WILEY

Higher Education Quarterly

RESEARCH ARTICLE OPEN ACCESS

The Impact of Project-Based Learning on Student Knowledge Exchange for Sustainability: The Case for University–Business Collaborations

Ana Rita Domingues[1] | Gamze Yakar-Pritchard[2] | Muhammad Usman Mazhar[3] | Francesco Luke Siena[4] | Richard Bull[4]

[1]Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds, UK | [2]School of Geography, University of Nottingham, Nottingham, UK | [3]Nottingham Business School, Nottingham Trent University, Nottingham, UK | [4]School of Architecture, Design, and the Built Environment, Nottingham Trent University, Nottingham, UK

Correspondence: Ana Rita Domingues (a.r.domingues@leeds.ac.uk)

Received: 16 September 2024 | **Revised:** 25 February 2025 | **Accepted:** 20 April 2025

Funding: Knowledge Exchange Department at Nottingham Trent University through the Higher Education Innovation Funding (HEIF).

Keywords: higher education institutions | small- and medium-sized enterprises | sustainability consultancy | sustainability education

ABSTRACT

Knowledge exchange in higher education is an emerging area delivered in multiple ways, including university–business collaboration, combining academic knowledge and business needs. Knowledge exchange can act as a vehicle for embedding sustainability in the curriculum and help address significant challenges we face as a society. Student knowledge exchange is driven by students who work on real-world projects, often with businesses involved. There is a need to assess the impact of knowledge exchange on students to inform curriculum design and development for a better student experience and outcomes. This research aimed to better understand the impact of university–business collaboration on student knowledge exchange for sustainability by adopting project-based learning pedagogy. The study draws lessons from the School of Architecture, Design and the Built Environment and Nottingham Business School at Nottingham Trent University. The study found that project-based learning significantly impacts students' sustainability knowledge and competencies. Besides knowledge and competencies, students who work with businesses also gain sustainability skills, attitudes, and behaviours. The design and implementation of project-based learning affect the outcomes, including activities integrated into the curriculum versus extracurricular activities, bespoke versus ad hoc student projects and the duration of students' exposure to sustainability-related topics. This study contributes to higher education teaching and learning and impacts students' capacity building, affective domain and career readiness. Project-based learning can enhance student knowledge exchange for sustainability, particularly when collaborating with businesses, impacting students and businesses.

1 | Introduction

Sustainability is an emerging topic worldwide, with increasing concerns about environmental degradation, social inequality and economic disparities. However, human activities continue progressing rapidly on an unsustainable path (Albareda-Tiana et al. 2018). To develop a more sustainability-oriented society, higher education institutions (HEIs) have a key leadership role to play in enhancing sustainability literacy, educating graduates in line with the necessary technical knowledge and developing a new generation of sustainability-minded global citizens (Briens et al. 2023; Segalàs et al. 2010). Societies need scientists, engineers and business and management professionals to design sustainable solutions, new technologies and economic activities for environmental integrity, economic viability and a just society for present and future generations (Segalàs et al. 2010;

UNESCO 2017). There is a call to integrate sustainability and Sustainable Development Goals (SDGs) into the curriculum through a holistic and systemic approach, which is currently lacking (Alcántara-Rubio et al. 2022).

Over the past decade, there has been increasing interest among HEIs in integrating real-world learning processes into their curriculum and helping prepare students for a future where sustainability skills and competencies will be crucial to help society overcome the most difficult sustainability challenges (Alm et al. 2022). According to a recent literature review conducted by Yakar-Pritchard et al. (2024), both are key towards capacity building. Sustainability skills are transferable learned qualities, such as teamwork, communication and leadership; sustainability competencies are gained through creating specific teaching and learning environments to apply, for example, knowledge and skills to develop, for example, systems thinking, interdisciplinary work, anticipatory or future thinking and critical thinking and analysis. Competencies are considered to promote sustainability. It is argued that practice-oriented education can help learners gain the competencies needed to become change agents in their future careers (Sattich et al. 2024).

Previous research has demonstrated that incorporating sustainability in the curriculum using real-world problems through project-based learning (PBL) can enhance awareness of and responses to sustainability issues and gain skills and competencies usually unattained in the conventional lecture theatre environment (Belwal et al. 2020; Trencher et al. 2018; Sales de Aguiar and Paterson 2018). It can also contribute to students' self-perceived competencies development in sustainability (Birdman et al. 2022), such as problem-solving, linking knowledge to action and collaborative work while applying concepts and methods from the field of sustainability (Brundiers et al. 2010). Exposing learners to sustainability problems can support them in their professional careers in coping with the complexity and uncertainty of sustainability issues more creatively and successfully (Brundiers et al. 2010). For instance, Heiskanen et al. (2016) argue that a sustainability-oriented real-life consultancy course helps to prepare students for their challenges at work. However, this will only be successful through innovative ways of teaching to help develop capacities.

Student knowledge exchange (KE) can be an avenue to explore innovative ways to incorporate teaching and learning related to sustainability. KE implies a knowledge-sharing process with mutual benefits and multi-learning between various actors, such as researchers, decision-makers, practitioners and businesses (Fazey et al. 2013, 2014). KE practice can involve HEIs working with external partners to translate knowledge into practice, creating positive change and significant impact. There is a growing tendency towards co-production processes, where researchers are no longer the sole producers of knowledge. Consequently, students and decision-makers have increasingly been included in the coproduction of knowledge (Fazey et al. 2014; Karcher et al. 2022; Tho 2017). HEIs can be crucial in supporting organisational sustainability changes through teaching, research and KE practice.

In England, KE has become institutionalised in HEIs as part of the third mission, which involves the interaction of different actors. Consequently, HEIs have an institutionalised role in creating value for society that can be measured. KE measures an impact, change or benefit resulting from the interaction of different actors or activities, such as teaching and learning (Segalàs et al. 2010; Johnson 2022). It can be measured in multiple ways: gains in students' knowledge, skills and competencies and businesses' labour market value resulting from the exchange (Johnson 2022). Thus, KE could contribute to creating innovative learning activities that lead learners to gain the key skills and competencies needed to solve sustainability problems. Students' KE can contribute to understanding the outcomes of participatory teaching and learning methods, such as PBL design, to provide consultancy solutions to specific sustainability problems.

The benefits of PBL, particularly related to student teams, have been widely discussed in the literature. For instance, You (2023) argues that a good team learning experience is a key motivation to develop a positive attitude towards team-based learning. Thus, the role of instructors is essential to designing and operating a learning activity that supports team-based learning. Aligning PBL to real-life consultancy projects with real organisations can potentially create a significant learning experience for students and enhance KE practice (see, e.g., Domingues et al. 2024). HEIs' significant and positive impact on organisations (such as small and medium-sized enterprises—SMEs) has been widely discussed (e.g., McCauley-Smith et al. 2022).

Countries such as England, the Netherlands and Germany have a close university–business collaboration focusing on developing student competencies (Perusso and Wagenaar 2022). This reflects the typical Anglo-Saxon education model, where it is perceived that developing individual competencies supports learners to better deal with change and challenging situations (Sam et al. 2014). Collaboration is a key tool for generating knowledge, as Parsons (2021) discusses. English HEIs also benefit from being self-governing institutions and autonomous academic disciplines as opposed to other countries where governance is the state's responsibility (Sam et al. 2014). Consequently, in the English HEIs, engaging non-academic actors, such as organisations, in curriculum and specific teaching and learning activities might be more flexible and achievable than in other countries.

Despite the growing awareness of the need for enhanced KE among universities and sustainability researchers, an implementation gap remains in this area of teaching and learning (Cvitanovic et al. 2021). There has been a large number of studies focused on developing key competencies in sustainability in HEIs with different pedagogical approaches (e.g., Barth et al. 2007; Segalàs et al. 2010; Sprain and Timpson 2012; Wiek et al. 2014; Brundiers et al. 2021; Alm et al. 2022; Birdman et al. 2022; Wang et al. 2022; Lozano et al. 2017). However, little has been discussed on the relationship between KE and students' sustainability competencies in academic settings (Naderi et al. 2022).

The present study aimed to better understand the impact of university–business collaboration on student KE for sustainability by adopting project-based learning pedagogy. It particularly aims to answer the following two research questions: (a) what

is the impact of PBL on students' capacity building (knowledge, competencies and skills); affective domain (perceptions, attitudes and behaviours); and career readiness on sustainability?; (b) how do the design and implementation of KE projects, including university–business collaboration, affect students' KE for sustainability? Consequently, this study analyses the impact of KE for sustainability on students in two academic schools in an English HEI, Nottingham Trent University (NTU). It measures the impact of KE, particularly from a broader range of activities in HEIs beyond commercialisation, as Marzocchi et al. (2023) suggest. Understanding different KE approaches and their impact on students' sustainability KE is important for designing and implementing KE in the future. The present study is focused on the impact of KE on students; a separate publication focuses on the impact of the *exchange* on businesses (see Mazhar et al. 2024).

2 | Research Design and Methods

2.1 | Research Context

This study adopts a case study approach based on two NTU schools: School of Architecture, Design and the Built Environment (ADBE) and Nottingham Business School (NBS). Both were supported by NTU's European Regional Development Fund (ERDF) Sustainability in Enterprise (SiE) programme aimed at supporting SMEs based in the Greater Nottingham area (England) on their journey to Net Zero, including student-led consultancy.

At ADBE, students provided bespoke sustainability consultancy to support SMEs in reducing their carbon emissions. In contrast, NBS students offered a similar framework to all businesses for carbon management consultancy by measuring the carbon footprint of SMEs and developing targets and recommendations. Both schools aimed to develop in-curricular and extracurricular activities using a variety of pedagogical approaches to enhance students' experience, knowledge, skills and competencies to enhance employability. Students worked in teams to support the delivery of projects, in most cases, in collaboration with SMEs. Academics with expertise in sustainability supported student teams through a series of lectures and seminar workshops. Student KE involves exchanging knowledge, skills and competencies among peers, between students and academics and between students and business representatives through meetings (in the business facilities or in the HEI) and site visits. Figure 1 illustrates the groups of students that participated in the current research.

At ADBE, BA (Hons) Interior Architecture and Design (Year 3) and BSc Product Design (Year 2) students worked on the SiE. Architecture students were invited to select SMEs enrolled in the SiE as their case studies for their project module. In teams, students produced a report including a baseline analysis of SMEs' current carbon emissions and recommendations for reducing them. The project lasted 3 weeks, including a site visit and two seminar-based weeks. Students had the opportunity to collaborate with the SMEs' representatives, such as the Facilities Manager and Director.

The product design students were invited to work on redesigning an outdoor camping product from an SME. Students needed to identify how the product could reduce environmental impact by using more sustainable materials and extending its life cycle. The project spanned 2 weeks. In the first week, there was a 2-day deep dive into the brand and its toolset. The following week comprised a 5-day design sprint. This sprint culminated in students presenting their ideas in a 5-min pitch to the company, backing their final proposals and processes with data. Each proposal aimed at carbon reduction, with students presenting various carbon-saving solutions in their final submissions. For more details, see Winfield et al. (2023).

Besides the SiE, Year 1 BSc Project Design students also worked on a Sustainability Week (SW) project. SW utilised a traditional design sprint methodology commonly used in the industry to address business problems, enabling students to complete the design challenge within the event's 1-week timeframe. The student cohort participated in a streamlined design thinking-based process to uncover insights, prototype ideas and test solutions. The design sprint approach provided a flexible framework to complete a product design-focused challenge within design teams to enhance the chances of creating a successful product or service (Banfield et al. 2015). In this case, students were challenged to identify a problem related to the SDGs on NTU campuses. Students were asked to work in teams to design a product or system, considering a more sustainable solution in the product or system's lifecycle. PBL was supplemented with sustainability-focused teaching through various lectures, workshops, and brief research and design activities. Each day featured a structured set of activities,

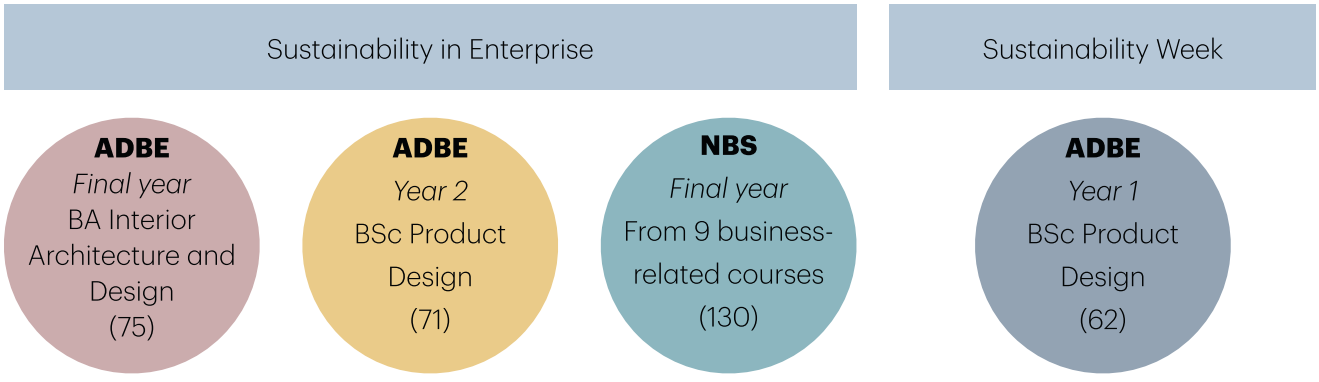

FIGURE 1 | Number of undergrad students who participated in the current research.

including research, design sketching, computer-aided design, material database exploration, product development and modelling, culminating in the final design realisation and presentation by the end of the week. Although this approach did not involve working directly with an organisation or their representatives outside the context of the university, a business/systems thinking approach was taken to the content delivery, with student outcomes focused on demonstrating sustainable gains.

At NBS, final-year students undertook a team-based carbon management consultancy project in the SiE module. Students were from nine single and joint honours undergraduate courses, including business, international business, accounting and finance, economics, marketing and entrepreneurship. Students could choose this module instead of the Research project in their final year. Student teams of four to five students work with a business to provide carbon management consultancy. They work with the client business for about 4–5 months, and academics support them weekly through lectures and seminars. Each student team carried out a business needs assessment, reviewed the project brief and resource data and carried out the desktop research, including a review of current environmental policy and strategy (if applicable), identification of risks and opportunities associated with carbon management, setting the scopes and organisational/operational boundary, calculation of carbon footprint, and assessment of carbon footprint and associated costs of consumption. The final output was a carbon footprint assessment with recommendations to reduce carbon emissions, associated cost savings and a set of carbon reduction targets for the business. The project findings were presented to the business through a poster presentation at a conference and networking event to which all client businesses were invited.

2.2 | Data Collection

Data were collected during the academic year 2022–2023 using a quantitative questionnaire survey. Before the primary data collection process, ethical clearance was secured from NTU's Research Ethics Committee (REC) (Schools of Art, Architecture, Design and Humanities REC) by following the official process. The related documents, such as informed consent, participant information sheet and data management plan, were developed for consideration and approval. The data were collected, analysed and reported accordingly.

The primary data collection instrument, the questionnaire survey, was designed to gather information about the following key variables: (i) capacity building (knowledge, competencies and skills); (ii) affective domain (perceptions, attitudes, and behaviours); and (iii) career readiness for sustainability. The items measured under each variable are shown in Figure 2.

The variables and items measured in the survey were identified from the framework developed by Yakar-Pritchard et al. (2024) to assess the impact of student KE for sustainability. Students' knowledge of sustainability was measured considering the focus and content of the projects, aiming to capture a holistic understanding of sustainability themes among the students, reflecting the field's interdisciplinary nature. The sustainability competencies were measured using items adapted from the framework developed by Wiek et al. (2011). The survey briefly defined each key competency to ensure a shared understanding among all participants. The items used to measure the students' skill development were adapted from the framework developed by Yakar-Pritchard et al. (2024). Items to measure the students' perceptions of sustainability were adapted from Ngo and Chase (2021), items to measure their attitudes were adapted from Ceulemans and Severijns (2019), and those to measure their behaviours were adapted from Heeren et al. (2016). The career readiness scale was adapted from Read et al. (2022).

The survey consisted of seventeen (17) closed-ended questions, and the variables and items (see Figure 2) were measured using a 5-point Likert scale. Sustainability knowledge (1 = not at all knowledgeable to 5 = very knowledgeable); sustainability competencies and skills development (1 = very poor to 5 = excellent); sustainability perceptions (1 = very low to 5 = very high); sustainability behaviours (1 = never to 5 = always); and sustainability attitudes and career readiness (1 = strongly disagree to 5 = strongly agree).

Students were asked to make self-assessments before and after the project. Data were obtained anonymously through the pre- and post-intervention surveys collected between 25 October 2022 and 6 April 2023. Microsoft Forms was used for data collection. Fazey et al. (2014) highlighted a research gap in education when comparing different KE approaches using the *before* and *after* data collection methods. Thus, this method was used to analyse the impact of student KE for sustainability. The pre-intervention survey was available in the NTU Online Workspace (a virtual learning environment—VLE) on the first day of the project when the modules started, and all students who were going to participate in the project were asked to complete it to establish a baseline following the brief introduction of the project. The post-intervention surveys were collected at the end of the projects using the same method, and students were reminded to complete them via the module VLE and emails from the module team.

In total, 338 students participated in the projects, including three groups in the SiE: 75 from BA Interior Architecture and Design (Year 3), 71 from BSc Product Design (Year 2) and 130 students from the SiE module at NBS; and 62 from the SW at ADBE. A total of 229 students (68%) answered the pre-intervention survey. Of these students, 80 (34.9%) participated in the SiE ADBE project, 101 (44.1%) participated in the SiE NBS project and 48 (21.0%) participated in the SW ADBE project. In addition, 139 students (41.1%) answered the post-intervention survey. Data sets obtained from self-assessment surveys may contain some invalid data due to careless and insufficient effort to provide responses (Curran 2016). In the study, two post-intervention surveys that were found to be answered carelessly and inattentively were excluded to eliminate errors that could affect the survey results. A total of 137 valid responses from students were analysed; 43 (31.4%) participated in the SiE ADBE project, 47 (34.3%) participated in the SiE NBS project and 47 (34.3%) participated in the SW ADBE project.

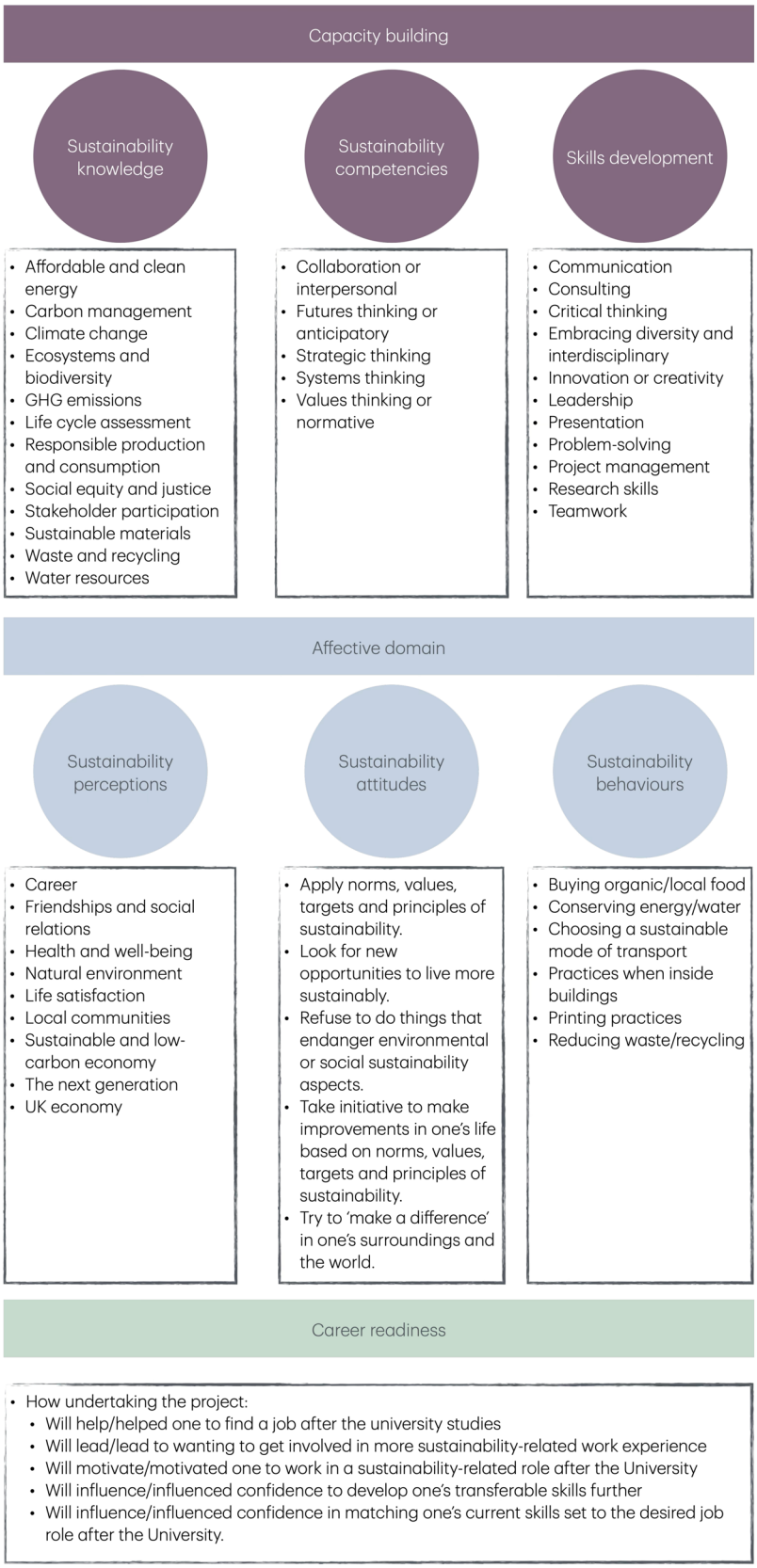

FIGURE 2 | Variables and items considered in data collection.

2.3 | Data Analysis

Data were analysed using IBM SPSS Statistics 28.0.1.1. Descriptive statistics provided information about the mean, standard deviation, percentage and frequency of the variables in the data set. A reliability analysis was conducted using Cronbach's alpha coefficient. The results were used to answer the first research question, 'What is the impact of PBL on students' capacity building (knowledge, competencies and skills); affective domain (perceptions, attitudes and behaviours); and career readiness on sustainability?'

Table 1 shows the variables measured in the study, the number of items under each variable, and the pre- and post-intervention Cronbach's alpha values in calculating the internal consistency reliability. A Cronbach's alpha value higher than 0.7 demonstrates the scale's reliability (Hair et al. 2014). Most variables had strong internal consistency, except the pre-intervention internal reliability of the variable regarding sustainability behaviours. This could have been due to a low understanding of sustainable behaviours before the projects took place. The post-intervention internal reliability value was higher than 0.7.

The skewness and kurtosis values obtained from the study were between −2 and +2, and the normality assumption was determined to be met (George and Mallery 2010). Therefore, an independent samples *t*-test was conducted to determine whether there were differences between the pre- and post-intervention results of the students' knowledge, competencies and skills; their perceptions, attitudes and behaviours; and their career readiness on sustainability. A one-way analysis of variance (ANOVA) test was performed to determine whether there was a difference among the projects in which students were included. These results were used to answer the second research question, 'How do the design and implementation of KE projects, including university–business collaboration, affect students' KE for sustainability?'

TABLE 1 | Reliability of the measurement instrument.

Variables	Number of items	Pre-intervention Cronbach's alpha	Post-intervention Cronbach's alpha
Capacity building			
Sustainability knowledge	12	0.897	0.891
Sustainability competencies	5	0.759	0.837
Skills development	11	0.827	0.877
Affective domain			
Sustainability perceptions	9	0.808	0.833
Sustainability attitudes	5	0.788	0.862
Sustainability behaviours	6	0.556	0.739
Career readiness	5	0.748	0.860

Among the limitations of the research design and methods is that it was not possible to match the pre- and post-intervention responses as personal data were not gathered to allow students to answer the survey to avoid perceiving this would influence their final mark. The significant number of responses made it difficult to ask questions to identify general aspects about the student as these could have been similar among students. Linking pre- and post-survey answers would have allowed the analysis of additional factors regarding the responses given. Moreover, the difference in the number of students responding to the pre- and post-intervention surveys could have resulted in a significant amount of data being excluded from the study if matching was attempted. The survey is also based on students' self-evaluation and reflection using pre- and post-intervention responses. However, this is still one of the most used methods to measure impact in the HEI context; similar studies have adopted the same method (Caraballo-Cueto et al. 2024; Ning and Downing 2010). Lastly, the impact is context-related, so other variables might be more relevant in contexts outside England to measure the impact of university–business collaboration on students' KE for sustainability.

3 | Results

3.1 | SiE Impact on Students' KE for Sustainability

3.1.1 | Capacity Building: Students' Knowledge, Competencies and Skills

Results show a significant difference between the pre- and post-intervention levels of sustainability knowledge of the students who participated in the SiE ($p < 0.001$). Considering the total score, the students reported a higher level of knowledge about sustainability after the intervention ($M = 3.48$, SD = 0.61) than in the pre-intervention period ($M = 2.77$, SD = 0.68). These results show that the SiE intervention contributed significantly to the students' sustainability knowledge. Figure 3 details the variables assessed on sustainability knowledge. It shows that before the project, waste and recycling was where students felt they had the highest knowledge, but after the project, the knowledge in three other areas substantially increased: carbon management, life cycle assessment and greenhouse gas (GHG) emissions. These themes represent the key focus of the projects.

Figure 4 shows the results for sustainability competencies associated with the project. There was a significant difference between students' total pre-intervention score ($M = 3.53$, SD = 0.51) and post-intervention score ($M = 3.71$, SD = 0.56) for sustainability competencies ($p = 0.011$). Particularly, there was a significant increase in the students' post-intervention strategic thinking ($M = 3.80$, SD = 0.70) compared to their relevant pre-intervention level ($M = 3.59$, SD = 0.73, $p = 0.027$) and values thinking or normative (before: $M = 3.40$, SD = 0.75; after $M = 3.66$, SD = 0.73, $p = 0.007$).

Figure 5 summarises the results of skills development. It indicates a significant difference between the pre- and

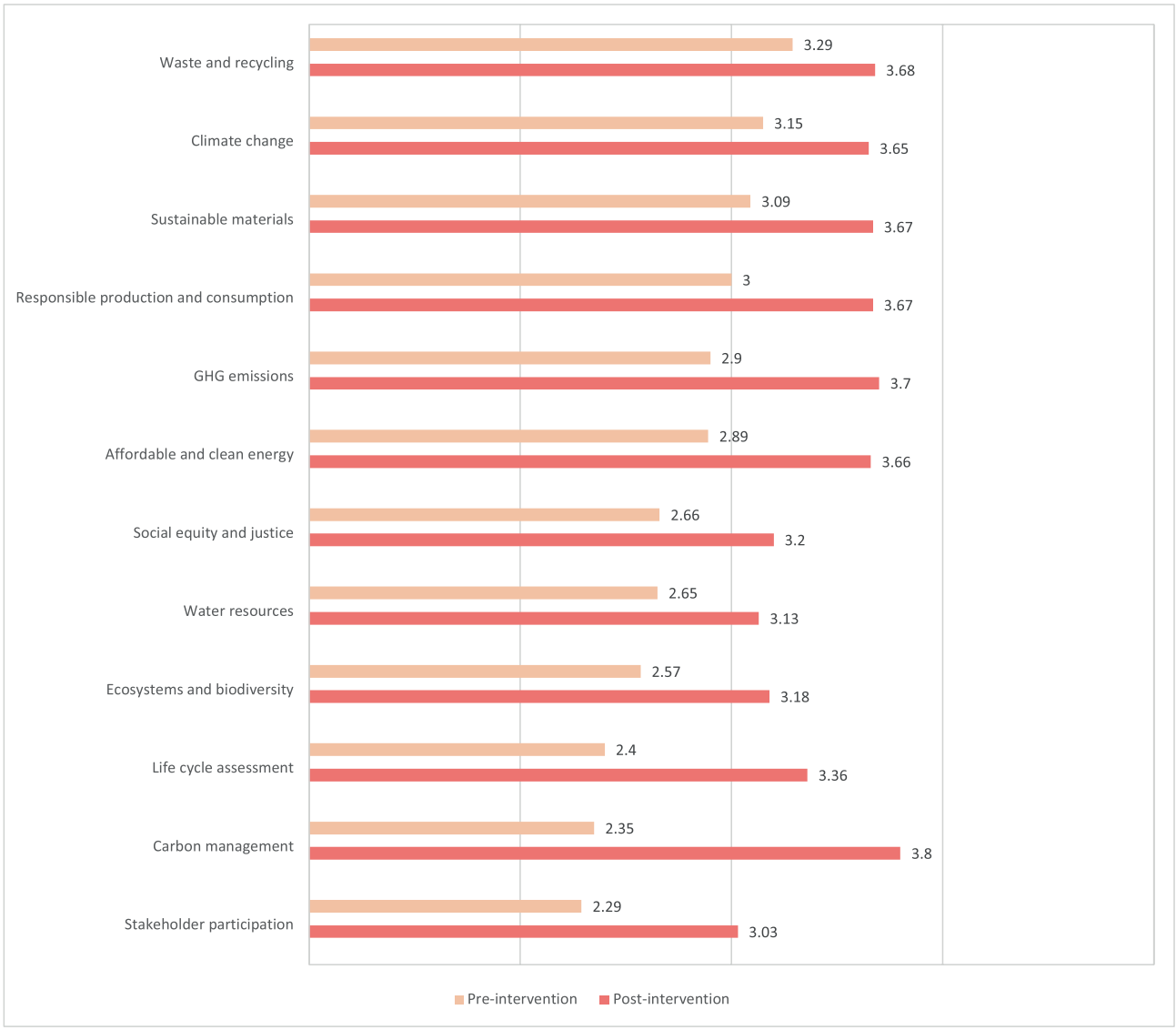

FIGURE 3 | Pre- and post-intervention mean scores on sustainability knowledge: SiE.

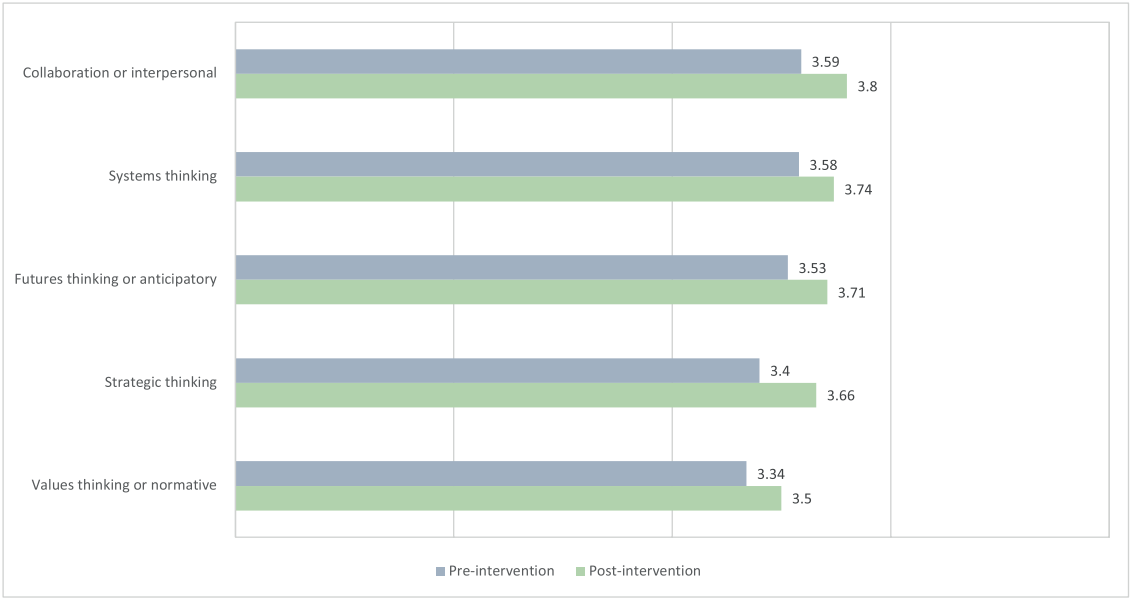

FIGURE 4 | Pre- and post-intervention mean scores on sustainability competencies: SiE.

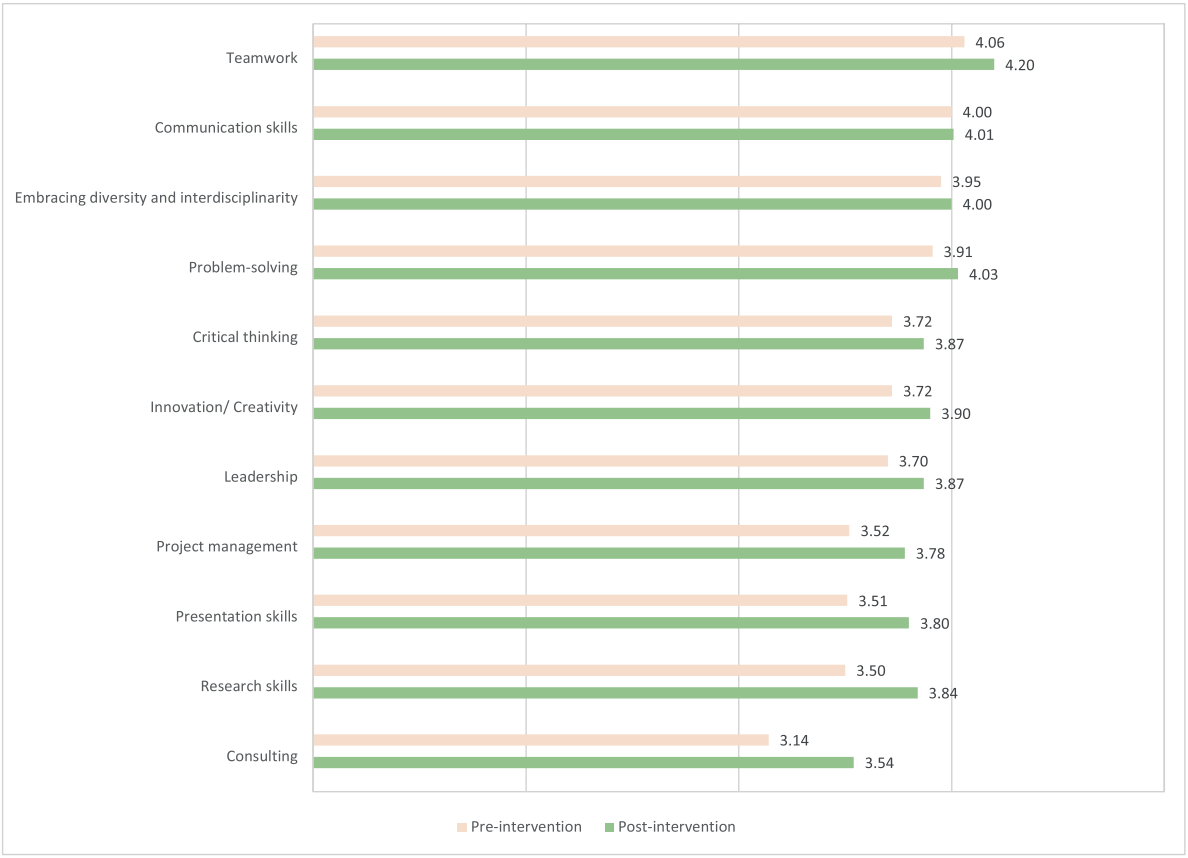

FIGURE 5 | Pre- and post-intervention mean scores on skills development: SiE.

TABLE 2 | Pre- and post-intervention mean scores on perceptions, attitudes and behaviours towards sustainability: SiE.

	Pre-intervention ($N=181$)		Post-intervention ($N=90$)		*t*-test for equality of means		
Variables	**Mean**	**SD**	**Mean**	**SD**	***t***	**df**	***p***
Sustainability perceptions	3.96	0.52	3.93	0.55	−0.404	269	0.687
Sustainability attitudes	3.61	0.59	3.81	0.62	2.503	269	0.013*
Sustainability behaviours	3.64	0.49	3.80	0.60	2.285	269	0.023*

Abbreviations: df, degrees of freedom; *N*, total number of participants; SD, standard deviation.
*$p < 0.05$.

post-intervention scores of the students who participated in the SiE, particularly the items with lower scores in the pre-intervention: consulting, research, presentation skills and project management ($p < 0.05$). The biggest difference was in consulting skills, as there was a significant increase in the students' post-intervention score ($M = 3.54$, SD = 0.79) compared to their pre-intervention score ($M = 3.14$, SD = 0.85). Other significant differences were related to research skills ($M = 3.84$, SD = 0.79) compared to their relevant pre-intervention result ($M = 3.50$, SD = 0.80); presentation skills ($M = 3.80$, SD = 0.93) compared to their relevant pre-intervention result ($M = 3.51$, SD = 0.95); and project management skills were significantly higher after the intervention ($M = 3.78$, SD = 0.71) compared to those before the intervention ($M = 3.52$, SD = 0.79). Considering the total score, there was a significant difference ($p = 0.004$) between the students' pre-intervention ($M = 3.70$, SD = 0.49) and post-intervention ($M = 3.89$, SD = 0.54) results regarding skills development because of participating in the SiE ($p = 0.004$). Therefore, these results suggest that the SiE intervention positively impacted the students' skill development.

3.1.2 | Affective Domain: Students' Perceptions, Attitudes and Behaviours

Table 2 shows pre- and post-intervention results related to the affective domain. It indicates that there was a significant difference between the pre- and post-intervention attitudes and behaviours of students towards sustainability who participated

in the SiE ($p < 0.05$). The students were stated to have more sustainable attitudes after the intervention ($M = 3.81$, SD = 0.62) than before ($M = 3.61$, SD = 0.59). Similarly, students had more sustainable behaviours after the intervention ($M = 3.80$, SD = 0.60) than before ($M = 3.64$, SD = 0.49). However, there was no significant difference between the students' pre-intervention ($M = 3.96$, SD = 0.52) and post-intervention ($M = 3.93$, SD = 0.55) scores for their perception of sustainability ($p = 0.687$). These results suggest that university–business collaboration through PBL positively impacted students' attitudes and behaviours towards sustainability. However, their perceptions seem to be similar. This might be due to students' relatively high sustainability perception before participating in the project. Therefore, this might have left less room for improvement than changes in behaviour and attitude, as most projects within the SiE had a short duration.

3.1.3 | Career Readiness

Table 3 depicts the results for career readiness, a key focus of HEIs. It illustrates a significant difference between the pre-intervention ($M = 3.90$, SD = 0.58) and post-intervention ($M = 3.69$, SD = 0.74) results of the students who participated in the SiE for their career readiness level. However, this difference was in the negative direction. Surprisingly, the students' career readiness level was found to be lower after the project than their level before the project. On the one hand, this result could suggest that university–business collaboration through PBL might not be perceived as apt for career readiness. On the other hand, it could have made students more aware of industry needs and increased awareness of high perceived expectations. Alternative projects, such as work-based projects (e.g., where students work within organisations for a longer period, for example, apprenticeships, internships and placements), might show different results due to the nature of the student experience.

3.2 | SW Impact on Student KE for Sustainability

3.2.1 | Capacity Building: Students' Knowledge, Competencies and Skills

Figure 6 compares the pre- and post-intervention results on sustainability knowledge for SW ADBE. There was a significant difference between the pre- and post-intervention scores of the students for each item under each theme of sustainability knowledge ($p < 0.05$). Considering the total score, the students reported a higher level of sustainability knowledge after the intervention ($M = 3.57$, SD = 0.49) compared to the pre-intervention period ($M = 2.97$, SD = 0.54). The most significant differences were related to carbon management, social equity and justice and stakeholder participation, directly reflecting the topics addressed in the SW.

Figure 7 shows the pre- and post-intervention results on sustainability competencies for the SW. There was a significant difference between students' total pre-intervention ($M = 3.43$, SD = 0.52) and total post-intervention ($M = 3.70$, SD = 0.47) scores for sustainability competencies ($p = 0.010$), particularly between the pre-intervention ($M = 3.16$, SD = 0.69) and post-intervention ($M = 3.55$, SD = 0.61) scores on systems thinking competency level ($p = 0.005$). Similarly, the students' post-intervention score ($M = 3.76$, SD = 0.69) for futures thinking or anticipatory competency was significantly higher than their pre-intervention score ($M = 3.33$, SD = 0.63) ($p = 0.002$). These results suggest that the SW positively impacted the development of students' sustainability competencies. The competencies with the most significant differences also reflect the approach adopted in this project, where students were challenged to identify possible impacts using systems thinking and considering alternative scenarios.

Results on the sustainability skills from the SW ADBE students show no significant difference between the pre- and post-intervention overall scores ($p > 0.05$). This may be explained by the fact that these students were not directly engaged in a real-world experiential learning project with a business as a client. The 'hands-on' experience could have allowed them to develop sustainability skills, as seen in the case of students collaborating with businesses on real-world projects. Therefore, embedding the interaction with businesses in modules can potentially support the development of skills in sustainability.

3.2.2 | Affective Domain: Students' Perceptions, Attitudes and Behaviours

Results suggest no significant difference between the students' pre- and post-intervention scores for their perceptions, attitudes and behaviours towards sustainability ($p > 0.05$). This might be related to the SW's duration, which lasted only 5 days. While short-term projects enhance students' sustainability knowledge, longer-term projects are necessary to develop and deepen sustainability attitudes and behaviours.

3.2.3 | Career Readiness

Table 4 presents students' pre- and post-SW career readiness. It indicates that there was a significant difference between the

TABLE 3 | Pre- and post-intervention mean scores on career readiness: SiE.

	Pre-intervention ($N = 181$)		Post-intervention ($N = 90$)		*t*-test for equality of means		
Variable	**Mean**	**SD**	**Mean**	**SD**	***t***	**df**	***p***
Career readiness	3.90	0.58	3.69	0.74	−2.550	269	0.020*

Abbreviations: df, degrees of freedom; *N*, total number of participants; SD, standard deviation.
*$p < 0.05$.

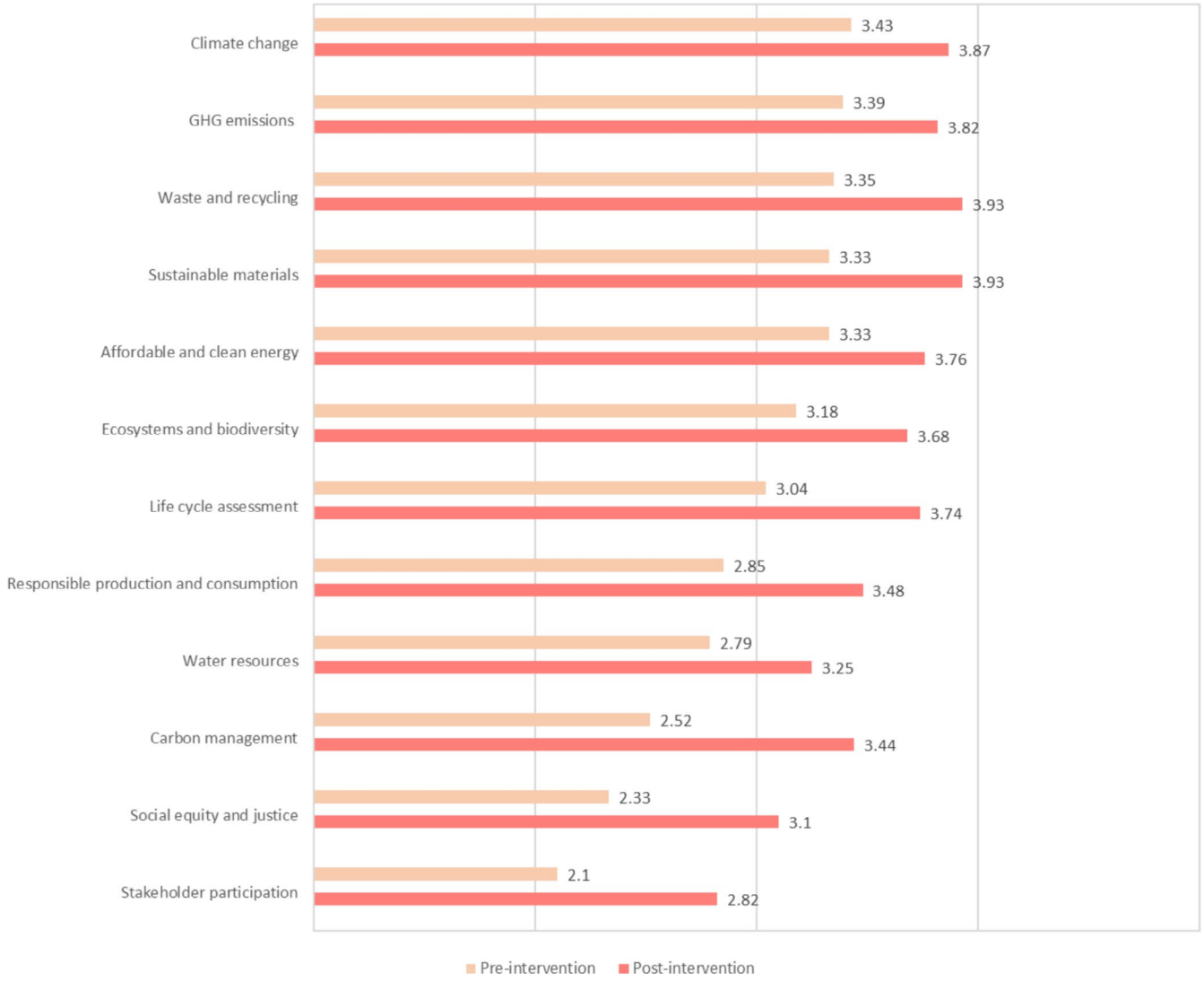

FIGURE 6 | Pre- and post-intervention mean scores on sustainability knowledge: SW.

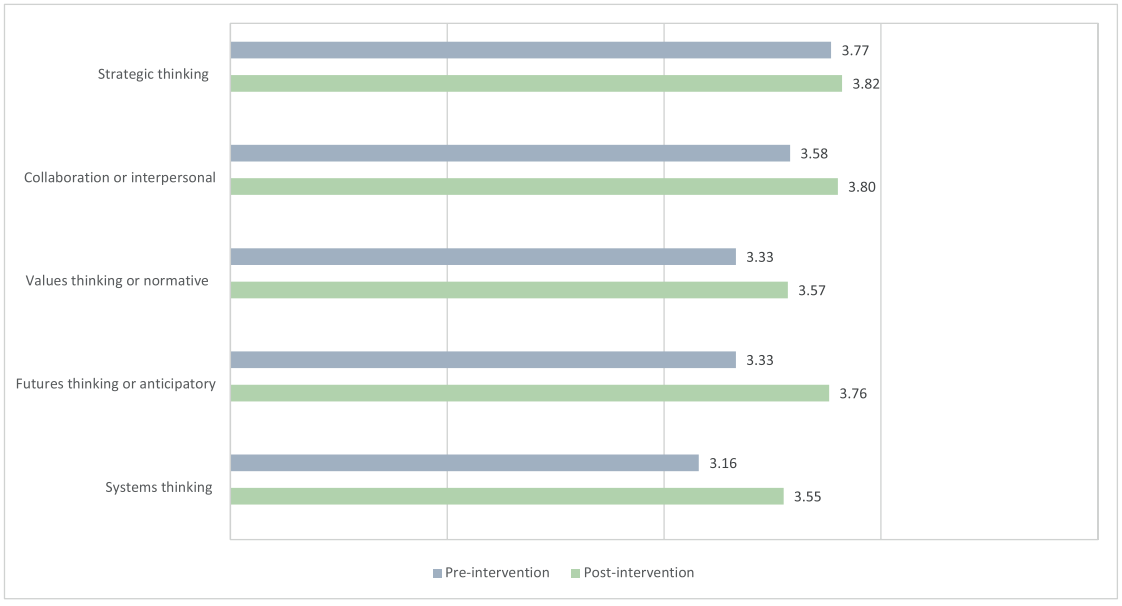

FIGURE 7 | Pre- and post-intervention mean scores on sustainability competencies: SW.

TABLE 4 | Pre- and post-intervention mean scores on career readiness: SW.

	Pre-intervention ($N=48$)		Post-intervention ($N=47$)		*t*-test for equality of means		
Variable	**Mean**	**SD**	**Mean**	**SD**	***t***	**df**	***p***
Career readiness	3.69	0.40	3.34	0.56	−3.454	93	< 0.001***

Abbreviations: df, degrees of freedom; *N*, total number of participants; SD, standard deviation.
***$p < 0.001$.

pre-intervention ($M=3.69$, SD = 0.40) and post-intervention ($M=3.34$, SD = 0.56) scores ($p < 0.001$). However, this difference was in the negative direction. The students' level of readiness for a career in sustainability was determined to be higher before they participated in the SW than their level after the project. This result might indicate that, given the complex nature of sustainability, students require longer-term work-based projects rather than short-term project-based activities in the module to feel adequately prepared for a career in sustainability. However, engagement with short-term projects in the SW can be a positive learning experience for students (as seen in the previous variables), encouraging them to explore and gain knowledge and competencies.

3.3 | Design and Implementation of KE Projects: Results as per School and Type of Project

Table 5 demonstrates the ANOVA test results conducted to determine whether there were significant differences in the students' post-intervention scores for their capacity building, affective domain and career readiness based on the school and projects they participated in.

There was a significant difference in the students' level of sustainability knowledge based on the projects they participated in ($p = 0.003$). After the project intervention, the NBS students who participated in the SiE and the ADBE students who participated in the SW had a higher level of sustainability knowledge than the ADBE students who participated in the SiE. However, there was no significant difference among the students' scores for developing competencies and skills based on the projects they participated in ($p > 0.05$).

Also, there was a significant difference among the students' scores for perceptions, attitudes, and behaviours towards sustainability based on the projects they participated in ($p < 0.05$). After the intervention, the NBS students who participated in the SiE had a higher level of sustainability perception than the ADBE students who participated in the SiE. Furthermore, the NBS students who participated in the SiE were found to have a higher level of attitudes and behaviours towards sustainability compared to the ADBE students who participated in the SW. One reason might be that NBS students are exposed to sustainability-related topics longer than the other students (even the final year ADBE students, as sustainability was still mostly absent from the curriculum).

Finally, there was a significant difference in the students' career readiness level based on the projects they participated in ($p < 0.001$). After the intervention, the NBS students who participated in the SiE had a significantly higher level of readiness for a career regarding sustainability compared to the ADBE students who participated in the SiE and those who had taken part in the SW. This could be because NBS has been mainstreaming sustainability in and outside the core curriculum from the first year while aligning sustainability with employability through a range of Continuing Professional Development (CPD) opportunities.

The design and implementation of KE projects in the curriculum affect students' KE for sustainability. At NBS, the SiE is integrated into the curriculum through the final year undergraduate module, SiE Project, which is an alternative to the traditional research dissertation. At ADBE, due to time restrictions related to the funded project window, it was not possible to integrate the SiE formally into the curriculum. Embedding sustainability and PBL pedagogy can be resource-intensive and requires engagement with course and module teams and space within the course curriculum. At ADBE, there was still an opportunity for architecture students in their final year to opt in to engage in the SiE, and the product design students in Year 2 were engaged due to the interest of one of the module leaders. Therefore, engagement with relevant academics is key to bringing change within the curriculum as long as it aligns with the module and course learning outcomes.

Another difference is that NBS provided a set framework that all students used in the SiE module to provide carbon management consultancy to a diverse population of SMEs who act as clients. Furthermore, SiE NBS was developed based on previous experience running a similar GHG management consultancy project for final-year BA Business students. At ADBE, the type of support was bespoke, reflecting the nature of the design assessment processes. Each group created its own analysis, including identifying key aspects to be assessed and naturally differentiating between architecture and design students, which led to the variety of sustainability knowledge acquired. However, the opportunity to tailor the project for students might be seen as too demanding as often students are not confident enough, even with the support of academics. At the same time, at NBS, students were in their final year, so they had already been exposed to sustainability and SDGs-related topics in the earlier years. At ADBE, it was predominantly the first time that students engaged in such topics. Consequently, there seem to be significant and positive impacts if KE for sustainability is embedded within the core curriculum, using a set framework for all teams and students are exposed to sustainability-related concepts and topics for longer during their studies.

TABLE 5 | ANOVA test results of the comparison of the impacts of student KE for sustainability by school and project.

Variables	Project	*N*	Mean	SD	*F*	*p*
Capacity building						
Sustainability knowledge	SiE NBS	47	3.67	0.62	6.199	0.003**
	SiE ADBE	43	3.27	0.54		
	SW ADBE	47	3.57	0.49		
Sustainability competencies	SiE NBS	47	3.82	0.55	2.038	0.134
	SiE ADBE	43	3.59	0.55		
	SW ADBE	47	3.70	0.47		
Skills development	SiE NBS	47	3.96	0.55	2.141	0.122
	SiE ADBE	43	3.82	0.53		
	SW ADBE	47	3.75	0.40		
Affective domain						
Sustainability perceptions	SiE NBS	47	4.05	0.57	3.362	0.038*
	SiE ADBE	43	3.79	0.49		
	SW ADBE	47	3.84	0.46		
Sustainability attitudes	SiE NBS	47	3.93	0.64	6.227	0.03*
	SiE ADBE	43	3.67	0.57		
	SW ADBE	47	3.49	0.60		
Sustainability behaviours	SiE NBS	47	3.93	0.61	6.407	0.02*
	SiE ADBE	43	3.66	0.57		
	SW ADBE	47	3.48	0.62		
Career readiness	SiE NBS	47	3.93	0.80	10.503	<0.001***
	SiE ADBE	43	3.43	0.57		
	SW ADBE	47	3.34	0.56		

Abbreviations: *N*, total number of participants; SD, standard deviation.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

4 | Discussion

This study shows that PBL significantly impacts students' KE for sustainability. As Birdman et al. (2022) suggested, it can help students gain sustainability knowledge and competencies. By comparing students who collaborated with a business as their client to SW students who did not collaborate with a real business, besides gaining knowledge and competencies, the university–business collaboration component also supported students in gaining sustainability skills, attitudes and behaviours. The university–business collaboration supported the development of key skills such as consulting, research, presentation and project management. These skills would not be gained using traditional teaching methods (Belwal et al. 2020), such as passive students listening in lecture theatres. This difference was also found in sustainability attitudes and behaviours, where the students who collaborated with a business benefited the most. The benefits are also for businesses, as often SMEs rely on these projects to start their sustainability journey (see, e.g., Mazhar et al. 2024). This aligns with previous studies highlighting the benefits of multiple actors collaborating in the knowledge-sharing process in the context of KE (Fazey et al. 2013, 2014).

Sustainability perceptions and career readiness did not significantly change after the projects, including the students who worked with businesses and those who did not. Previous research by Heiskanen et al. (2016) highlights that consultancy-type courses support students' work challenges. In contrast, the present research shows that students do not feel that the intervention prepares them for a career. This could be because students are exposed for the first time to industry expectations, often higher than previously expected by students or unknown, and students might feel there is still more to learn. It could also have been due to the relatively short duration of the projects and the fact that students still work primarily in the academic environment.

When comparing the two groups that collaborated with businesses, the SiE NBS students scored higher than SiE ADBE

students in their sustainability perceptions, which illustrates the fact that the first group has been exposed to sustainability-related topics for longer from their first year in the course when compared to SiE ADBE students. Previous research has shown how work-based projects, where students work with the industry for part of their studies, such as apprenticeships, placements or studentships, might be perceived as preparing students for a career in the industry (Samuel et al. 2018). PBL could be combined with a period of work experience with a business, allowing students to work longer with a business on a real-world problem. This supports the argument that practice-based education can help learners gain the competencies for sustainability required to support the transformation (Sattich et al. 2024).

ADBE and NBS strive to embed sustainability in the curriculum in line with the United Kingdom HEIs requirements and NTU's strategy, where embracing sustainability is a strategic theme. There is a commitment for courses to have sustainability-related learning outcomes by integrating SDGs and education for sustainability. NTU has a long history of strategically embedding sustainability and SDGs; sustainability reviews of courses have taken place in every school. Through this, sustainability, employability and personalisation initiatives are being extended throughout the institution (Winfield and Ndlovu 2019). For instance, sustainability is now part of learning outcomes in multiple modules, which were previously absent.

The present research also shows how schools from different disciplines collaborate and provide real-world projects to students for a novel experience in line with the course and module learning outcomes. Differences between schools show the importance of exposing students to sustainability-related topics for longer and in a more formal and structured way, as SiE NBS mean scores on the impact of student KE were higher in all variables analysed. Furthermore, an opportunity for cross-school learning is recognised to make future enhancements in courses and modules for a better student experience and to enhance their employability.

In both schools, a learner-centred approach was prioritised, where the hierarchy of lecturer over student is removed to create a critical learning community. Sandri and Holdsworth (2022) have discussed how this approach supports critical thinking and reflection for self-transformation and requires a shift in the structure of HEIs. It also contributed to teaching students' capacity instead of only sustainability-related concepts to prepare them for the multiple sustainability challenges they might face in the organisations they will work for once they graduate. The funded SiE programme was essential to developing a PBL environment as it provided the resources and infrastructure to allocate academics to support students' work. Also, institutional support and KE activity need to be treated in an intersection with other university activities, as discussed by Marzocchi et al. (2023).

At ADBE, due to the SW and SiE, the development and integration of sustainability in teaching through PBL was just the start of the wider adoption and enhancements with more focus on sustainability. Due to its success, some modules now include 10–15 weeks dedicated to sustainability topics, and the industry is engaged whenever possible. The assessments were also designed to measure key knowledge, such as life cycle analysis, carbon emission assessment and design for sustainable behaviour change. Assessment is crucial when it comes to embedding capacity building. However, further work should be developed on, for example, how sustainability competencies are currently assessed in the curriculum (Redman and Wiek 2021).

Elective projects have also been introduced at ADBE because of the course rewrite, and at this point, students can once again choose to specialise in a sustainability-focused project. Beyond individual assignments, individual taught sessions are dedicated to sustainability through activities such as teaching life cycle assessment/analysis software. Interestingly, many students who participated in the SiE programme and are now in their final year have sustainability at the core of their final projects.

Enhancements are also being made at NBS to offer a more joined-up approach to integrating sustainability at a course level while ensuring learning progression. This aligns with Alcántara-Rubio et al. (2022), who argue for a holistic and systemic approach to integrate sustainability into the curriculum. Efforts are made to scaffold sustainability learning, leading to the SiE module in the final year. Therefore, courses are being reviewed to make any necessary changes through action planning to achieve a more systematic approach to developing sustainability knowledge, competencies and skills among business students at NBS.

Lastly, several challenges exist in developing and delivering PBL in collaboration with businesses. Firstly, there might be a misalignment between business needs, curriculum and module learning outcomes and the scope or targets of the funded business support programme. Developing projects that meet the business, learning and project requirements can be challenging. Adopting bespoke projects is more time-consuming for instructors and learners, even though it might align with business goals. The existence of a specific framework or methodology for students to use in a module, such as in the case of SiE NBS, might support less confident students in engaging with businesses. Furthermore, exposure to sustainability for a longer period can also add value to the student learning experience and outcomes. Secondly, HEIs must integrate this approach into their core curriculum and teaching and learning activities and be less dependent on external funding such as ERDF. However, this has resource implications and might not be ideal in the current situation of funding constraints in the sector. Recruiting businesses for student projects demands significant business development and marketing activity. Thus, it relies on individual academics, particularly course and module leaders, willing to integrate sustainability and university–business collaboration through PBL into the curriculum. An option is to integrate PBL in modules where students must apply what they have learnt in the other modules (as shown in the SiE NBS). This could support integrating a more interactive and relevant pedagogy to prepare students to face and solve sustainability challenges.

5 | Conclusions and Recommendations

The university sector in England and Wales faces significant challenges as the value of university degrees is increasingly

questioned about the costs of fees, mounting student debt and graduate outcomes. Put simply, is a degree worth it? In that context, the impact of a student's learning experience at university is rightly scrutinised, and this study offers a novel contribution. In terms of developing academic knowledge via the impact of student KE activities on sustainability, our research shows that there are benefits to conducting PBL, but the impact is greater when students collaborate directly with businesses. It also represents a novelty in combining data from two disciplines, business and architecture and design schools.

Among the lessons from this research is the need to integrate collaboration with businesses within the curriculum at universities. This can be done by enhancing students' exposure to sustainability from the beginning of their courses to prepare them for their final year of collaborating with businesses and providing consultancy in sustainability for KE. The study shows it can enhance students' sustainability knowledge, competencies, skills, attitudes and behaviours. It can also benefit in creating a set framework that students can use to provide consultancy to various businesses. This can be accomplished by surveying businesses on their needs on the topic of sustainability and matching them with the learning outcomes of different courses and modules. However, the process is resource-intensive as there is a need to create and maintain a network of businesses to collaborate with the university. There is also a need to manage negative outcomes from the collaboration, for example, when students' outputs do not meet businesses' expectations.

Future work can explore how to enhance sustainability perceptions and career readiness, for instance, by comparing project-based versus work-based teaching and learning alternatives. It would be helpful to conduct further studies on the graduates who participated in the present or similar research to analyse their perceptions and career development after graduating. This future research can add value to current and future students and impact society's readiness for an uncertain future.

Author Contributions

Ana Rita Domingues: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing – original draft, writing – review and editing. **Gamze Yakar-Pritchard:** conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing – original draft, writing – review and editing. **Muhammad Usman Mazhar:** conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, writing – review and editing. **Francesco Luke Siena:** data curation, methodology, resources, supervision, writing – review and editing. **Richard Bull:** funding acquisition, investigation, project administration, resources, writing – review and editing.

Acknowledgements

The authors would like to thank the Knowledge Exchange Department at Nottingham Trent University for funding this research through the Higher Education Innovation Funding (HEIF). The research project was conducted in the context of the Sustainability in Enterprise (SiE) programme at Nottingham Trent University, United Kingdom, part-funded by the European Regional Development Fund (ERDF). All organisations mentioned in this paper, including authors' affiliations and funding sources, played no part in the paper's design, analysis, interpretation, writing-up or the decision to publish it.

Ethics Statement

Ethical approval to conduct the present research was obtained from the Research Ethics Committee at Nottingham Trent University—School of Architecture, Design and the Built Environment.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The research data for this article are deposited in the NTU Data Archive and are available to bona fide researchers with confirmed ethical consent. To arrange to access a copy of this research data set, contact the Library Research Support team: libresearchteam@ntu.ac.uk.

References

Albareda-Tiana, S., S. Vidal-Raméntol, and M. Fernández-Morilla. 2018. "Implementing the Sustainable Development Goals at University Level." *International Journal of Sustainability in Higher Education* 19, no. 3: 473–497. https://doi.org/10.1108/IJSHE-05-2017-0069/FULL/PDF.

Alcántara-Rubio, L., R. Valderrama-Hernández, C. Solís-Espallargas, and J. Ruiz-Morales. 2022. "The Implementation of the SDGs in Universities: A Systematic Review." *Environmental Education Research* 28, no. 11: 1585–1615. https://doi.org/10.1080/13504622.2022.2063798.

Alm, K., T. H. Beery, D. Eiblmeier, and T. Fahmy. 2022. "Students' Learning Sustainability—Implicit, Explicit or Non-Existent: A Case Study Approach on Students' Key Competencies Addressing the SDGs in HEI Program." *International Journal of Sustainability in Higher Education* 23, no. 8: 60–84. https://doi.org/10.1108/IJSHE-12-2020-0484/FULL/PDF.

Banfield, R., C. T. Lombardo, and T. Wax, eds. 2015. *Design Sprint: A Practical Guidebook for Building Great Digital Products*. 1st ed. O'Reilly Media.

Barth, M., J. Godemann, M. Rieckmann, and U. Stoltenberg. 2007. "Developing Key Competencies for Sustainable Development in Higher Education." *International Journal of Sustainability in Higher Education* 8, no. 4: 416–430. https://doi.org/10.1108/14676370710823582.

Belwal, R., S. Belwal, A. B. Sufian, and A. Al Badi. 2020. "Project-Based Learning (PBL): Outcomes of Students' Engagement in an External Consultancy Project in Oman." *Education and Training* 63, no. 3: 336–359. https://doi.org/10.1108/ET-01-2020-0006/FULL/XML.

Birdman, J., A. Wiek, and D. J. Lang. 2022. "Developing Key Competencies in Sustainability Through Project-Based Learning in Graduate Sustainability Programs." *International Journal of Sustainability in Higher Education* 23, no. 5: 1139–1157. https://doi.org/10.1108/IJSHE-12-2020-0506/FULL/PDF.

Briens, E. C. M., Y. Chiu, D. Braun, et al. 2023. "Assessing Sustainability Knowledge for Undergraduate Students in Different Academic Programs and Settings." *International Journal of Sustainability in Higher Education* 24, no. 1: 69–95. https://doi.org/10.1108/IJSHE-10-2021-0455.

Brundiers, K., M. Barth, G. Cebrián, et al. 2021. "Key Competencies in Sustainability in Higher Education—Toward an Agreed-Upon Reference Framework." *Sustainability Science* 16, no. 1: 13–29. https://doi.org/10.1007/S11625-020-00838-2.

Brundiers, K., A. Wiek, and C. L. Redman. 2010. "Real-World Learning Opportunities in Sustainability: From Classroom Into the Real World." *International Journal of Sustainability in Higher Education* 11, no. 4: 308–324. https://doi.org/10.1108/14676371011077540.

Caraballo-Cueto, J., M. Franco-Ortiz, R. L. Tremblay, J. Hernández-Serrano, and I. Godreau. 2024. "Can Coaching Bridge the Gap for Incoming Latinx Graduate Students?" *Studies in Higher Education* 50, no. 3: 439–463. https://doi.org/10.1080/03075079.2024.2341118.

Ceulemans, G., and N. Severijns. 2019. "Challenges and Benefits of Student Sustainability Research Projects in View of Education for Sustainability." *International Journal of Sustainability in Higher Education* 20, no. 3: 482–499. https://doi.org/10.1108/IJSHE-02-2019-0051/FULL/XML.

Curran, P. G. 2016. "Methods for the Detection of Carelessly Invalid Responses in Survey Data." *Journal of Experimental Social Psychology* 66: 4–19. https://doi.org/10.1016/J.JESP.2015.07.006.

Cvitanovic, C., R. J. Shellock, M. Mackay, et al. 2021. "Strategies for Building and Managing 'Trust' to Enable Knowledge Exchange at the Interface of Environmental Science and Policy." *Environmental Science & Policy* 123: 179–189. https://doi.org/10.1016/J.ENVSCI.2021.05.020.

Domingues, A. R., P. Jensen, and R. Bull. 2024. "Business-University Collaboration Through Student-Led Sustainability Consultancy: Drivers, Challenges, and Outcomes." In *How to Enable Engagement Between Universities and Business*. Edward Elgar Publishing. https://doi.org/10.4337/9781035316809.00050.

Fazey, I., L. Bunse, J. Msika, et al. 2014. "Evaluating Knowledge Exchange in Interdisciplinary and Multi-Stakeholder Research." *Global Environmental Change* 25, no. 1: 204–220. https://doi.org/10.1016/J.GLOENVCHA.2013.12.012.

Fazey, I., A. C. Evely, M. S. Reed, et al. 2013. "Knowledge Exchange: A Review and Research Agenda for Environmental Management." *Environmental Conservation* 40, no. 1: 19–36. https://doi.org/10.1017/S037689291200029X.

George, D., and M. Mallery. 2010. *SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 Update*. 10th ed. Pearson.

Hair, J. F., W. C. Black, B. J. Babin, and R. E. Anderson. 2014. *Multivariate Data Analysis*. Pearson Education Limited.

Heeren, A. J., A. S. Singh, A. Zwickle, T. M. Koontz, K. M. Slagle, and A. C. McCreery. 2016. "Is Sustainability Knowledge Half the Battle?: An Examination of Sustainability Knowledge, Attitudes, Norms, and Efficacy to Understand Sustainable Behaviours." *International Journal of Sustainability in Higher Education* 17, no. 5: 613–632. https://doi.org/10.1108/IJSHE-02-2015-0014/FULL/XML.

Heiskanen, E., Å. Thidell, and H. Rodhe. 2016. "Educating Sustainability Change Agents: The Importance of Practical Skills and Experience." *Journal of Cleaner Production* 123: 218–226. https://doi.org/10.1016/j.jclepro.2015.11.063.

Johnson, M. T. 2022. "The Knowledge Exchange Framework: Understanding Parameters and the Capacity for Transformative Engagement." *Studies in Higher Education* 47, no. 1: 194–211. https://doi.org/10.1080/03075079.2020.1735333.

Karcher, D. B., C. Cvitanovic, I. E. van Putten, et al. 2022. "Lessons From Bright-Spots for Advancing Knowledge Exchange at the Interface of Marine Science and Policy." *Journal of Environmental Management* 314: 114994. https://doi.org/10.1016/J.JENVMAN.2022.114994.

Lozano, R., M. Y. Merrill, K. Sammalisto, K. Ceulemans, and F. J. Lozano. 2017. "Connecting Competences and Pedagogical Approaches for Sustainable Development in Higher Education: A Literature Review and Framework Proposal." *Sustainability* 9, no. 10: 1889. https://doi.org/10.3390/SU9101889.

Marzocchi, C., F. Kitagawa, F. Rossi, and E. Uyarra. 2023. "Reconceptualising Knowledge Exchange and Higher Education Institutions: Broadening Our Understanding of Motivations, Channels, and Stakeholders." *Studies in Higher Education* 48, no. 5: 673–682. https://doi.org/10.1080/03075079.2023.2184791.

Mazhar, M. U., A. R. Domingues, G. Yakar-Pritchard, R. Bull, and K. Ling. 2024. "Reaching for Net Zero: The Impact of an Innovative University-Led Business Support Programme on Carbon Management Strategy and Practices of Small and Medium-Sized Enterprises." *Business Strategy and the Environment* 33: 6940–6960. https://doi.org/10.1002/BSE.3844.

McCauley-Smith, C., S. Smith, L. Nantunda, and X. Zhu. 2022. "The Role of Anchor Institutions in Creating Value for SMEs: Insights From North East of England Owner-Managers." *Studies in Higher Education* 47, no. 6: 1121–1133. https://doi.org/10.1080/03075079.2020.1861593.

Naderi, N., F. Monavvarifard, and L. Salehi. 2022. "Fostering Sustainability-Oriented Knowledge-Sharing in Academic Environment: A Key Strategic Process to Achieving SDGs Through Development of Students' Sustainable Entrepreneurship Competences." *International Journal of Management Education* 20, no. 1: 100603. https://doi.org/10.1016/j.ijme.2022.100603.

Ngo, T. T., and B. Chase. 2021. "Students' Attitude Toward Sustainability and Humanitarian Engineering Education Using Project-Based and International Field Learning Pedagogies." *International Journal of Sustainability in Higher Education* 22, no. 1: 254–273. https://doi.org/10.1108/IJSHE-06-2020-0214/FULL/XML.

Ning, H. K., and K. Downing. 2010. "The Impact of Supplemental Instruction on Learning Competence and Academic Performance." *Studies in Higher Education* 35, no. 8: 921–939. https://doi.org/10.1080/03075070903390786.

Parsons, S. 2021. "The Importance of Collaboration for Knowledge Co-Construction in 'Close-To-Practice' Research." *British Educational Research Journal* 47, no. 6: 1490–1499. https://doi.org/10.1002/BERJ.3714.

Perusso, A., and R. Wagenaar. 2022. "The State of Work-Based Learning Development in EU Higher Education: Learnings From the WEXHE Project." *Studies in Higher Education* 47, no. 7: 1423–1439. https://doi.org/10.1080/03075079.2021.1904233.

Read, J., C. Rigby, T. Dray, et al. 2022. "Student Knowledge Exchange Impact Toolkit."

Redman, A., and A. Wiek. 2021. "Competencies for Advancing Transformations Towards Sustainability." *Frontiers in Education* 6: 785163. https://doi.org/10.3389/FEDUC.2021.785163.

Sales de Aguiar, T. R., and A. S. Paterson. 2018. "Sustainability on Campus: Knowledge Creation Through Social and Environmental Reporting." *Studies in Higher Education* 43, no. 11: 1882–1894. https://doi.org/10.1080/03075079.2017.1289506.

Sam, C., P. Van Der Sijde, C. Sam, Á. P. Van Der Sijde, and P. Sijde. 2014. "Understanding the Concept of the Entrepreneurial University From the Perspective of Higher Education Models." *Higher Education* 68, no. 6: 891–908. https://doi.org/10.1007/s10734-014-9750-0.

Samuel, G., C. Donovan, and J. Lee. 2018. "University–Industry Teaching Collaborations: A Case Study of the MSc in Structural Integrity Co-Produced by Brunel University London and the Welding Institute." *Studies in Higher Education* 43, no. 4: 769–785. https://doi.org/10.1080/03075079.2016.1199542.

Sandri, O., and S. Holdsworth. 2022. "Pedagogies for Sustainability: Insights From a Foundational Sustainability Course in the Built Environment." *International Journal of Sustainability in Higher Education* 23, no. 3: 666–685. https://doi.org/10.1108/IJSHE-01-2021-0002/FULL/XML.

Sattich, T. M., S. Stedronsky, and B. Ås. 2024. "Promoting Sustainability Through Competencies? An Explorative Case Study on Higher Education in Norway." *Journal of Asian Public Policy*: 1–18. https://doi.org/10.1080/17516234.2024.2363087.

Segalàs, J., D. Ferrer-Balas, and K. F. Mulder. 2010. "What Do Engineering Students Learn in Sustainability Courses? The Effect of the Pedagogical Approach." *Journal of Cleaner Production* 18, no. 3: 275–284. https://doi.org/10.1016/J.JCLEPRO.2009.09.012.

Sprain, L., and W. M. Timpson. 2012. "Pedagogy for Sustainability Science: Case-Based Approaches for Interdisciplinary Instruction." *Environmental Communication: A Journal of Nature and Culture* 6, no. 4: 532–550. https://doi.org/10.1080/17524032.2012.714394.

Tho, N. D. 2017. "Knowledge Transfer From Business Schools to Business Organizations: The Roles Absorptive Capacity, Learning Motivation, Acquired Knowledge and Job Autonomy." *Journal of Knowledge Management* 21, no. 5: 1240–1253. https://doi.org/10.1108/JKM-08-2016-0349/FULL/XML.

Trencher, G., S. Vincent, K. Bahr, S. Kudo, K. Markham, and Y. Yamanaka. 2018. "Evaluating Core Competencies Development in Sustainability and Environmental Master's Programs: An Empirical Analysis." *Journal of Cleaner Production* 181: 829–841. https://doi.org/10.1016/J.JCLEPRO.2018.01.164.

UNESCO. 2017. "Education for Sustainable Development Goals. The Global Education 2030 Agenda." 1–68. https://bangkok.unesco.org/content/education-sustainable-development-goals-learning-objectives.

Wang, Y., M. Sommier, and A. Vasques. 2022. "Sustainability Education at Higher Education Institutions: Pedagogies and Students' Competences." *International Journal of Sustainability in Higher Education* 23, no. 8: 174–193. https://doi.org/10.1108/IJSHE-11-2021-0465/FULL/PDF.

Wiek, A., L. Withycombe, and C. L. Redman. 2011. "Key Competencies in Sustainability: A Reference Framework for Academic Program Development." *Sustainability Science* 6, no. 2: 203–218. https://doi.org/10.1007/s11625-011-0132-6.

Wiek, A., A. Xiong, K. Brundiers, and S. van der Leeuw. 2014. "Integrating Problem and Project-Based Learning Into Sustainability Programs: A Case Study on the School of Sustainability at Arizona State University." *International Journal of Sustainability in Higher Education* 15, no. 4: 431–449. https://doi.org/10.1108/IJSHE-02-2013-0013/FULL/PDF.

Winfield, F., and T. Ndlovu. 2019. "'Future-Proof Your Degree': Embedding Sustainability and Employability at Nottingham Business School (NBS)." *International Journal of Sustainability in Higher Education* 20, no. 8: 1329–1342. https://doi.org/10.1108/IJSHE-10-2018-0196.

Winfield, K. E., J. Woolley, E. G. Bradley, et al. 2023. "Sustainable Innovation Through Datadriven Design Using Lifecycle Analysis (LCA) Methodology." In *DS 123: Proceedings of the International Conference on Engineering and Product Design Education (E&PDE 2023).* https://doi.org/10.35199/EPDE.2023.41.

Yakar-Pritchard, G., M. U. Mazhar, A. R. Domingues, and R. Bull. 2024. "Measuring the Impact of Student Knowledge Exchange for Sustainability: A Systematic Literature Review and Framework." *Cleaner Production Letters* 6: 100056. https://doi.org/10.1016/J.CLPL.2024.100056.

You, J. W. 2023. "Relationship Between Team Learning Profiles and Outcomes in Team Project-Based Learning: A Cluster Analysis." *Studies in Higher Education* 49, no. 1: 16–32. https://doi.org/10.1080/03075079.2023.2219298.