seize opportunities, creatively navigate challenges and resourcefulness, and develop innovative solutions – skills that are valuable not only for starting ventures but also for addressing complex sustainability challenges (Hermann & Bossle, 2020).

Methodology

This investigation comprised three primary stages: (1) desktop literature review, (2) synthesis of literature, and (3) case study review. The following sections outline our process for each stage and our reasoning behind these choices.

Stage 1: Desktop Literature Review

The goal of this stage was to gather sufficient sources to develop a firm understanding of the current discourse on sustainability and entrepreneurship in engineering education. To this end, we prioritised recent sources and existing systematic literature reviews, using a few case studies to exemplify this practice.

Due to the relatively new nature of these topics and the general lack of existing literature, we decided to break the literature search down into three subtopics: (a) sustainability in engineering education, (b) entrepreneurship in engineering education, and (c) sustainable entrepreneurship in engineering education.

We began with an initial unstructured search to familiarise ourselves with the literature. Following that, we conducted a structured search of the literature using a combination of Google Scholar and EBSCOhost databases. For each of the subtopics, we used the following search terms:

a) (Sustainability OR Sustainable) AND (engineering) AND (education) AND (review)
b) (Entrepreneurship OR Entrepreneurially) AND (engineering) AND (education) AND (review)
c) (Sustainability OR Sustainable) AND (Entrepreneurship OR Entrepreneurially) AND (education OR Students OR Learning OR Teaching) AND (engineering)

For topics a) and b), we searched with both Google Scholar and EBSCOhost, limiting the search to the title only. For topic c), we only used EBSCOhost as it allowed more control over the search terms, with the "Sustainability" and "Entrepreneurship" terms restricted to the title while "Engineering" would be included if it was in the key terms field as well as other fields. We also limited results to peer-reviewed publications from 2010 onwards. The search for subtopic *a* resulted in 10 unique results, subtopic *b* had eight and subtopic *c* had four. Note that subtopic *c* is not limited to review papers only.

This method was chosen as an effective means to gain a rapid understanding of the topic's current state. It was especially suitable in our case since there is a significant gap in published works related to SE in engineering education.

Stage 2: Synthesis of Literature

During stage 2, we read and reviewed the literature until we felt we had achieved saturation of the concepts and ideas presented in these works. We then extracted key trends and innovations in the fields, as well as examples of practice.

Stage 3: Case Study Analysis

In the final stage, we took a retrospective look at our own SE in engineering subject. The purpose of this analysis is to compare our subject to what the literature identified as best practice and identify opportunities and challenges when implementing these practices in an existing subject.

Results and Discussion

Synthesis of Literature

Analysis of the literature reveals a growing interest in incorporating sustainability and entrepreneurship into engineering education, with the majority of papers being published in the last five years. However, these efforts tend to be siloed, focusing either on sustainability or entrepreneurship in engineering education. There is limited dedicated research on integrating these two areas (Alcorta de Bronstein et al., 2023). Indeed, in our search, we only identified four papers on sustainability and entrepreneurship in engineering education, three of which are case studies.

To bridge this gap, we expanded our search to include research integrating sustainability and entrepreneurship in higher education fields outside engineering. Initially, we found a systematic

review of competence frameworks for SE by Diepolder et al. (2021), in which the authors note that although a young field, SE had already yielded three separate competence frameworks in the period 2014-2019. These were authored by Lans et al. (2014), Biberhofer et al. (2019), and Foucrier and Wiek (2019). However, these frameworks focus on identifying the competencies required for SE, rather than offering strategies on how to effectively teach these competencies in higher education. This aligns with Kotla and Bosman's (2023) observation of a key gap in SE education: the lack of practical guidelines for educators, including learning frameworks, instructional strategies, and teaching instruments.

Mindt and Rieckmann ((2017) do respond to the "how" of teaching SE by examining the teaching-learning approaches for SE education. While this work presents valuable insight, it lacks a unifying framework. Similarly, Sharma et al. (2020) summarise the state of research into SE education. Both works underscore the importance of active, experiential, problem-based and real-world learning, including collaboration with external partners, with Mindt and Rieckmann also highlighting interdisciplinarity, a point not addressed by Sharma et al. While Halberstadt et al. (2019) propose a teaching framework focused on service learning, we sought to explore a broader range of approaches than this single method.

The most comprehensive framework we found was by Hermann and Bossle (2020), who propose a teaching framework that presents key concepts that should be considered when blending sustainability and entrepreneurship outcomes, including teaching and learning approaches and how they interrelate with other pedagogical and learning elements (Hermann & Bossle, 2020). Although the framework does not explicitly discuss competencies, it draws from Lans et al.'s (2014) key SE competencies. This framework provides a valuable foundation for exploring our first research question (RQ1): *What are effective approaches for teaching and learning for sustainable entrepreneurship?* We adopted it as the primary lens for analysing our own practice.

Framework for sustainable entrepreneurship education

The four-stage Hermann and Bossle (2020) framework suggests key concepts they contend should be considered in subjects that integrate sustainability and entrepreneurship outcomes. (1) Define the educational focus, (2) Define the teaching and learning approaches, (3) Identify the themes that connect entrepreneurship and sustainability, and (4) Collaborate with external stakeholders and the community.

Case Study

This section will analyse the subject "Entrepreneurship for Sustainability (MULT30024)" through the lens of the four stages in the Hermann and Bossle (2020) framework. As the name suggests, MULT30024 integrates concepts from both entrepreneurship and sustainability. This subject is available to second- and third-year undergraduate students across humanities and STEM faculties. It was first offered in 2022, once per year, for approximately 20 students per semester. The content and activities remained mostly unchanged during the first two years of delivery.

Stage 1: Define educational focus

MULT30024 is a cross-discipline full credit point elective subject. Engineering students comprise approximately 25% of the cohort, with the rest coming from various other faculties. The subject attracts a high degree of cultural and institutional diversity among students, with approximately 75% of the cohort in each delivery period consisting of exchange students, usually visiting from European, North American and Southeast Asian countries.

The subject is open to any students interested in learning about entrepreneurial approaches to addressing real challenges, not just learners with entrepreneurial intent at the outset.

Stage 2: Define the teaching and learning approaches

The Hermann and Bossle (2020) framework suggests that active and real-world-oriented learning approaches should be considered. To that end, the following section outlines how these learning strategies are incorporated into the subject, omitting others.

In MULT30024, students work in teams of 4-5 on a project that tackles a real-world challenge aligned with an SDG of their (team's) choice. A focus on open-ended, local challenges reflects a place-based approach (Larty, 2021), encouraging students to consider a specific context when developing solutions. This approach exemplifies the project-based and real-world learning approaches highlighted in the Hermann and Bossle framework (2020). By choosing their project focus, students develop a sense of ownership, motivation and responsibility, which encourages self-directed learning, a crucial aspect of project-based learning (Mentz et al., 2019; Larsen, 2022).

Teams are formed by the instructor, with a two-fold focus: (1) finding commonalities in SDG interests and (2) promoting diversity in team composition, including academic background for interdisciplinarity, nationality, gender, and sustainability/ entrepreneurial experience.

The types of problems students choose to tackle, such as environmental issues (waste reduction, stormwater management) and social issues (social isolation, youth employability), exemplify the subject's interdisciplinary nature. Students are encouraged to step outside their disciplinary silos and integrate knowledge from various fields to develop solutions ranging from technical and service-oriented to social and policy-driven approaches.

Students are introduced to methods and tools to support their problem-solving journey. The double-diamond design process exemplifies a problem-based learning approach within the framework. This process guides teams to develop deep user empathy through stakeholder interviews and data gathering – a form of experiential learning (Hermann & Bossle, 2020).

MULT30024 strives to impart holistic learning outcomes, focusing on the affective (associated with emotions and attitudes) and conative (associated with motivation, volition and behaviour) learning domains (Larsen, 2022), alongside cognitive outcomes related to entrepreneurship education. In this subject, students are supported in developing their entrepreneurial mindset through various teaching and learning tools. For example, the 'mindset markers' matrix, a self-assessment tool created specifically for this subject, breaks down the entrepreneurial mindset into key markers, allowing students to assess their own progress through the semester and reflect on their development. Another example is the use of instructor videos sharing personal examples, exposing students to relatable real-world stories and challenges, and demonstrating how these mindset markers translate into real-world entrepreneurial action.

Although developing an entrepreneurial mindset is an individual and largely autonomous pursuit, peer discussions enable students to build relationships and provide constructive feedback through a collaborative learning model (De Hei et al., 2015). The project serves as a practical application for practising and developing these skills, reinforcing the real-world learning approach.

MULT30024 also uses weekly peer mentoring sessions. These sessions promote knowledge-sharing through a jigsaw learning structure, where students actively contribute to other teams' projects by offering insights, posing thought-provoking questions, and sharing relevant resources. This format exposes students to diverse perspectives, further supporting their project development.

Notably, the peer mentoring element of the subject has been co-created with students, incorporating ideas and feedback from students across both the 2022 and 2023 deliveries. This approach supports a sense of ownership, autonomy and greater engagement in the activities (Bovill, 2019).

Stage 3: Identify the themes that connect entrepreneurship and sustainability

Problem-based learning naturally bridges entrepreneurship and sustainability by tackling an SDG challenge using an entrepreneurial approach. Sustainability is also woven into existing entrepreneurial frameworks. For example, the Business Model Canvas is adapted to include sections on "beneficiaries and impact", prompting students to consider the social and environmental impact alongside the financial aspects of their ventures.

Stage 4: Collaborate with external stakeholders and the community

As described in Stage 2, all projects require some interaction with external stakeholders through interviews. Sometimes, these interactions develop into deeper, collaborative relationships with specific invested stakeholders for the duration of the project.

Students are responsible for identifying, sourcing and arranging stakeholder interactions, fostering entrepreneurial confidence while ensuring a manageable workload for the instructor. The instructor may introduce specific experts or organisations where existing relationships help with access, but students take the lead in building relationships.

Alignment between framework and MULT30024

In general, MULT30024 closely aligns with Hermann and Bossle's framework for SE education (2020). It covers all four stages of the framework, including teaching and learning approaches (MULT30024 incorporates seven out of eight "active learning" approaches and one out of two "real-world oriented" approaches), establishing a meaningful connection between entrepreneurship and sustainability, and collaboration with external stakeholders.

Gaps in framework

While MULT30024 closely aligns with Hermann and Bossle's framework (2020), it also incorporates additional approaches and foci.

Entrepreneurial mindset

MULT30024 places a strong focus on developing an entrepreneurial mindset. This aligns with the perspectives of Larsen (2022) and Neck et al. (2021), who argue that an entrepreneurial mindset goes beyond the desire to start a venture, also contributing to an individual's ability to deal with novelty, change and uncertain conditions, which are common attributes of sustainability challenges. Interestingly, Hermann and Bossle (2020) acknowledge the need for educators to equip themselves with appropriate pedagogies to foster this mindset when tackling complex sustainability challenges, even though it is not explicitly addressed in their framework.

Diversity beyond interdisciplinarity

In addition to the framework's focus on interdisciplinarity, MULT30024 promotes the value of diversity in a broader sense. It aligns with the work of Phillips (2014) and Hewlett et al. (2013), who argue that diverse perspectives gained through different types of diversity in teams (e.g., cultural, gender, age) lead to enhanced creativity, decision-making and ultimately, more innovative outcomes – a must for addressing complex sustainability challenges.

Collaborative learning

MULT30024 exercises collaborative learning beyond team-based projects. It actively promotes collaboration outside project groups through peer mentoring for the entrepreneurial mindset and encourages support across teams. Laal and Ghodsi (2012) suggest that the benefits of collaborative learning extend beyond academic achievement, fostering better relationships, social competence, and self-esteem – all of which align with the subject's holistic and affective learning goals.

Instilling a sense of ownership

Pawson and Poskitt (2019) suggest that a sense of ownership over learning fosters deeper engagement, critical thinking skills, and interpersonal growth among students. MULT30024 facilitates this by empowering students to choose project themes and co-create aspects of the learning experience.

Integrating with engineering

Active learning encompasses a wide range of approaches, catering to different levels of complexity. Problem- and project-based learning, among the more complex approaches, are

widely adopted in engineering education, including in institutions like Aalborg University and The University of Queensland (Hernández-de-Menéndez et al., 2019). Their focus on real-world problem-solving aligns well with the demands of the engineering field, particularly when addressing sustainability challenges (Neves et al., 2021; Sukacke et al., 2022). As Neves et al. (2021) highlight, project-based learning allows students to engage with core aspects of engineering, from "creation, design, development, implementation" to "interdisciplinarity, teamwork, communication, stakeholder management". However, active learning does not have to be elaborate. More straightforward methods like think-pair-share or jigsaw learning activities can be easily integrated into existing delivery structures, promoting similar benefits such as active student participation, collaboration, and reflection (Hernández-de-Menéndez et al., 2019).

For educators interested in fostering SE, we recommend venturing beyond purely technical or academic skill development. Viewing the entrepreneurial mindset as a 'frame of mind' encompassing cognitive, affective and conative elements (Larsen, 2022), we advocate for a transformative learning approach built on reflection, peer discussion and interdisciplinary learning. This approach encourages students to question beliefs, assumptions and values (Mezirow, 1997 in Larsen, 2022). Singer-Brodowski (2023) highlights the growing prominence of transformative learning in sustainability education due to its emphasis on shifting perspectives and meaning-making. Notably, the literature (Huang-Saad et al., 2018; Arshad & Romatoski, 2023) already indicates a growing focus on the entrepreneurial mindset in engineering education, presenting an opportunity to build on existing approaches and encourage wider adoption.

The success of these recommendations hinges on the instructor's role and ability to effectively implement them. Educational institutions may need to provide training to equip faculty with the necessary competencies and support them in integrating these approaches into their existing teaching practices (Neves et al., 2021). While this aspect falls outside the scope of this paper, it remains a crucial consideration for future research.

Conclusion

This paper explored the integration of sustainability and entrepreneurship within engineering education through a desktop review and case study analysis. Our analysis reveals that while there is a growing recognition of the importance of incorporating SE into engineering curricula, significant gaps and challenges persist. The literature remains somewhat fragmented and limited in scope, particularly concerning empirical studies that provide robust evidence of the effectiveness of these educational strategies. Additionally, existing frameworks, while helpful, do not always fully capture the dynamic interplay between entrepreneurial mindset and sustainability objectives.

Future research should focus on empirical testing of the pedagogical approaches discussed, assessing their long-term impacts on student outcomes, and exploring the dynamics of interdisciplinary teamwork in educational settings. Furthermore, the broader adoption of these integrative approaches will likely necessitate enhanced institutional support, including faculty training and curriculum adjustments. Addressing these challenges will be crucial in equipping future engineers with the skills necessary to effectively innovate and lead in sustainable development.

By bridging the gap between sustainability and entrepreneurship, engineering education can play a pivotal role in addressing the complex challenges outlined in the UN SDGs. It is our hope that this paper sparks further dialogue and research in this area, ultimately contributing to the advancement of sustainable engineering education and a more sustainable future.

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