

ANALYSIS

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Engaging for the future: challenge-based learning and stakeholder partnerships in sustainability education

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Abstract

This paper aims to illustrate a mechanism and the impact of collaboration between academia and external stakeholders using a challenge-based learning (CBL) approach, with ill-defined open challenges as the starting point of the learning journey. The context of the study is a sequence of three connected courses that enabled students to address pressing sustainability challenges both in the Global South and the Global North in a variety of fields, such as health, urban living, agriculture and waste management. The courses aimed to equip students with knowledge and skills on how to tackle the challenges and design responsible innovations, as well as inspire them to make an impact in the world, while collaborating with external stakeholders. The insights gained from this study are that the courses effectively fostered critical thinking, organizational skills, and teamwork capabilities among students. The collaboration with external partners was particularly valued by the students for its relevance to their learning and potential career progression, as it allowed them to take ownership of the challenges to tackle, thereby enhancing motivation and deepening their learning experience. Furthermore, the courses were successful in enabling students to apply knowledge to real-world cases and engage in meaningful debates on responsible innovation and SDGs.

Keywords Responsible innovation, Sustainability education, Challenge-based learning, Partnerships, Student agency

Introduction

In the face of escalating global sustainability challenges, the role of education as a catalyst for change is increasingly important. This case study aims to elucidate the pivotal role of education in addressing sustainability challenges through the lens of the SDGs, with a particular focus on SDG 17 (partnerships for the goals) [1]. To effectively tackle sustainability changes, it is important

to develop curricula that are relevant and adaptable to emerging challenges and opportunities. Such curricula should foster effective collaboration among all the stakeholders, such as academia, government, NGOs and industry, which is essential to infuse students learning at universities with real-life challenges [2] and build competencies for addressing SDGs. Furthermore, enabling inclusive stakeholder engagement, characterised by open dialogue and mutual learning, creates an environment conducive to innovation [3, 4]. Such collaborative approaches are integral in creating rich educational experiences that impart both theoretical knowledge and real-life insights through experiential learning [5]. Furthermore, collaborative learning methodologies have been shown to significantly enhance students' knowledge

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of the SDGs, deepening their understanding of sustainability challenges and solutions [6], which underpins the necessity for universities to promote such activities.

Partnerships and interdisciplinary approaches are necessary to address the complex problems associated with sustainability [7, 8]. The transition from traditional teaching models to more collaborative, holistic approaches underpins the need for integrating various stakeholders in the educational process [9]. Co-creation of curricula, involving both academics and external stakeholders, promotes the integration of real-life scenarios and perspectives [10]. Collaborative research partnerships have emerged as a prominent feature in sustainability education and universities collaborating with industries and NGOs are found to foster environments that enable the generation of novel solutions to sustainability issues [11]. This can also influence the educational content and methodologies, making them more responsive to contemporary challenges.

Challenge-based learning (CBL) is one such innovative teaching approach that uses co-creation between academic and external stakeholders to enable self-directed learning for students [12]. This approach typically involves students from different disciplines working together in small teams to address open-ended real-world challenges and find transdisciplinary solutions [12, 13]. By actively collaborating with social entrepreneurs, companies, and NGOs, students are asked to apply their academic knowledge and skills outside of the university context to gain practical experience in the broader context. This type of collaboration and engagement promotes a “learning-to-learn” attitude where students are motivated to take on responsibility for their learning and develop “a basis for effective lifelong learning” [14]. Thus, CBL provides a useful framework for setting up courses that enable students to develop problem-solving skills and apply their knowledge in a meaningful way [15]. By incorporating principles of constructive, collaborative, contextual, and self-directed learning, CBL can lead to higher student satisfaction and engagement [15]. Furthermore, CBL aligns well with the concept of sustainability and interdisciplinary collaboration, making it a valuable approach for addressing complex societal issues [16, 17].

Thus, we used the CBL framework to design a set of undergraduate courses to enable students to learn and engage with sustainability issues while collaborating with external stakeholders and working on real-world challenges. We married the CBL approach with the notion of “responsible research and innovation” (RRI), in order to give students useful tools for critical reflection while working on sustainability challenges. RRI aims to address the grand socio-environmental challenges of our times by paying attention to the socio-ethical values involved

in the process of research and innovation and by emphasising principles such as stakeholder inclusion, reflection and responsiveness [18–20]. RRI acknowledges the important role innovations play in fostering sustainable development and contributing to SDGs. Thus, our case study aims to answer the research question: *what is the impact of the course design, including the partnership with the external stakeholders, on learners taking our CBL courses on responsible innovation for sustainable development?*

In Sect. 2, we provide a context of our study (description of our course) and how partnerships with external stakeholders were designed and implemented. In Sect. 3, we list the data collection and analysis methods. The results are presented in Sect. 4, examining the impacts that our course design and involvement of the external stakeholders had on the students. In Sect. 5, we discuss the findings of our study, highlighting the benefits and learning opportunities that stem from partnering with external stakeholders when preparing future generations to engage with SDGs.

Context of the study

Our case study uses as a context a sequence of three connected courses, forming a “learning line,” called *Responsible Innovation for the World*. Each course was two months in duration, altogether spanning over one and a half semesters. The learning lines are provided at the Eindhoven University of Technology (TU/e) as electives to 2nd and 3rd -year undergraduate students to enable them to examine the intricate relationship between scientific and technological advancements and their societal and ethical implications. The *Responsible Innovation* courses focussed specifically on the socio-ethical and environmental dimensions. They aimed to enable students to address pressing socio-environmental challenges, both in the Global South and the Global North, in a variety of fields and in collaboration with external stakeholders. The courses ran for four years (between 2019 and 2022) and were designed and taught by the first author, as an extension of her professional practice and interests. The courses took place in TU/e innovation Space, which is a learning hub and centre for expertise that provides support for CBL courses [21]. The courses aimed to skill up and empower students to tackle urgent sustainability challenges in diverse fields, including healthcare, urban development, agriculture, and waste management. The courses emphasized collaborative efforts in developing sustainable and responsible innovations, intending to motivate and equip students to effect positive change globally. An important part of the courses was fostering partnerships with external stakeholders and bridging the gap between theory and practical application, using the advantages of the CBL approach to learning (see Table 1).

Motivation to use the CBL framework

Three main considerations motivated the lecturer to engage in the design of these courses. Firstly, from teaching other courses, the lecturer noticed students' desire to

Table 1 A generalized comparison between different approaches to engaging students with sustainability issues

Feature	CBL	Internships	Instruction-Based Learning
Learning Context	Learning is constructed around solving open-ended, authentic problems.	Learning occurs through the practical application within an organizational setting.	Learning is commonly based around theoretical knowledge and predefined examples.
Problem Definition	Students identify problems based on real-world scenarios.	Problems are predefined by the organization.	Problems are typically outlined by the instructor.
Engagement	Can be implemented early in undergraduate studies.	Typically integrated into later stages of study.	Can be implemented at any stage.
Expertise Integration	Involves external stakeholders in problem identification and solving.	Students work within the established framework of the organization.	Primarily leans on educators' expertise and predefined curriculum.
Problem-Solving Approach	Encompasses identification, analysis, and solution creation of problems.	Primarily focuses on execution of solutions.	May not involve direct problem-solving, but a theoretical understanding.
Reflective Component	Integral, with structured pathways for critical reflection.	Often limited or non-existent.	Often limited or non-existent.
Relevance & Responsiveness	Maintains high relevance by engaging with current, real-world challenges.	May or may not address pressing, contemporary issues.	May generalize issues without tying them to real-time challenges.
Skill Development	Encourages analytical, evaluative, and problem-identification skills.	Tends to focus on application and execution skills.	Often prioritizes knowledge acquisition over skill development.
Student Autonomy	Students often have more freedom to explore and define problems and solutions.	Defined roles and tasks with limited autonomy.	Usually features a predetermined curriculum with limited autonomy.

apply their academic knowledge by engaging in real-life issues outside of the university. Generally, only graduate programs offer such experiences and opportunities for students at the undergraduate level were rare. The second motivation came from a desire to engage with external stakeholders and thereby broaden the scope of conventional education by bringing expertise from outside the university. Thirdly, the lecturer wished to make a more "tangible" impact explicitly through her teaching practice. Concurrently, the lecturer was inspired by the early CBL courses at TU/e innovation Space [21], realising that CBL was the final piece of the puzzle for designing her courses.

The result was the creation of the three courses as a method of connecting students and external stakeholders using CBL as an approach and enabling their respective interests and efforts to contribute to responsible changes towards sustainability. In Table 1, we highlight some of the advantages of using CBL as an approach to engaging students with sustainability issues in comparison with more typical instruction-based or internship-based approaches.

Forming partnerships for learning *about* and *for* sustainability

As an integral part of the CBL framework, the collaboration with external stakeholders played a key role in enabling students' learning and working on their projects. External stakeholders were selected to make sure that tackling sustainability challenges was a dominant frame in which their organizations positioned their work and efforts. The bandwidth of stakeholders engaged in the course was intentionally broad, ranging from non-profit organizations to public authorities, from small start-ups to large companies. This ensured a variety of viewpoints, approaches and organizational forms in the course. The stakeholders operated in a broad range of areas, including agriculture, health, energy, waste and urban planning. These external stakeholders were also very motivated to be involved, as they hoped to receive fresh perspectives from younger generations on their respective challenges. Additionally, it is an opportunity for them to introduce their organization as a potential future workplace for upcoming graduates.

The collaboration between external stakeholders and the student teams would unfold around the so-called sustainability "challenges" that the external stakeholders were facing in their work. The scope of these challenges was co-shaped between the stakeholders and the lecturer to allow for such a balance that there was enough clarity on the sustainability issues that were to be tackled by students while leaving enough space for creativity and students' agency to make the challenge their own. Examples of challenges included designing carbon-neutral energy

Table 2 Summary of the three courses and the roles of the lecturer and the external stakeholders per course

Course title	Context Matters!	Make it Matter!	For the World!
Guiding idea of the course	Understand the challenge in its broader context.	Make reflected design choices to address the challenge.	Iterate design of the responsible innovation and understand complexity of solution in relation to broader critical debates on sustainability.
Role of the lecturer	Help students find literature (academic and “grey”) and other relevant sources that explain and relate to their specific challenge.	Help students reflect on their specific design choices, taking into considerations insights from the first course and requirements from their external stakeholders	Provide broader critical literature and input (e.g., guest lectures) on sustainable development challenges- and discuss them with students. Ensure that students relate insights of these discussions to their respective projects.
Role external stakeholders	Explain the specifics of the challenge in detail by giving insight into organization’s approach and thinking about it. Define the specifications of deliverables together, with the students in the lead.	Discuss the proposed steps to tackle the challenge and define the deliverable’s specifications together, with the students in the lead.	Further discuss possible design changes and define the deliverable’s specifications together, with the students in the lead.

solutions for mobile clinics for rural Africa (in collaboration with an NGO and related to SDG 7 Energy), finding more sustainable materials for bedframes (in collaboration with two industry partners and related to SDG 12 on consumption and production), and innovating participation processes for urban renewal projects (in collaboration with the local municipality and related to SDG 11 on cities and communities).

Two guiding principles were found to be especially relevant when designing collaboration with external stakeholders. First, the collaboration and co-creation of challenges aimed to provide space for students to critically reflect on these challenges and their proposed solutions. This is an important element of learning in CBL, one that adds a distinct dimension in comparison to a more traditional form of students engaging with industry

Table 3 The closed survey questions were used in this study, and questions pertaining explicitly to partnership with external stakeholders are highlighted in bold text

Closed survey questions	
Q1	My team has regularly reflected on our progress
Q2	My team has been open to modifying our project direction and/or process as needed
Q3	Working with external partners was motivating for my learning.
Q4	Working with external partners was useful for my career.
Q5	The possibility and freedom to co-shape the content of the deliverables for the external partner was motivating for me.
Q6	Working on this project helped me improve my organizational and planning capacity
Q7	Working on this project improved my motivation during the course.
Q8	Working on this project made easier to understand theory in the course.
Q9	Working on this project helped me improve my interpersonal and team-working skills.
Q10	Working on this project increased my knowledge regarding the broader topic of responsible innovations.
Q11	Working on this project helped me become more critical of different type of information sources.
Q12	Working on this project helped me gain useful skills for my future studies and career.

through internships (see Table 1). The rationale behind this was to ensure that students thoroughly grasp the specific social, environmental and economic intricacies of their project and prevent students from habitually jumping into narrow “solutionism” based on quick technological answers. Thus, the first course was labelled “Context Matters” to enable students to understand their challenge in the broader context, not only from the viewpoint of their respective challenge “partner” (i.e., external stakeholder). During the second course (labelled “Make it Matter”), students had to reflect on their design decisions and the trade-offs that come along with this. During the third course (labelled “For the World”), students were encouraged to relate their sustainability work to a broader context, e.g. through considering input from guest lectures and engaging with critical literature relevant to the field of responsible and sustainable innovation (see Table 2).

This progression of working on the challenges was coupled with the intention to maximise student agency by providing students with a lot of space for shaping their deliverables to their external stakeholders. For each course, the stakeholders and the student teams would agree on what the deliverables would work on while being regularly (weekly to bi-weekly) advised by their stakeholders. This setup aimed to increase ownership and engagement by both parties. It also aimed to ensure that the collaboration was designed to go beyond the

execution of apriori-fixed ideas set out at the start of the course.

Data collection and analysis

To collect the data, we use the mixed-method approach, combining qualitative and quantitative research methods to explore students' learning experiences in the three courses. A total of 25 students, out of 32 invited in the 2021–2022 cohort, voluntarily participated in the survey, and four students also partook in the focus group discussion. The survey contained 12 closed items, which were measured using a 5-point Likert scale (from "strongly disagree" to "strongly agree"), and one open-ended question was included at the end to capture anything else that the students wanted to share.

The survey was administered anonymously in the last week of the semester to encourage candid responses and to maintain the confidentiality of the participants. Following the survey, a focus group was conducted by a researcher (the second author) to gather more in-depth insights into the students' experiences in the course. The focus group session was recorded and later transcribed verbatim to aid in the analysis process, ensuring accuracy and authenticity in capturing participants' perspectives. Personal identifiers were removed during the transcription process to maintain the anonymity of the participants.

The survey data was analysed to derive the frequency of responses to all of the questions. The qualitative data from the open-ended question and the focus group discussions were analysed by the researcher, initially using deductive coding in line with the research question. Subsequently, inductive coding was performed to identify sub-themes and capture all the insights from the participants. Through careful reading and re-reading of the data, discussion of the interim findings between both authors and moving between deductive to inductive coding, we aimed to perform a comprehensive analysis of the qualitative data. This dual coding strategy not only allows for the validation of initial findings but also for the discovery of unforeseen insights and themes, thereby enhancing the credibility and reliability of the research findings. The iterative back-and-forth between these two coding phases ensures that the analysis remains closely aligned with the research objectives while remaining adaptable to the authentic voices and experiences of the participants.

Results

Insights from the quantitative data

In this paper, we sought to discern students' experiences in the set of three courses focused on sustainability and responsible innovation in which students work on open-ended projects in collaboration with

external stakeholders. Here we present an analysis of their responses to a structured questionnaire encompassing several characteristics of the course which reveal different dimensions of this collaborative learning process. In Fig. 1 we present the frequency of the responses to the closed survey questions.

As can be seen, the students expressed overwhelmingly positive experiences with many aspects of the courses. When it came to collaborating with external partners, students exhibited strong positive sentiments, noting high levels of motivation driven by the perceived relevance of these collaborations to their learning and potential career progression. This was reflected in the strong agreement concerning the motivating nature of the freedom to co-shape the content of the deliverables for the external partners, a factor that possibly fuelled their engagement and deepened the impact of their learning experience. The majority agreed that the course had enabled them to gain more knowledge and broadened their understanding of the topics of sustainability and responsible innovations. The majority also agreed on gaining a heightened ability to critically analyse different sources of information, an essential skill in a contemporary society rife with diverse and at times conflicting information streams.

Insights from the qualitative data

Eight students provided additional responses to an open-ended question in the survey, which added nuances to our understanding of their experiences. One student expressed appreciation for the interdisciplinary nature of the course and the fresh perspective it brought to their learning journey. Another student reported shifts in their career perspectives, fostering a desire to contribute positively to the world:

"The learning line did change my view on my career. It incentivized me to make the world better and showed me the fact that I can actually. By working with the external parties and learning about European bodies I noticed that we are able to make a difference."

Therefore, the course appeared to not only facilitate skill and knowledge development but also nurture a deeper sense of responsibility and capability to initiate change. The other two students expressed appreciation for the lecturer's enthusiasm, which was a motivational catalyst for one of them to invest more effort in the course. Some students also pointed out areas for potential refinement. For instance, the timing of guest lectures was pointed out as a potential bottleneck, limiting students' ability to integrate insights into their projects. Moreover, a suggestion

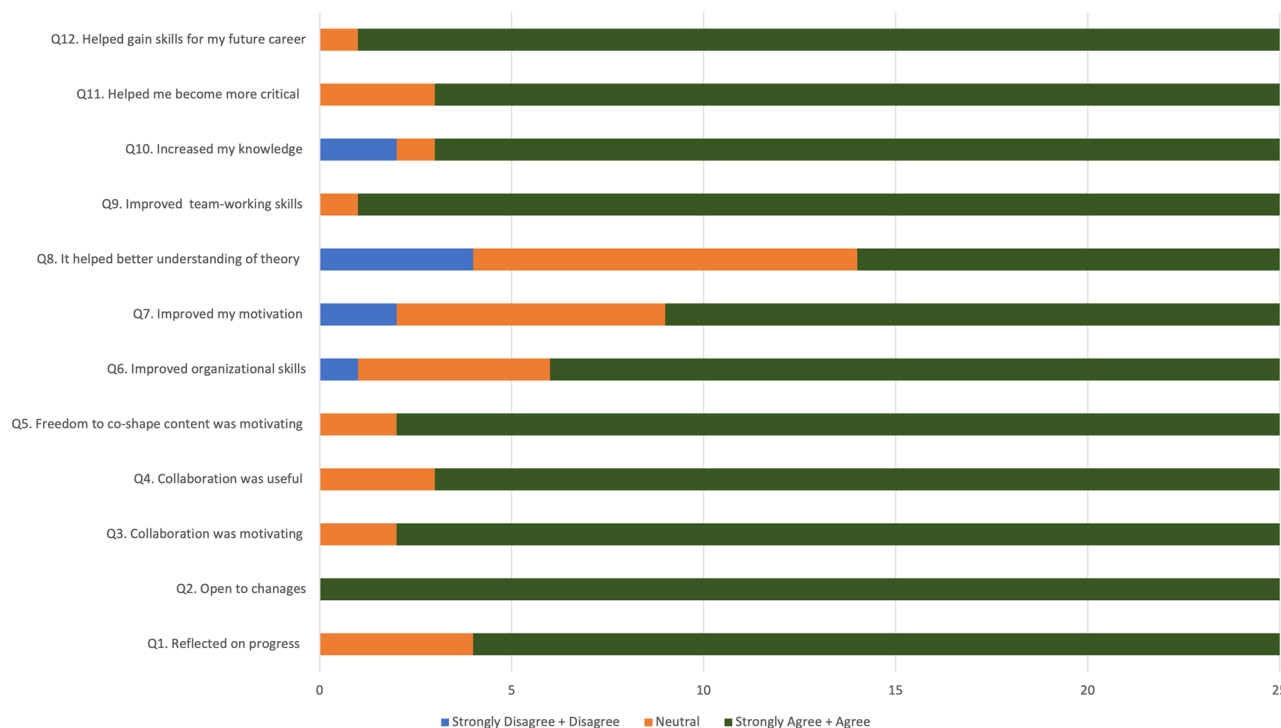


Fig. 1 The frequency of responses to 12 closed questions of the survey was given as the number of students agreeing or disagreeing with the statements from Table 3, also listed in a shortened form here

Table 4 Identified themes from the focus group with the participants and the frequency of their occurrence

Themes (frequency)	Sub-themes
Exposure to real-life contexts and practical application (6)	Invaluable experience through real-life projects Tangible impacts witnessed Deepened understanding of sustainability concepts
Collaboration with external experts (10)	Enhanced understanding via access to expert networks and resources Avenues for guidance and feedback from professionals Broader perspective gained through insights from various sectors
Peer learning and skill exchange through interdisciplinary learning (3)	Benefit from varied skill sets and expertise within teams
Development of critical skills (12)	Fostering critical thinking, analytical, and communication skills Navigating conflicting interests and effective multi-stakeholder communication
Iterative learning and adaptation (3)	Necessity to adjust project focuses through critical reflection Stimulated by insights provided by external partners and/or the lecturer

for earlier hands-on engagement in projects was voiced, to allow for more iterations.

The students participating in a focus group expressed a sentiment that working in a team and collaborating with external stakeholders in learning about sustainability brings forth several benefits and learning opportunities, albeit with certain challenges that could be streamlined for a more enriching experience. In Table 4, we give a summary of identified themes.

Students highlighted the invaluable experience of working on projects that have real-life implications, allowing them to witness the tangible impacts of their efforts. In the words of the students:

For me it was the possibility to have real world impact with something I'm doing as a student. Because I think, like, most of the things I do now are focused on me and developing myself and that's it. But this gave me the opportunity to... Made me feel valuable and actually have some real world impact, which I thought was pretty exciting.

The students enjoyed gathering insights and data from various sectors and sources, gaining a broader perspective that goes beyond theoretical knowledge, and aiding them in understanding sustainability concepts deeper. The collaboration with the external stakeholders and the potential to make a tangible impact spiked the students'

interest and engagement levels. The access to a network of external experts and resources enhanced their understanding and provided avenues for helpful guidance and feedback. By working in interdisciplinary teams, the students had the opportunity to learn from peers from different majors, benefiting from varied skill sets and expertise within their teams.

Working on the challenges enabled the development of various skills critical for their future studies and careers, including critical thinking, communication, negotiation, and conflict resolution skills. Students learned to critically evaluate information from various sources, navigate conflicting interests, and communicate effectively with multiple stakeholders. In the words of the students:

“[At a furniture fair] there were a lot of companies saying that they were circular and had a circular mattress and we interviewed all of them and they were talking about materials which aren’t circular. And they said, “If you put this in the ground for five years, it will be gone. So it’s bio-based.” Then we’re like, “No, that’s not true.” (Student 1).

“Because we also had our sources from different companies (...). They told us these materials are not circular. If you put them in the ground, they will still be there after certain amount of years, like forever. And we told this to the companies at the fair and they said the exact opposite. And I’m like, “We’ll play along, but we know that’s not true.” (Student 2).

The students mentioned the necessity of adjusting project focuses based on new insights from external partners or the lecturer, leading to iterative learning and adaptation, which are critical in the ever-evolving field of sustainability. However, the collaboration was not without its collaboration challenges. The students encountered issues pertaining to communication clarity and mismatched expectations. In the words of the students:

We were working with [two different] companies and one had worked with [the lecturer] before and I could really notice the difference between [them]. Because [person 1] understood that it was for learning. And [person 1] knew what we would be capable of and had fair expectations and focused on our learning. And the other person was focused more on what [they] could get out of it.

Yet, students acknowledged that these collaboration challenges serve as fertile grounds for learning and adaptation. The presence of support structures facilitated by the lecturer suggests the necessity for a learning ecosystem that is both safe and conducive for students to navigate

successfully the complexities of engagements with external stakeholders.

Discussion

In contemporary educational landscapes, incorporating experiences of collaborating with a variety of external stakeholders within undergraduate studies has emerged as a crucial pathway to foster important competencies in learners [22]. Our empirical study exploring students’ experiences with a course on sustainability and responsible innovation, delivered in collaboration with external stakeholders, offers an insight into the multifaceted benefits and learning opportunities as a result of partnering for SDGs with industry, government organisations and NGOs.

First and foremost, the collaboration based on the CBL approach was demonstrated to be a rich source of experiential learning, providing students with a direct avenue to apply theoretical knowledge in real-life contexts [12, 16]. The students were able to gather authentic insights from external partners and stakeholders and participate in projects with tangible impacts, thus fostering a more profound and nuanced understanding of sustainability concepts [23]. This aligns with the pedagogical principle of CBL and situated learning, which posits that learning is most effective when it occurs in the context in which it is going to be applied [24]. This facilitation of real-life application of knowledge not only heightens the interest and engagement levels of students but also inspires an elevated sense of responsibility and initiative, encouraging them to independently seek opportunities for learning and growth [25].

The learners underscored the importance of peer learning and interdisciplinary approaches when looking for sustainability solutions. Collaborative problem-solving using complex, context-rich problems among peers has indeed been found to be effective [26]. In the rapidly evolving field of sustainability, which often demands multifaceted approaches and the amalgamation of diverse knowledge bases, such interdisciplinary interactions can potentially nurture professionals who are adept at navigating the complexities of the workforce [27] and evolving terrains of the sustainability landscapes [2]. By fostering the development of these competencies, universities can ensure that graduates are not only theoretically proficient but also practically adept, thereby bridging the gap between academia and the industry [10].

Accessibility to expert networks and resources emerged as a vital benefit of the partnership with external stakeholders, giving students a more comprehensive understanding of global sustainability issues and fostering potentially transformative learning and collaborative knowledge exchange [28]. Despite facing collaborative challenges, such as non-clarity in communication with

external partners and mismatched expectations, students acknowledged the moderating effect of the supportive learning environment facilitated by the course lecturer.

The insights derived from this study serve as a demonstration of the viability of partnerships between universities and a variety of external stakeholders as a potent mechanism for enhancing curricula focused on responsible innovation and sustainability. Through this synergy, academic institutions can foster a learning environment that is flexible, responsive and relevant, ensuring that students are not only proficient in the theoretical aspect of their field but are also adept at navigating the practical complexities of the industry [29]. As demonstrated by our study, engaging students hands-on in such experimentation brings multiple benefits.

Our case study, while insightful, has two main limitations. Firstly, the findings might not be generalizable beyond the specific context of our course or the institution, or the cohort studied. Secondly, the number of our participants was relatively small (25 participants). Therefore, the insights from our study might have limiting applicability to broader student numbers or different settings.

Conclusion

In summary, the findings from our study present an overwhelmingly positive learner experience in a set of CBL courses about sustainability and responsible innovation, delivered in collaboration with external stakeholders. Collaborating with a variety of external stakeholders to learn about SDGs provided students with a multi-faceted and authentic learning experience, developing their skills and knowledge in a real-life context and preparing them more effectively for their future careers. Furthermore, it gave them inspiration that they can make the world better. This collaborative work on solving the challenges enabled the fostering of critical thinking and practical problem-solving skills and exposed them to the complexities and challenges of implementing sustainable practices in a variety of contexts, thereby offering a more rounded and enriched educational experience compared to a purely academic course. Therefore, such educational approaches enable the fostering of young professionals who are potentially more responsive to the needs of modern society.

Author contributions

JH and JLG designed the study together, JLG took the lead on data collection and analysis, JH and JLG wrote the manuscript collaboratively.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to the fact that they contain information that

could compromise participant privacy/consent but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics approval was obtained for the collection and use of this data by the Ethics Research Board ERB2021ESOE16.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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