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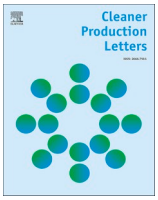

Measuring the impact of student knowledge exchange for sustainability: A systematic literature review and framework

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ABSTRACT

Knowledge Exchange is a rapidly emerging phenomenon in the higher education sector. Nevertheless, it remains a niche area with limited studies examining the impact of knowledge exchange for sustainability on students. This research adopted a systematic literature review approach to review sustainability-oriented project-based learning and student knowledge exchange with a view to developing a framework to measure the impact of student knowledge exchange for sustainability. The literature review was based on 38 journal papers selected out of 3578 search results with an application of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart methodology. A qualitative content analysis was used to identify and explore the main concepts and variables to evaluate the content of the articles selected by SLR. The results showed three main categories to be systematically measured to understand their impact: (i) capacity building, (ii) affective domain, and (iii) career readiness. Capacity building requires measuring students' sustainability knowledge, competence, and skill levels. The affective domain evaluates changes in students' perceptions, attitudes, and behaviours identified as affective learning outcomes for sustainability. Career readiness assesses a student's level of preparation for the workplace. These variables/constructs informed the development of a framework to measure the impact of student KE for sustainability in a systematic and comprehensive way. The proposed framework is the study's main contribution, supporting measuring the impact of student knowledge exchange for sustainability. It provides a way to address impact holistically and define what specific variables/constructors should be measured to quantify students' impact.

1. Introduction

Education is crucial in developing future transformational and sustainable leaders, and there is an increasing focus on integrating sustainability into the higher education institutions (HEIs) curriculum. Education for Sustainable Development (ESD) is acknowledged as critical for sustainable development (UN General United Nations General Assembly, 2022). Agenda 21 has stated that education is *'critical for achieving environmental and ethical awareness, values and attitudes, skills and behaviour consistent with sustainable development and for effective public participation in decision-making'* (United Nations Sustainable Development, 1992). Brundiers et al. (2010) noted that for students to cope with the complexity and uncertainty of sustainability issues creatively and successfully, they need to be exposed to these problems in their education. Therefore, HEIs need to explore innovative ways to develop the capacity for students to acquire sustainability knowledge, skills, and competencies for a sustainable future. In this context, a curriculum enhancement or change is necessary for universities to encourage students to progress toward sustainability and a humanistic paradigm in teaching and learning (García-Feijoo et al., 2020). Incorporating sustainability into the curriculum requires systems thinking and interdisciplinary approaches and calls for pedagogical innovations that enable interactive, experiential, transformative, and real-world learning (Lozano et al., 2017; Brundiers et al., 2010).

November 2023 saw the United Arab Emirates host the 28th Conference of the Parties (COP) of the UNFCCC (United Nations Framework

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Convention on Climate Change), seven years after COP21 in Paris, where there was an agreement to limit global warming to 1.5 °C. Whilst there was a muted agreement to begin to phase away from fossil fuels the latest report from the United Nations Environment Programme (UNEP), published the previous year drew the sobering conclusion that the national pledges since COP26 have made a negligible difference to predicted 2030 emissions and that we are far from the Paris Agreement goal of limiting global warming to well below 2 °C, preferably 1.5 °C (UNEP, 2022). Considering the limited progress of 28 COPs in addressing the issue of climate change, it is vital to reflect on how future generations can be formed and motivated to accelerate the reduction in carbon emissions and climate change mitigation to become more sustainable. HEIs must play a key role in educating students with the necessary knowledge, skills, and competencies to be sustainability-minded global citizens to bring transformative change in society (Briens et al., 2022; Segalàs et al., 2010).

Knowledge Exchange (KE) is a related concept that contributes to developing innovative learning strategies for sustainability and climate change issues by providing a better understanding of the outcomes of participatory learning methods such as work or project-based learning (PBL) and real-life experiential learning or consultancy opportunities. It implies a two or multi-directional knowledge-sharing process with mutual benefit and multi-learning between researchers, decision-makers, practitioners, businesses, and other beneficiaries (Fazey et al., 2013, 2014). The traditional approach of academics as the '*sole producers of knowledge*' has been challenged by an increasing interest in a co-production of knowledge gained as a result of involving multiple interactions such as engaging students and decision-makers (Karcher et al., 2022; Fazey et al., 2014). A key principle of KE practice is focused on engaging HEIs with stakeholders and broader society to bring change. KE aims to measure the academic, economic, and societal impact, change or benefit of learning, teaching, or other activities in HEIs (Johnson, 2022). This benefit can be measured across a wide spectrum, from enhancing students' knowledge, skills, and competencies and increasing labour market values to businesses generally seeking support resources at no cost or below market rates (Anderson, 2018; Johnson, 2022).

The present research was situated within a wider context of a student KE programme rather than education for sustainable development. Funded by the European Regional Development Fund (ERDF), the Sustainability in Enterprise (SiE) project enabled a range of services for Small to Medium Sized Enterprises (SMEs) that included free, practical support from specialists in sustainable business operations, building management, product design, and employee engagement and included carbon management workshops for SMEs and free consultancy from academics, practitioners, and students from the multi-disciplinary team at Nottingham Trent University (NTU), UK. Framed within this context of KE, rather than ESD, this paper utilises two related concepts: project-based learning (PBL) and KE.

PBL is employed as an engagement tool to implement KE activities for sustainability in HEIs and has received increasing attention for providing students with real-world experience to solve sustainability challenges. Kumpunen et al. (2023) highlight that project-based collaboration constitutes the most favoured approach for KE programs and articulate that PBL presents an efficacious method for developing new skills, attitudes, or ways of thinking. Project-based curriculum planning, and implementation are based on John Dewey's (1916) theory of '*learning by doing*' (Chang et al., 2018), which argues that students should be at the centre of the learning process and develop skills to prepare them for the future (Fernandes, 2014). Courses having PBL employ constructivist and experiential learning approaches (Brundiers and Wiek, 2013). These courses educate students and build a workforce of enthusiastic, knowledgeable, and systemic problem-solving individuals who can cope with sustainability issues in creative and holistic ways (Wiek et al., 2011). PBL courses often require interaction with key stakeholders such as students, academics, and organizational partners (Kricsfalusy et al., 2018) and offer opportunities for students and other stakeholders to exchange knowledge during the course for change.

In the UK context, the UK Government has taken several steps to promote participation as a tool for KE (Johnson, 2022). The Knowledge Exchange Framework (KEF) was introduced by Research England (RE) in 2020 as a new assessment tool (UK Research and Innovation, 2022) and the Office for Students (OfS) and RE launched a student involvement programme worth £10 million in 2020 to develop effective practices for student participation in KE activities outside of their curriculum. An evaluation report published by the OfS (2022) shows that approximately 16,700 students and 2300 partners have been involved in KE projects. Due to the inherent nature of KE, the method of measuring impact will vary according to different applications, stakeholders, or fields (Anderson, 2018). Consequently, there is a need to develop measurement tools for various types of KE activities. Despite some isolated examples of good practice, KE activity remains a niche activity – a gap this paper aims to address. There is a need for a study that will guide how to conduct a holistic evaluation of the impact of KE on students for sustainability.

The starting point of this study is to understand which variables need to be examined to measure the impact of student KE in the field of sustainability. A framework was developed by the University of Birmingham and Keele University (2022) to measure the impact of student KE (Read et al., 2022). However, this does not focus on sustainability and is limited in terms of holistic assessment and KE impact on students. Our study develops a framework using a systematic literature review (SLR) based on PBL approaches to fill this knowledge gap and contribute to this area of work (Lumsdon and McGrath, 2011; Leshem and Trafford, 2007). This framework can guide future studies to demonstrate the impact. The paper collects, critically analyses, and synthesises the existing literature studies on the concept of PBL and student KE. The main research questions underpinned by the aim of the study are as follows:

1. RQ1: What variables are examined in the academic literature to measure the impact of PBL for sustainability on students and student KE?
2. RQ2: What are the key skills and competencies mentioned as sustainability learning outcomes in the literature?
3. RQ3: How can the impact of student KE for sustainability be measured systematically?

The next section covers the research methodology, in which the SLR process and the chosen method for data analysis are discussed. Section 3 presents the findings obtained from the descriptive and content analysis of the literature found. This section also discusses the proposed framework to measure the impact of student KE for sustainability. Finally, section 4 presents the conclusions with the study's research contributions and practical implications, as well as recommendations for future developments.

2. Research methodology

This research adopts an SLR approach that is considered appropriate for studies with a specific research question and aims to analyse and synthesise existing studies' compilation to produce findings (Syaifullah et al., 2022). Systematic reviews represent a typical method of mapping the field and tracing recent developments in both educational science and sustainability science (Aboytes and Barth, 2020). As a research method, the SLR has potential contributions, such as determining whether the examined impact is consistent across studies and identifying future studies needed to demonstrate the impact (Snyder, 2019). In this study, which strives to develop a framework for consistently measuring the impact of KE for sustainability on students, the SLR has been determined to be an appropriate method. The SLR was conducted to identify and examine the relevant research studies in the literature that

link sustainability-oriented PBL, sustainability learning outcomes, and student KE to determine the variables or constructs that need to be measured to determine the impact of student KE on sustainability.

The SLR method is applied in areas of uncertainty where new studies are needed and in recognising evolving themes to contribute to developing a conceptual framework (Snyder, 2019; Galleli et al., 2020; Naderi et al., 2022). Also, to ensure that the SLR method is valuable, researchers should provide a transparent, complete, and clear report explaining why the review was done, what they did, and what they found (Moher et al., 2010; Page et al., 2021) via a specific protocol and clear logic (Serafini et al., 2022). This research utilises the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to conduct the SLR. It was published in 2009 to address inadequate SLR reporting and improve the quality of systematic reporting (Moher et al., 2010). PRISMA flow chart is a frequently used method to explain the research process of SLR studies conducted in the field of sustainability (Syaifullah et al., 2022; Macke and Genari, 2019) and sustainability education (Serafini et al., 2022; García-Feijoo et al., 2020). Fig. 1 presents the PRISMA flow chart used to guide the four steps of the SLR process: (i)identification, (ii) screening, (iii) eligibility, and (iv) inclusion.

2.1. Identification

This step aims to identify relevant articles on the core subject of this study. SCOPUS database was analysed for journal articles, which is considered to be the largest database of peer-reviewed literature (Piwowar-Sulej and Iqbal, 2022), between August and September 2022, using several keywords (student AND knowledge AND exchange; knowledge AND exchange AND in AND higher AND education; knowledge AND exchange AND for AND sustainability; project-based AND learning AND for AND sustainability; student AND sustainability AND consultancy; students' AND sustainability AND competencies). Although KE has rapidly evolved as a phenomenon in the HEI sector in recent years, it still remains an immature field. This has necessitated the expansion of keyword search criteria in this study. Scopus encompasses the majority of journals indexed in the Web of Science (WoS) and covers more journals in the social sciences field than WoS (Aksnes and Sivertsen, 2019; Piwowar-Sulej and Iqbal, 2022). Additionally, it possesses more exclusive journals than WoS (Baier-Fuentes et al., 2019). Thus, this reduces the risk of omitting documents for this study.

Title, abstract, and keywords were used to frame the search. During the database review, data was restricted to refine the results by selecting 'article' as the type of document, 'journal' as the type of source, and 'English' as the language in which the article is published. As a result, a total of 3577 articles were identified from the SCOPUS database and one report from the grey literature related to the subject of the study due to its focus. A report published by the University of Birmingham and Keele University was used. It focuses on developing a student KE impact toolkit. As it is one of the only studies found attempting to explore the impact of student KE, it was appropriate to use in SLR.

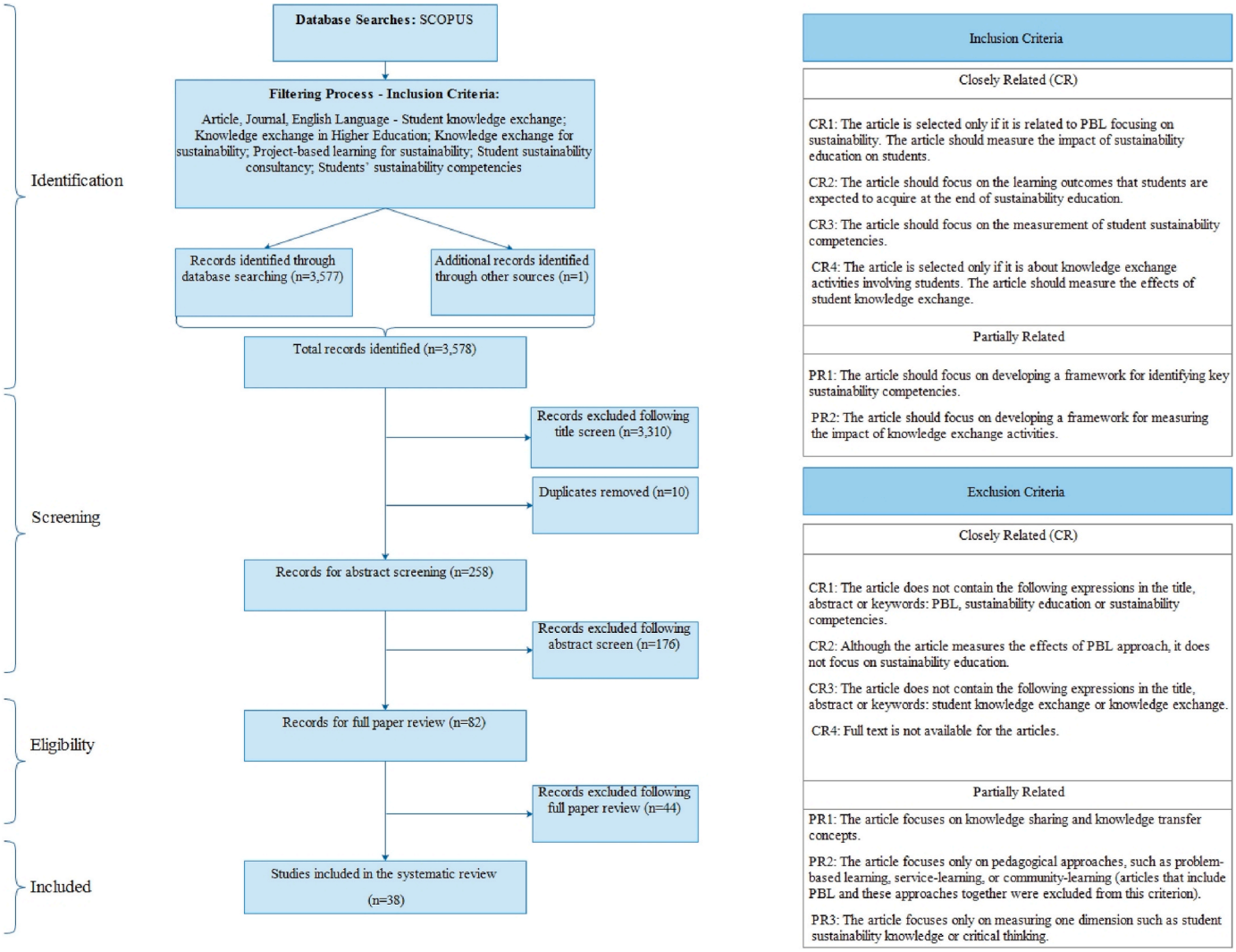

Fig. 1. PRISMA flow chart (Adapted from Moher et al., 2010).

2.2. Screening

At this stage of SLR, the studies obtained at the previous step were independently reviewed by two researchers to ensure robustness. Then, the articles were eliminated based on their title, duplication, and content within the abstract. To do so, we first read the article titles and screened 3310 articles unsuitable for the study, considering the research aim and questions. Before proceeding, 10 duplicate articles were also excluded. Therefore, 258 articles were identified for abstract review, checked for compatibility with the study's objective and research questions, and unsuitable ones were manually evaluated and screened. The articles that did not contain concepts such as project-based learning, experimental learning, sustainability education, sustainability competencies, student knowledge exchange or knowledge exchange in the title, abstract or keywords were excluded from the study.

In addition, we considered conceptual terms during the screening process. Although there are fundamental differences in the meanings of terms in the literature, we excluded the articles focusing on '*knowledge transfer*' (refers to the flow of knowledge in a one-way process) and '*knowledge sharing*' (refers to a similar process to exchange but possesses greater recognition of the value of exchanged knowledge by those involved in the sharing process). It is observed that these terms are used to define the KE process in some studies in the literature. However, Fazey et al. (2013) emphasised that different names of these terms are not the key, and each person includes metaphors with different basic suggestions that may lead to different applications. In line with the aim of this article, we define KE as HEIs' process of producing, sharing and/or using various approaches when undertaken with stakeholders (Fazey et al., 2013; Johnson, 2022). The parts that fall outside this definition are excluded from the article. 82 articles were left that were deemed suitable for full-text analysis.

2.3. Eligibility

82 articles were subjected to full-text analysis considering several components, particularly theoretical background, pedagogical approach, research question, research method, data collection method, sample, research area, determinants, variables, testing time and results. After reviewing all research articles, 44 articles were excluded from the data analysis due to their ineligible content. For example, articles that had not measured sustainability learning outcomes or only measured sustainability knowledge were excluded. Among the articles obtained using the keywords related to KE, only those focusing on the development of a conceptual framework related to KE (three articles) and those focusing on student-mediated KE (five articles) were selected for further steps in the SLR. However, 30 articles were selected to examine the impact of sustainability education on students. Of them, 21 came from the sustainability-oriented PBL literature. These articles were selected considering pedagogical approaches. Studies examining the effect of active learning pedagogies, such as experiential learning and project-based learning on students were selected for the next stage. In addition, 9 articles were included in the study to determine student sustainability competencies, which are frequently measured in the literature as learning objectives of sustainability education. Although three of these selected articles (Wiek et al., 2011; Lozano et al., 2017; Brundiers et al., 2021) did not measure student sustainability competencies empirically, they were included in the study because they developed conceptual frameworks to identify sustainability competencies which have been widely cited in the literature. As a result, 38 articles with the required qualification criteria were included in the further step.

2.4. Inclusion

All 38 articles selected in the previous step of SLR were reviewed systematically to produce findings in line with the proposed research questions using content analysis. The results of the content analysis served to address the research questions and the development of a framework to measure the impact of student KE for sustainability from the perspective of students. The framework highlights the key variables which need to be assessed to measure the impact of PBL for sustainability and student KE.

2.5. Content analysis

Content analysis is a method used in SLRs that begins with well-structured research questions (Sovacool et al., 2018). It is considered a suitable research methodology for this study as it focuses on drawing valid conclusions from the content of data (Krippendorff, 2018). It identifies key concepts, categories and variables regarding the case being studied (Singh and Thurman, 2019). This method allows an in-depth analysis and synthesis of the studies obtained from the SLR (Ceulemans et al., 2015). Therefore, it is commonly used to analyse SLR studies (e.g., Syaifullah et al., 2022; Macke and Genari, 2019; Ceulemans et al., 2015). Content analysis includes quantitative and qualitative research strategies (Weber, 1990). This study performed a qualitative content analysis to determine the main concepts and variables emphasised while evaluating the content of the articles selected by the SLR process. These variables then informed the development of a framework to measure the impact of student KE for sustainability as constructs.

3. Results and discussion

3.1. Descriptive analysis

This section presents a descriptive analysis of 38 selected studies through the SLR. Fig. 2 shows the distribution of the articles selected within the scope of the research. Considering the journals in which the articles were published, the research reveals that 31.6% of them (12 articles) were published in the International Journal of Sustainability in Higher Education; 18.4% of the articles (seven articles) in Sustainability and 13.2% (five articles) in the Journal of Cleaner Production. These three journals comprise 63.2% (24 articles), while the remaining 34.2% (13 articles) were published in 12 different journals. Also, one of the studies (2.6%) is from grey literature.

SLR shows that academic publications have evolved in this area. Fig. 3 presents the evolution of publications on the research theme from 2009 to 2022 (as of September 2022). These results identified three stages (Macke and Genari, 2019) in the evolution of publications. These stages have been determined as the incubation stage, which includes the articles published (5.3%) in 2009, the incremental growth stage covering the studies conducted (28.9%) between 2011 and 2017, and the last stage covering the years 2018–2022 when the number of publications increased rapidly (65.8%). The results highlight a rising trend in recent years towards sustainability-oriented PBL, KE and student KE.

It can be seen that literature on student KE in sustainability remains underdeveloped and under-researched. Table 1 presents which countries and institutions lead studies on the theme of sustainability in HEIs. Accordingly, 15 studies were developed by one institution in a single country (local level), six studies were developed with the collaboration of more than one institution in the same country (national level), and nine studies were developed with the cooperation of various institutions from different countries (global level). The USA was found to include institutions that collaborated on a national or global basis in the relevant field. On a continental basis, eight studies were conducted in Europe, eight in North America, two in Asia, two in South America, and one in Oceania. Considering that nine studies covered countries from different continents, no single-continent experience could be obtained. Regarding all local, national, or global experiences, the following countries produced the highest number of studies in the field of sustainability education respectively: the USA (12 articles), Germany (six articles),

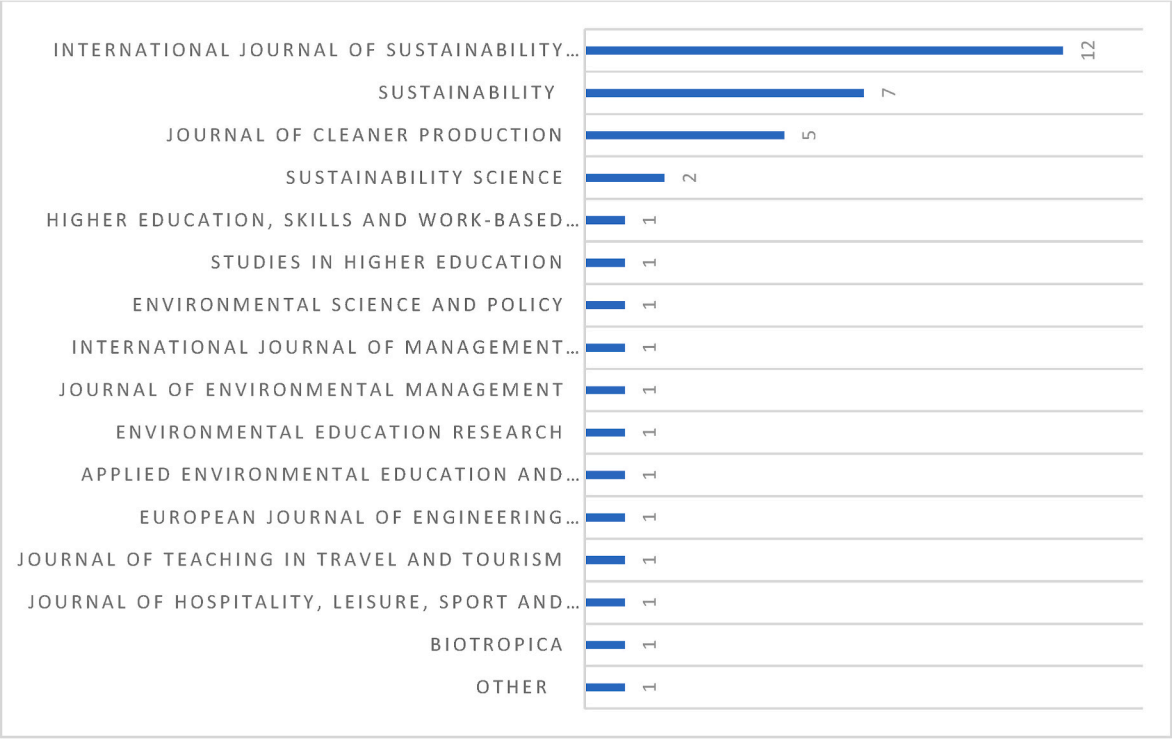

Fig. 2. Number of articles published by Journal.

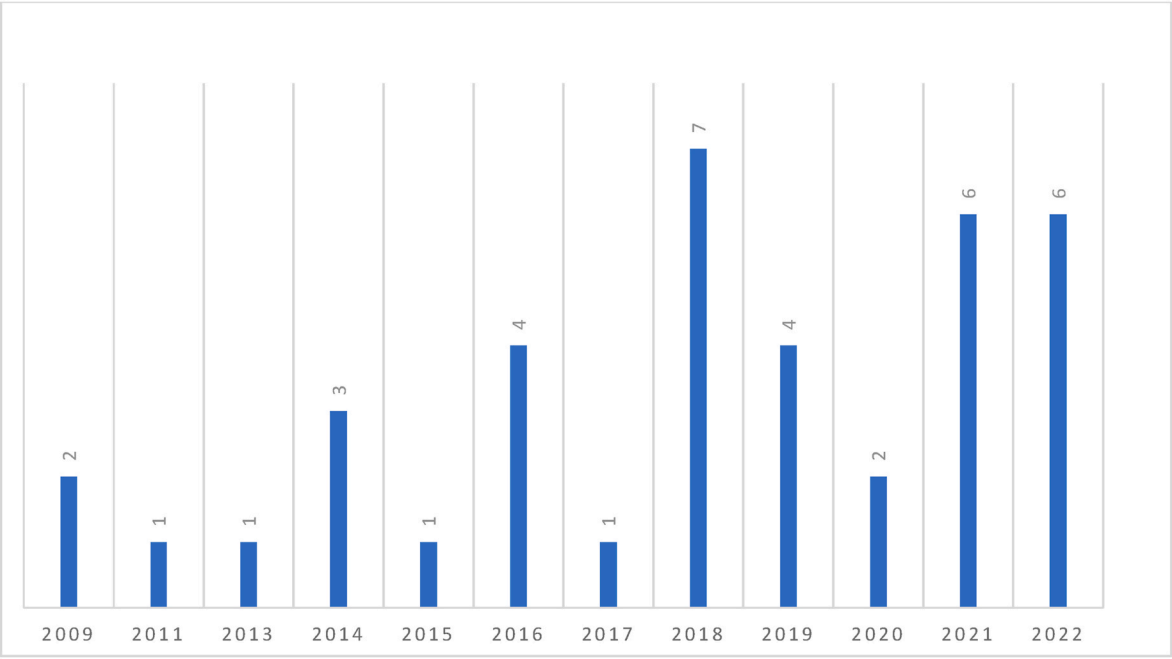

Fig. 3. Articles per year of publication.

Canada (four articles) and Spain (four articles). Table 2 presents the countries and institutions where studies on KE and student KE were conducted. Considering their scopes, three studies resulted in experiences at the local level, three were conducted in cooperation with initiatives at the national level, and two were performed with the initiatives of institutions from different countries at the global level. It was determined that most of the studies were conducted with the collaboration of various institutions in accordance with the nature of KE. However, 50% of the studies were conducted by institutions in the UK which shows that the UK appears to be leading in this area. This may be due to recent policies developed in this area.

3.2. *Project-based learning for sustainability*

Table 3 provides an overview of the results from the content analysis of the selected articles (n = 11) on PBL for sustainability. These results indicate that the quantitative approach was the most common method used in these studies (n = 6). Many studies (n = 7) evaluated the PBL

Table 1
The countries and institutions of origin of the articles related to sustainability education.

Source	Institution name	Country
Alm et al. (2022)	Kristianstad University	Sweden
Naderi et al. (2022)	Razi University	Iran
Braβler and Sprenger (2021)	Universität Hamburg	Germany
Ngo and Chase (2021)	University of San Diego	USA
Caldana et al. (2021)	University of São Paulo	Brazil
Terrón-López et al. (2020)	Universidad Europea de Madrid	Spain
Fuertes-Camacho et al. (2019)	Universitat Internacional de Catalunya	Spain
Trad (2019)	University of Technology Sydney	Australia
Albareda-Tiana et al. (2018)	Universitat Internacional de Catalunya	Spain
Kricsfalusy et al. (2018)	University of Saskatchewan	Canada
Heiskanen et al. (2016)	Lund University	Sweden
Savage et al. (2015)	Dalhousie University	Canada
Lans et al. (2014)	Wageningen University	The Netherlands
Wiek et al. (2014)	Arizona State University	USA
Wiek et al. (2011)	Arizona State University	USA
Quelhas et al. (2019)	Federal Fluminense University and State University of Campinas	Brazil
Soini et al. (2019)	Natural Resources Institute Finland and University of Helsinki	Finland
Meza Rios et al. (2018)	University of Calgary; Beyond Chacay Foundation and Humboldt Association in Quito	Canada
Chang et al. (2018)	Lunghwa University of Science and Technology; National Taiwan Normal University and National Taiwan Normal University	Taiwan
McPherson et al. (2016)	New York Institute of Technology and Illinois Institute of Technology	USA
Perrault and Albert (2018)	Purdue University and University of Wisconsin-Eau Claire	USA
Birdman et al. (2022)	Leuphana University of Lüneburg and Arizona State University	Germany and USA
Konrad et al. (2021)	Leuphana University of Lüneburg and Arizona State University	Germany and USA
Brundiers et al. (2021)	Arizona State University; Leuphana University of Lüneburg; Universitat Rovira i Virgili; Furman University; Laval University; Bellevue College; University of Auckland; University of South Dakota; University of Hawai'i; University of Michigan; Mahatma Gandhi Institute of Education for Peace and Sustainable Development; University of Vechta; Northern Arizona University and Chatham University	USA, Germany, Spain, Canada; New Zealand and India
Konrad et al. (2020)	Arizona State University and Leuphana University of Lüneburg	USA and Germany
Fini et al. (2018)	North Carolina A&T State University and Birzeit University	USA and Palestine
Lozano et al. (2017)	University of Gävle; Organizational Sustainability, Ltd; University of Toulouse and Tecnologico de Monterrey	Sweden, UK, USA, France and Mexico
Leal Filho et al. (2016)	Manchester Metropolitan University; Bournemouth University and University of Beira Interior	UK and Portugal
Caniglia et al. (2016)	Arizona State University and Leuphana University of Lüneburg	USA, Germany and Austria
Du et al. (2013)	Aalborg University and Beijing Normal University	Denmark and China

Table 2
The countries and institutions of origin of articles related to KE and Student KE.

Source	Institution name	Country
Johnson (2022)	Lancaster University	UK
Marvell (2018)	University of Gloucestershire	UK
Breakey et al. (2008)	The University of Queensland	Australia
University of Birmingham and Keele University (2021)	University of Birmingham and Keele University	UK
Reed et al. (2014)	Birmingham City University; University of Leeds; University of Dundee; Project MAYA CIC and Robert Gordon University	UK
Ibidunni et al. (2020)	Covenant University; Federal University of Agriculture Abeokuta and Federal Inland Revenue Service Abeokuta	Nigeria
Zhang et al. (2022)	Leibniz Centre for Tropical Marine Research; The Ministry for Climate Protection, Bremen; Hainan Academy of Ocean and Fishery Sciences and University of Bremen	Germany and China
Duchelle et al. (2009)	University of Florida and Instituto do Homem e Meio Ambiente da Amazonia (IMAZON)	USA and Brazil

before and after the course using the scaled self-assessment survey. Redman et al. (2021) indicated that scaled self-assessment was the most chosen assessment tool to measure the students' sustainability competencies, and our results supported this. In these studies, various learning activities were employed, the most common of which were teamwork, lecturing, student presentations, workshops, partnership working, and fieldwork. The results show that the variables measured in the selected studies were generally divided into two main categories. First, we found PBL and real-world connections to contribute to capacity building for students' sustainability knowledge, skills and competencies and examined these variables under the capacity building category. Secondly, studies focused on measuring the impact of PBL courses on students' perceptions, attitudes, and behaviours towards sustainability and examined these variables under the affective domain category. Therefore, the results show that PBL supports students' acquisition of sustainability competencies and skills by providing insights into real-world issues.

3.3. *Students' sustainability competencies and skills*

The SLR results presented in Tables 4 and 5 show the competencies and skills considered sustainability learning outcomes in the relevant literature. Table 4 shows the most common competencies in the existing literature, including systems-thinking competence, futures thinking/anticipatory competence, values thinking/normative competence, strategic thinking/action-oriented competence, and collaboration/interpersonal competence. These are also known as key competencies in sustainability and are considered to be a reference framework by Wiek et al. (2011). This is the most frequently cited framework to date (Brundiers et al., 2021). A curriculum to acquire the necessary learning outcomes at the end of sustainability education can be developed by combining these five competencies (Alm et al., 2022). However, in the Education for Sustainable Development (ESD) publication of UNESCO (2017), critical thinking, self-awareness, and integrated problem-solving competencies have been added to these five key competencies. Furthermore, Table 5 shows the most frequently mentioned skills as sustainability learning outcomes in the literature. In the selected literature, the most cited skills were teamwork, communication, problem-solving, leadership, project management, presentation, research, consulting, and innovation. These can often be generic skills employers might be looking for in different work areas.

However, in the literature, the term '*competencies*' is generally

Table 3
Description of variables measured, methodologies used, and learning activities in articles related to sustainability oriented PBL.

Source	Methodology	Tools for data collection	Measured variables	Learning Activities
Birdman et al. (2022)	Qualitative	Self-assessments and interviews	SC	Literature, instructor/advisor interaction, working with peers, working partnership, workshop, creating a consumer product
Konrad et al. (2021)	Qualitative	Observation, semi-structured interviews, focus groups, photovoice	Students' interpersonal competence	Lectures, peer observation, teamwork, fieldwork, workshop, student-mentor interaction
Braβler and Sprenger (2021)	Quantitative	Self-assessments survey	Sustainability knowledge, behaviours and attitudes	Lectures, interdisciplinary teamwork, presentation (e.g., posters, handicrafts, video)
Ngo and Chase (2021)	Quantitative	Self-assessments survey, conventional test	Students' perceptions, attitudes and behaviors about sustainability, students' knowledge of sustainability and sustainable engineering concepts, humanitarian engineering experiential learning	Group work, writing and oral presentation, case studies, field work, collaborative work with community members
Terrón-López et al. (2020)	Qualitative and quantitative	Semi-structured interview, student survey, student portfolio	SC	Literature, group exchange, online video-call, working partnership
Fuertes-Camacho et al. (2019)	Quantitative	Performance observation	SC	Lectures, individual learning, group work, presentations
Albareda-Tiana et al. (2018)	Quantitative	Performance observation	SC, research competencies	Group work, workshop, presentation (oral and written), posters
Kricsfalusy et al. (2018)	Quantitative and qualitative	Self-assessment survey, client's feedback, instructors' observation	Sustainability knowledge, professional skills	Lectures, group work, working with client, fieldwork, writing project report by students, reflective public presentation
Perrault and Albert (2018)	Quantitative	Self-assessments survey	Severity, susceptibility, self-efficacy, response-efficacy, behavioral intention, general attitude	Background reading, group work, conducting in-depth interviews, oral presentations
McPherson et al. (2016)	Quantitative	Self-assessments survey	Personal effectiveness, workplace, academic and industry-wide technical competencies	Lectures, group work, workshops, internship, field visits, a final written report, oral presentation, working partnership
Savage et al. (2015)	Quantitative and qualitative	Self-assessments survey, open-ended questionnaires	SC	Group work, student-led training workshops (in-class), youth engagement activities

Sc: sustainability competencies.

associated with skills, abilities, capabilities, capacities, qualifications, and other concepts, which creates a terminological ambiguity in the literature (Pálsdóttir and Jóhannsdóttir, 2021). Wiek et al. (2011) identified five key competencies for sustainability by distinguishing them from regular academic competencies, such as critical thinking, research, and basic communication skills, which are expected to be developed in every high-quality academic programme (Pálsdóttir and Jóhannsdóttir, 2021; Brundiers et al., 2021). Some authors have expanded academic competencies by including self-regulated learning and generic problem-solving skills (Brundiers et al., 2021). It is also evident that many of these terms are used interchangeably and may not have the full consensus of authors. Therefore, there is a need to establish widely accepted, detailed descriptions of sustainability competencies to provide suitable guidance for curriculum and programme development in education for sustainable development (Shephard et al., 2019).

3.4. Evaluating KE and student KE

Table 6 provides an overview of the results obtained from the content analysis of the selected articles (n = 8) on KE and KE specifically through students. Overall, the articles adopted both qualitative and quantitative approaches to deliver KE. Among the methodologies of these KE studies, 75% (n = 6) consisted of a case study on KE. Considering the data collection tools used in the studies, only one data collection tool was used in seven studies and multiple data collection tools were used together in one study. Semi-structured interviews (n = 2), self-assessment questionnaires (n = 2), and reflective writing (n = 2) were used as data collection tools in the studies. In one study, semi-structured interviews and self-assessment questionnaires were used together. Also, data were collected through thematic analysis of government and sectoral documents in one study. However, most articles under this theme examined the impact of students' participation in KE (n = 5). In this regard, the variables measured were related to students' skills development and career readiness. In addition, it was determined that students were involved in the KE process with various stakeholders, including local and regional businesses, professionals, teachers, and other students.

3.5. Framework to measure the impact of student KE for sustainability

In this section, we identify and synthesise the existing variables or constructs to be measured to evaluate the impact of student KE for sustainability on students as a result of the main themes identified in the SLR. Our content analysis suggested three main categories to be systematically measured for impact: (i) capacity building (students' knowledge, competencies, and skills in sustainability), (ii) affective domain (students' perceptions, attitudes, and behaviours toward sustainability), and (iii) career readiness (students' workplace preparedness).

Fig. 4 shows the framework we developed and propose to measure the impact of student KE for sustainability on students. First, the capacity building category requires measuring students' sustainability knowledge, competencies, and skill levels. This category also determines the skills and competencies to be measured. Second, the affective domain categories measure the changes in students' perceptions, attitudes, and behaviours identified as affective learning outcomes for sustainability. The first two categories emerged from the literature review of sustainability-oriented PBL and sustainability learning outcomes. Finally, under the category of career readiness, it was determined that the student's level of preparation for the workplace should be measured. This category emerged from the literature review on PBL and student KE that required active learning pedagogies.

Table 4
The most frequent competencies mentioned as sustainability learning outcomes in the literature.

Source	Systems thinking competence	Futures thinking or anticipatory competence	Values thinking or normative competence	Strategic thinking or action-oriented competence	Collaboration or interpersonal competence	Integrated problem-solving competence	Critical thinking	Implementation competence	Embracing diversity and interdisciplinarity	Subject-specific competence
Birdman et al. (2022)	✓	✓	✓	✓	✓					
Alm et al. (2022)	✓	✓	✓	✓	✓					
Naderi et al. (2022)	✓	✓	✓	✓	✓				✓	
Brundiers et al. (2021)	✓	✓	✓	✓	✓	✓		✓		
Caldana et al. (2021)	✓	✓	✓	✓	✓				✓	
Quelhas et al. (2019)	✓	✓	✓	✓	✓	✓	✓			
Trad (2019)	✓	✓	✓	✓	✓		✓			
Albareda-Tiana et al. (2018)			✓	✓	✓		✓			
Meza Rios et al. (2018)	✓	✓	✓	✓	✓					
Lozano et al. (2017)		✓	✓	✓	✓		✓		✓	
Heiskanen et al. (2016)	✓	✓	✓	✓	✓					✓
Caniglia et al. (2016)	✓		✓		✓					
Savage et al. (2015)	✓	✓	✓	✓	✓					
Lans et al. (2014)	✓	✓	✓	✓	✓				✓	
Wiek et al. (2011)	✓	✓	✓	✓	✓					
Total frequency	13	13	15	14	15	2	4	1	4	1

Table 5
The most frequent skills mentioned as sustainability learning outcomes in the literature.

Source	Project management	Consulting	Research skills	Problem-solving	Leadership	Communication skills	Presentation skills	Teamwork	Innovation/ Creativity
Konrad et al. (2020)						✓		✓	
Soini et al. (2019)				✓	✓	✓		✓	✓
Albareda-Tiana et al. (2018)			✓	✓		✓	✓	✓	
Chang et al. (2018)	✓								
Fini et al. (2018)				✓		✓	✓	✓	✓
Kricsfalusy et al. (2018)	✓	✓	✓		✓	✓		✓	
Heiskanen et al. (2016)	✓	✓		✓	✓	✓		✓	
Leal Filho et al. (2016)	✓	✓	✓	✓	✓			✓	
Wiek et al. (2014)	✓			✓	✓	✓		✓	
Du et al. (2013)	✓			✓	✓	✓	✓	✓	✓
Total frequency	6	3	3	7	6	8	3	9	3

Table 6
Description of variables measured, and methodologies used in articles related to KE and student KE.

Source	Who is KE between?	Methodology	Tools for data collection	Researched Determinants or Measured Variables
Johnson (2022)	Not specified	An intrinsic case study-Qualitative approach	Thematic review	KE framework, engagement strategy, impact
Zhang et al. (2022)	Policymakers, natural resource management bodies, non-government organizations (NGOs), fisheries and science organizations	Case study	Semi-structured interviews	KE framework, knowledge brokering strategies, impact on policy changes, impact on stakeholder engagement
Read et al. (2022)	Students and industry (SMEs, public bodies, charities, and social enterprises)	Case study-Qualitative and quantitative approaches	Self-assessment questionnaire and semi-structured interviews	Student KE impact, career readiness, entrepreneurship competency
Ibidunni et al. (2020)	Teacher and student	Quantitative approach	Self-assessment questionnaire	Students' preparedness for the workplace
Marvell (2018)	Students and event professionals and other event students	Case study-Qualitative approach	Reflective writing	Students' professional skills development
Reed et al. (2014)	Researchers and stakeholders	Qualitative approach	Semi-structured interview	KE framework. Key principles for effective KE (design, represent, engage, impact, reflect and sustain)
Breakey et al. (2008)	Tourism student and regional tourism operators	Case study	Reflective writing (Journal-style workbook)	Students' learning outcomes, local skills development, workforce development, community awareness, stakeholders' involvement
Duchelle, et al. (2009)	Graduate student and local stakeholder	Case study	Self-assessment questionnaire	Student KE framework. Information sharing skills, student's skills development, cultivate attitudes, knowledge generation with local stakeholders

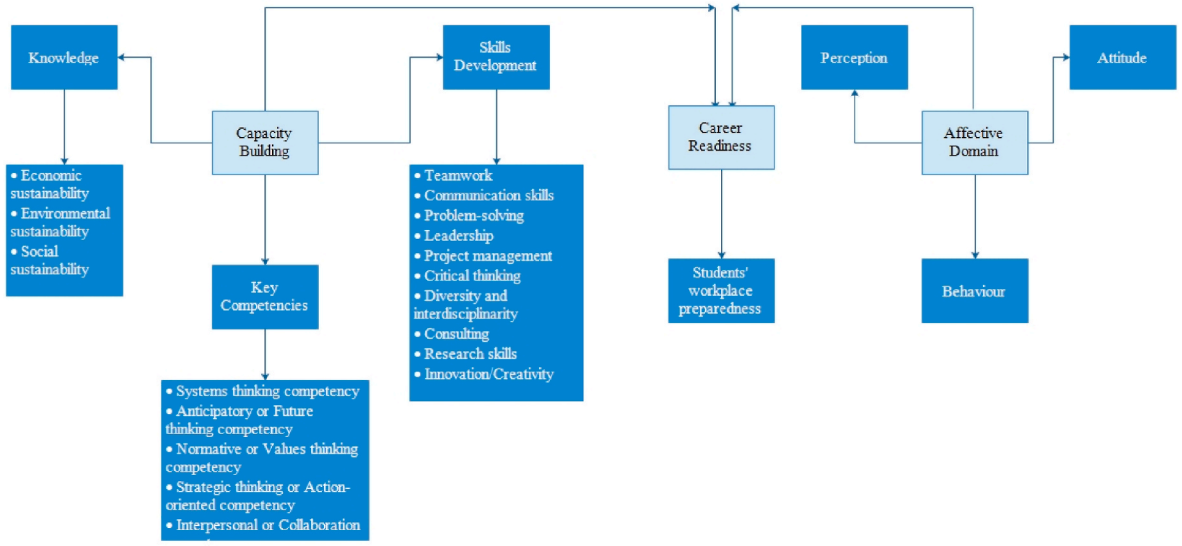

Fig. 4. Proposed framework to measure the impact of student KE for sustainability.

3.5.1. Capacity building: students' knowledge, competencies, and skills in sustainability

Sustainability in HEIs aims to move beyond enabling students to acquire and produce knowledge and develop value-oriented graduates who can think strategically and systematically about sustainability issues (Savage et al., 2015; Konrad et al., 2021; Birdman et al., 2022). Projects that include opportunities to exchange knowledge through students allow them to acquire knowledge and skills that are necessary to build the capacity to address and solve real-world sustainability problems in collaboration with business partners, local communities, and civil society (Wiek et al., 2014; Kricsfalusy et al., 2018). In this regard, student capacity building has been designated as the first component to be measured in the proposed framework. This category includes three interrelated concepts expected as key outcomes of sustainability education: knowledge of sustainability issues, sustainability competencies, and skills.

Students' sustainability knowledge: Sustainability education aims to provide all students with knowledge about sustainability issues to promote sustainable development (UNESCO, 2017). In the resolution adopted by the General Assembly, the United Nations (2022) emphasises the importance of promoting a holistic approach to sustainability education and encourages the reinforcement of interdisciplinary connections among the three pillars of sustainable development —economic, environmental, and social— across various fields of knowledge. Carew and Mitchell (2002) found that approximately 65% of students who had completed their education could not explain the concept of multidimensional sustainability (Perrault and Albert, 2018). Accordingly, sustainability education should strive to develop knowledge through the three pillars of sustainability and to understand the complexities and interconnections arising from the nature of sustainability (Braβler and Sprenger, 2021).

In addition to studies that measure general sustainability knowledge (economic, social, and environmental) (Alm et al., 2022; Braβler and Sprenger, 2021), some studies measure students' subject-specific knowledge, such as life cycle assessment (LCA), cleaner production (Heiskanen et al., 2016), carbon footprint, greenhouse gas, sustainable design (Ngo and Chase, 2021), agricultural sustainability, biosphere reserves (Kricsfalusy et al., 2018), food economy, waste management, and energy (Konrad et al., 2021). Students obtaining in-depth knowledge about subject-specific topics, which are especially necessary to overcome certain sustainability problems, requires active pedagogical approaches such as PBL, experiential learning or real-world learning. Students can acquire new knowledge about sustainability and improve their existing knowledge through transforming their experiences (Konrad et al., 2021). Therefore, evaluating students' knowledge acquisition or the improvement of their existing knowledge is important as a significant criterion for the success of sustainability-oriented student KE initiatives.

Key competencies in sustainability: There are certain competencies that are necessary for students to cope with today's sustainability challenges (UNESCO, 2017). Wiek et al. (2011) propose a framework based on the sustainability competencies that students should possess. These are systems-thinking competence, anticipatory competence, normative competence, strategic competence, and interpersonal competence. This integrated framework helps students achieve successful outcomes that will positively contribute to sustainability development while they work on specific sustainability challenges (Brundiers et al., 2021).

Alm et al. (2022) have stated that the learning environment significantly impacts the development of students' key competencies in sustainability. Albareda-Tiana et al. (2018) argued that students couldn't develop competencies in sustainability with methods based solely on knowledge transmission, which do not include an active learning process. Birdman et al. (2022) have stated that PBL activities contribute more to developing students' sustainability competencies than other known learning activities. Fuertes-Camacho et al. (2019) emphasised that students involved in a sustainability education project developed their sustainability competencies. Studies have shown that participatory learning design, in which students actively run projects with external customers, helps students develop sustainability competencies and achieve comprehensive learning outcomes (Terrón-López et al., 2020; Savage et al., 2015). Therefore, it is necessary to measure the development of students' key competencies in sustainability, supporting it with empirical evidence while evaluating the impact of the student KE process for sustainability.

Skills development: Projects including practices based on student KE provide students with opportunities to interact directly with their peers, businesses, and other professionals, enabling them to develop professional skills, such as teamwork, project management, research, written and verbal communication (Kricsfalusy et al., 2018; Heiskanen et al., 2016; Leal Filho et al., 2016; Wiek et al., 2014), and innovation (Du et al., 2013; Soini et al., 2019; Fini et al., 2018). In addition, conflicts between group members during the professional counselling practice help them learn how to work under time and information constraints (Kricsfalusy et al., 2018). The active learning process increases students' enthusiasm, learning motivation, and permanence as it responds to real and urgent needs (Heiskanen et al., 2016; Leal Filho et al., 2016). It also helps students develop skills, such as critical thinking and problem-solving (Heiskanen et al., 2016; Albareda- Tiana et al., 2018) and increase their self-efficacy (Fini et al., 2018). Encouraging critical and proactive thinking allows students to create their own ideas about sustainable citizenship and a good society. The process raises their awareness of the fact that they have the potential to shape the future with their actions and ensures that they have critical minds and self-confidence to develop knowledge and skills to shape their own careers and influence others (Marvell, 2018).

Heiskanen et al. (2016) stated that an approach where students step out of teachers' shadow and take responsibility for the process creates an important learning experience in developing their leadership skills. Kricsfalusy et al. (2018) emphasised that addressing real-world sustainability challenges and providing opportunities to interact directly with parties help students develop their critical leadership skills. Many studies have demonstrated that this approach promotes the adoption of professional roles and leadership (Leal Filho et al., 2016; Heiskanen et al., 2016; Du et al., 2013; Wiek et al., 2014). These results have brought about a comprehensive set of skills identified as important learning outcomes that can be used to assess the student sustainability KE process.

3.5.2. Affective domain: students' perceptions, attitudes, and behaviours toward sustainability

Focus is often placed only on the acquisition of necessary knowledge and skills as a criterion to evaluate the success of sustainability education initiatives (Perrault and Albert, 2018). However, sustainability education is no exception to learning outcomes that consist of affective characteristics, such as moral values, perceptions, attitudes, and behaviours (Savage et al., 2015). SLR demonstrated that sustainability education, especially in an active learning approach, may affect students' perceptions, attitudes, and behaviours as they indulge in the learning experience (Perrault and Albert, 2018; Ngo and Chase, 2021; Braβler and Sprenger, 2021; Savage et al., 2015).

Perrault and Albert (2018) examined the effect of the PBL approach on changes in students' attitudes towards sustainability. They found that students' attitudes towards exhibiting sustainable behaviours changed positively after the completion of the project and demonstrated that sustainability was a more significant issue. Ngo and Chase (2021) argued that the positive effects of PBL activities on students' perceptions and attitudes towards sustainability were effective in motivating them to participate in sustainable practices. On the other hand, Braβler and Sprenger (2021) obtained results different from those mentioned above. In their study, students who attended an interdisciplinary PBL course about sustainability improved their sustainability knowledge and behaviours at the end of the course. However, no change was observed in

their sustainability attitudes, which was attributed by the researchers to the fact that the students had already had high sustainability attitudes before they attended the course, leaving little room for improvement. These results show that it is not sufficient to measure cognitive learning outcomes, such as knowledge and skill development alone, to fully understand the impact of student sustainability KE projects on students. Measuring students' perceptions, attitudes, and behaviours towards sustainability is also necessary.

3.5.3. Career readiness: students' workplace preparedness

Wiek et al. (2011) emphasised the critical importance of understanding how ready students are to apply the sustainability knowledge and competencies acquired through education in their daily work lives. The results obtained from SLR indicate that PBL environments offer vast opportunities for students to gain experience, and student experiences through KE help students develop knowledge, skills, and attitudes necessary both for their post-graduation job readiness and for a smooth and functional transition to their job roles.

Marvell (2018) argued that students' experiences working with other students and professional activity experts helped them develop practical skills, such as critical thinking, professional writing, and communication, which will benefit them in the industry. Duchelle et al. (2009) suggested that students could develop professional skills, such as language, presentation, active listening, and teamwork through KE with local stakeholders and that it was a useful preparation for students to develop attitudes such as flexibility, open-mindedness, commitment, and humility to cope with several management and policy issues they may face throughout their careers. McPherson et al. (2016) stated that students' working with others in an experiential learning process provided them with the necessary perspective to understand the challenges of sustainability and its potential impact in real-world environments. These authors also suggested that such projects were an ideal simulation to prepare students for workplaces. In evaluating the effectiveness of an education model developed in this context, it is important to measure the impact of such projects on equipping students with the competencies needed in the market.

4. Conclusions and recommendations

This paper contributes to knowledge and KE practice by conducting an SLR to develop a framework that measures the impact of student KE for sustainability based on three categories. The impact of PBL for sustainability on students was examined, and PBL courses were found to contribute to the capacity building of students by improving their knowledge, skills, and competencies. Therefore, it is necessary to measure and evaluate students' knowledge, skills and competencies concerning sustainability to evaluate the impact of these projects on students. Secondly, the literature mentions several skills and competencies as learning outcomes of sustainability education. This study identified which sustainability competencies and skills are measured frequently in the literature and determined the skills and competencies that should be measured as sustainability learning outcomes. Thirdly, student KE and PBL approaches were found to contribute to preparing students for the future workplace. Career readiness was another variable that should be measured to evaluate the impact of these courses on students fully. Finally, a framework has been developed to measure the impact of student KE for sustainability systematically.

This framework entails the key variables or constructs that must be assessed to gauge KE's impact on students. The proposed framework is comprehensive in nature and aims to tackle all aspects of impact on students while getting engaged with experiential or PBL. The framework is the main contribution supporting the measurement of the impact of student KE, as current frameworks do not address the issues around impact holistically. Universities conducting student KE projects can empirically apply and validate this framework to measure the impact of these projects in different contexts and disciplines. KE applies to all disciplines, and there is an opportunity to embed KE in core curriculum across disciplines and explore which type of KE activities most impact student learning, experience, and progression. In addition to the impact evaluation, this framework can support decision-making in universities and how funding is allocated for KE in terms of their priority areas.

The present SLR reveals the need to develop impact assessment tools directed towards various types of KE activities. Future research can focus on how to measure the impact of KE activities implemented in HEIs on other stakeholders. This SLR is part of an ongoing research project where this framework will be applied and validated in an empirical investigation with undergraduate students of two schools involved in KE, Nottingham Business School and the School of Architecture, Design, and the Built Environment, at Nottingham Trent University. Future research could explore the impact of skills and competencies developed by students participating in KE projects on their post-graduation career choices and workplace success, for example through longitudinal studies linked to the graduate outcomes survey. Additionally, subsequent studies could examine innovative ways to integrate student KE into various disciplines and pedagogical approaches.

This study has certain limitations. Firstly, selecting articles focuses solely on the Scopus database and excludes other databases. Secondly, due to the nature of the search method, if the terms determined as search criteria are not included in the title, abstract or keywords of the articles examined, this situation may have caused some suitable articles to be overlooked. Future systematic reviews, especially in fields lacking standardised terminology, can use automated approaches such as text mining and keyword co-occurrence networks. These methods may help identify key terms crucial for reviews and reduce bias in search strategies (Grames et al., 2019). Finally, the results of the content analysis should be used with caution due to the possibility of misinterpretation of the content of the documents by the researchers. Nevertheless, the independent review of the articles from this SLR by two researchers helped reduce the biases that may arise from the research method and ensure the robustness of this study.

CRediT authorship contribution statement

Gamze Yakar-Pritchard: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft. **Muhammad Usman Mazhar:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Writing – original draft. **Ana Rita Domingues:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Writing – original draft. **Richard Bull:** Conceptualization, Funding acquisition, Investigation, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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