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Research

Assessing the impacts of sustainability teaching at higher education institutions

Walter Leal Filho[1,2] · Laís Viera Trevisan[3] · Subarna Sivapalan[4] · Muhammad Mazhar[5] · Aristea Kounani[6] · Marcellus Forh Mbah[7] · Ismaila Rimi Abubakar[8] · Newton R. Matandirotya[9,10] · Maria Alzira Pimenta Dinis[11,12] · Bruno Borsari[13] · Rikki Abzug[14]

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Abstract

The necessity of sustainability teaching (ST) has recently become increasingly crucial due to several interrelated factors. The world faces significant environmental challenges, such as climate change, biodiversity loss, deforestation, pollution, and resource depletion. ST equips students with the knowledge and tools to address these issues and work towards a more sustainable future. ST helps students understand these complex challenges and fosters holistic problem-solving skills. ST at higher education institutions (HEIs) can take place in various modalities, including lectures, hands-on projects, field trips, simulations, and collaborative learning to enhance knowledge and develop competencies. The impact of ST at HEIs may be measured through multiple avenues, such as student surveys, interviews with faculty, and research studies on the effectiveness of sustainability courses. This paper reports on a study that assessed the current impact of ST at HEIs. The data collection used a multi-methods approach, which included a bibliometric analysis, the assessment of a set of case studies, and an international survey conducted with teaching staff from HEIs in 38 countries. The evidence supporting ST is presented and discussed, indicating how current teaching programmes are being delivered and their degree of success. The results show that the literature on ST has evolved substantially over the past years and covers a wide range of areas, as demonstrated by the various clusters. The case studies, in turn, show multiple real-world examples of how HEIs across diverse geographic regions have implemented ST practices and their implications. The paper's

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✉ Laís Viera Trevisan, lais.trevisan@ufrgs.br; Walter Leal Filho, walter.leal2@haw-hamburg.de; Subarna Sivapalan, Subarna.Sivapalan@nottingham.edu.my; Muhammad Mazhar, muhammadusman.mazhar@ntu.ac.uk; Aristea Kounani, akounani@yahoo.gr; Marcellus Forh Mbah, marcellus.mbah@manchester.ac.uk; Ismaila Rimi Abubakar, irabubakar@iau.edu.sa; Newton R. Matandirotya, runyamore@gmail.com; Maria Alzira Pimenta Dinis, madinis@ufp.edu.pt; Bruno Borsari, bborsari@winona.edu; Rikki Abzug, Rabzug@ramapo.edu | [1]Faculty of Life Sciences, Hamburg University of Applied Sciences, Ulmenliet 20, 21033 Hamburg, Germany. [2]Department of Natural Sciences, Manchester Metropolitan University, Chester Street, Manchester M11 5GD, UK. [3]School of Administration, Federal University of Rio Grande Do Sul (UFRGS), 855 Washington Luiz St., Porto Alegre, RS 90010460, Brazil. [4]School of Education, University of Nottingham Malaysia, Jalan Broga, 43500 Semenyih, Selangor, Malaysia. [5]Department of Management, Nottingham Business School, Nottingham Trent University, 50 Shakespeare Street, Nottingham NG1 4FQ, UK. [6]Department of Agriculture, Program of Agricultural Economics & Entrepreneurship, International Hellenic University, Thessaloniki, Greece. [7]Manchester Institute of Education, School of Environment, Education & Development, University of Manchester, Oxford Rd, Manchester M13 9PL, UK. [8]Department of Urban and Regional Planning, Ahmadu Bello University, PMB 1045, Zaria, Nigeria. [9]Climate Change Adaptation and Resilience Centre, Beitbridge P.O Box 5, Zimbabwe. [10]Kgotso Development Trust, P.O. Box 5, Beitbridge, Zimbabwe. [11]Fernando Pessoa Research, Innovation and Development Institute (FP-I3ID), University Fernando Pessoa (UFP), Praça 9 de Abril 349, 4249-004 Porto, Portugal. [12]Marine and Environmental Sciences Centre (MARE), University of Coimbra, Edifício Do Patronato, Rua da Matemática, 49, 3004-517 Coimbra, Portugal. [13]Department of Biology, Winona State University, Winona, MN, USA. [14]Anisfield School of Business, Ramapo College of New Jersey, Mahwah, NJ, USA.

novelty lies in its approach to evaluating sustainability education's effectiveness and broader impacts on HEIs. It offers a unique approach by integrating assessments across multiple disciplines, showing how ST impacts students´ education. Also, the study tracks the impacts of the sustainability literature, providing insights into how sustainability education shapes students' professional prospects. Finally, the paper shows the status of sustainability education across different HEIs and countries, offering a broader perspective on how it is implemented into practice. The study concludes by suggesting measures that may maximise the impact of sustainability courses in HEIs curricula and, among other things, the overall campus culture toward sustainable development.

Keywords Sustainability teaching · Sustainable development · Higher education · Curricula · Universities · Higher education institutions

1 Introduction

Sustainability in higher education has been an evolving concept for the past 30 years. Until the mid-1980s, higher education institutions (HEIs) mainly focused on environmental protection. Since then, they have started to widen their approach and explore sustainable practices, emphasising the connections between energy efficiency, water conservation, and waste reduction [1, 2]. Over the last two decades, many HEIs worldwide have embraced sustainability as an integral part of their mission, creating comprehensive plans to reduce their environmental impact and address social justice. The rise of sustainability as a priority has been driven by student demand, faculty research, and the development of new technologies. Many HEIs have been implementing a range of initiatives, from creating "green" buildings and investing in renewable energy sources to developing courses and programmes on sustainability issues [3–5].

This paper reports on a study involving a literature analysis, case studies and a survey encompassing HEIs in 38 countries. The focus of this study in the higher education sector may shed some light on how HEIs handle sustainability issues as part of their teaching programmes. To this end, a mixed-methods approach was used, employing a bibliometric analysis of the relevant literature, case studies of sustainability teaching (ST) practices implemented in a selection of HEIs globally, and a survey to gather the perspectives of teaching staff on the perceived impacts of ST. The study addresses the challenge of evaluating the effectiveness of ST, which remains difficult due to the need for standardised assessment criteria.

Although sustainability education in a higher education context is deemed important, there are differences in the ways it is perceived and implemented. The research aims to fill this gap by identifying some of the current approaches and methods used. By identifying current works and practices, the study seeks to build a profile of the extent to which sustainability education programmes are being implemented in various contexts. The findings emerging from this study can aid policymakers, administrators, and faculty members in comprehending how they can contribute to fostering sustainability within HEIs. Gaining insight into the current landscape of ST within HEIs can lay the groundwork for a more sustainable future. The novelty of the work derives from the fact that it offers an analysis of the impacts of ST, with pieces of evidence showing how wide it may be.

2 Literature review

A three-pronged literature review is offered herein to help readers better understand what is known in current science regarding the topic under study. One focused on the history of sustainability in HEIs, the second tackled ST, and the third dealt with distinctive sustainability practices. Grant and Booth [6] conceded that comprehensive literature reviews could be useful for investigating new research areas or topics when developing novel directions and practices in scholarly works or assisting investigators in detecting trends or research gaps in any field [7].

2.1 A brief history of sustainability in HEIs

Over the years, numerous HEIs have demonstrated their commitment to sustainable development (SD) by endorsing various declarations, including the Magna Charta of European Universities (1988), the Talloires Declaration of University Presidents for a Sustainable Future (1990), the Halifax document "Creating a Common Future: an Action Plan for Universities" (1991), the COPERNICUS "Universities Charter for Sustainable Development" (1994), the Lüneburg Declaration on Higher Education for Sustainable Development (2001), the Ubuntu Declaration on

Education, Science, and Technology for Sustainable Development (2002), the Graz Declaration on Committing Universities to Sustainable Development (2005), the G8 University Summit Sapporo Sustainability Declaration (2008), and the G8 University Summit: Statement of Action (2010), among others. International organisations such as the Association for the Advancement of Sustainability in Higher Education (AASHE) in North America and the European School of Sustainability Science and Research (ESSSR) in Europe play a significant role by providing up-to-date information supporting sustainability education in higher education.

Table 1 presents a chronological overview of some of the critical milestones in the development of sustainability education. It is noticeable that some of these are related to global efforts, e.g. the Tbilisi Declaration, and some reflect developments seen at the country level, e.g., AASHE in the United States/Canada and Environmental Association for Universities and Colleges (EAUC) in the UK.

The publication of Our Common Future in 1987 was instrumental in establishing the widely accepted definition of SD, focusing on meeting the needs of the present without compromising the ability of future generations to meet their own needs [11]. Current literature has presented several factors necessary for integrating SD into university structures, including university leadership, culture, collaboration, commitment, knowledge, and attitudes [33]. However, changing attitudes and behaviour is a multifaceted issue, and, on some occasions, simply disseminating information is insufficient to change students' attitudes and behaviour. Instead, HEIs may increase awareness in support of sustainability through research and dissemination activities (conferences, seminars, workshops, etc.), offering curricula in sustainability, from individual courses to well-structured study programs, for various levels of instruction (undergraduates, postgraduates), and via promotion of environmentally responsible behaviour [34].

In addition, HEIs can contribute to SD by establishing formal and informal partnerships [35] with other key contributors, such as the industry. Moreover, HEIs are better placed to contribute towards SD through three pathways, namely: producing graduates that address sustainability challenges, application of real-world problem-based research, as well as engaging the private sector and civil society organisations [36]. Additionally, as knowledge producers, HEIs can ensure that all graduates are equipped with the appropriate professional skills to achieve sustainability within society [37, 38].

2.2 Sustainability teaching: its needs and challenges

Concerning education, ST in higher education has evolved in recent years to become more integrated into curricula across disciplines [39]. Whereas it was once a marginal topic discussed in specialised courses, sustainability is now vital to many degree programmes, including engineering, business, public policy, economics, science, technology, and the humanities [40]. This change has been driven by a growing awareness of sustainability and the need to prepare students to navigate the complexities of a rapidly changing global climate [41]. McCowan [42] argues that the climate crisis acts as a driving force for pedagogical renewal in higher education. The ongoing planetary crisis demands that climate change be integrated into sustainability education across all curricula. However, for this integration to be truly effective, it must extend beyond simply incorporating new content into existing curricular frameworks. Instead, it requires embedding climate change into the core values, knowledge systems, and societal structures that underpin education [43].

In recent years, increasing efforts to incorporate the United Nations (UN) Sustainable Development Goals (SDGs) into ST as a framework to enhance students' sustainability knowledge and competencies has advanced ST significantly [44–47]. Leal Filho, Shiel [48] highlight various advantages of introducing the SDGs into teaching, suggesting that this inclusion can boost student engagement with sustainability concepts in HEIs. Setó-Pamies and Papaoikonomou [49] argue that the SDGs provide a robust framework for integrating ethics, Corporate Social Responsibility (CSR), and sustainability into education. However, the implementation of the SDGs in ST is still in its early stages and requires more systematic efforts to increase its presence in HEIs' curricula [50]. Moreover, despite the many successful strategies reported over the years, HEIs face significant challenges in implementing sustainability practices due to a lack of planning and institutional support. This underscores the importance of understanding what is being done within the context of ST. There remains a need for a more systematic approach to mapping the impact of this integration and ensuring the effective implementation of sustainability policies in HEIs, as success continues to depend on the willingness and commitment of both leadership and students to engage in sustainable activities [33, 51].

Table 1 Some milestones in the evolution of sustainability teaching in higher education

Year	Development	Influence	Reference
1713	Hans Carl von Carlowitz coins the concept of sustainability: *Nachhaltigkeit*	Devises notion: "conservation and replanting of timber that there can be a continuous, ongoing and sustainable use"	Schmithüsen [8]
1970	April 22, Celebration of First Earth Day in the US	Helped Establish modern environmental movement in the US	Hughes and Thomson [9]
1977	Tbilisi Declaration from the 1977 United Nations (UN) Conference on Environmental Education	Instrumental in broadening ecological education to include cultural aspects and stewardship	Gillett [10]
1987	Publication of Our Common Future	Agreement on a widely used definition of SD	Brundtland [11]
1990	Talloires Déclaration	Highlights the central sustainability role of HEIs through research, teaching, policy generation, etc	Adlong [12]
1991	The graduate curriculum in sustainability in the U.S. (MS3), enrolled its first students at Slippery Rock University of Pennsylvania	Pioneer program (first graduate curriculum) to prepare leaders in SD in the U.S	Anderson [13] Borsari [14]
1993	US Nonprofit Second Nature is founded	Founded to mobilise a diverse array of HEIs to act on bold climate commitments, scale campus climate initiatives, and create innovative climate solutions	Second Nature Inc. [15]
1996	Environmental Association for Universities and Colleges (EAUC)	Initiated to enhance the visibility of environmental management and improve facilities for better environmental performance in further and HEIs Exists to lead and empower the post-16 education sector to make sustainability 'just good business'	Soini, Jurgilevich [16] EAUC [17]
1998	US Green Building Council creates the LEED green building rating	By including LEED-certified green buildings, colleges and HEIs work towards more sustainable solutions	Worden, Hazer [18]
2000	Establishment of the International Journal of Sustainability in Higher Education	Establishment of an outlet for international scholarly research on Sustainability in Higher Education	IJSHE [19]
2005	Launch of the Association for the Advancement of Sustainability in Higher Education	The first professional higher education association dedicated to the campus sustainability community in North America	Fien [20] AASHE [21]
2006	Launch of American College & University Presidents' Climate Commitment	Created a network of US HEI committed to reducing greenhouse gas emissions and spurring research in sustainability	Dyer and Dyer [22]
2006	Arizona State University creates a School of Sustainability	Establishes the first sustainability degree program in the US. Hundreds follow	Redman [23]
2007	Development of United Nations Principles for Responsible Management (UN PRME)	Legitimate Business School Faculty Teaching and Research in partnership with UN Compact, Focused on business school education	Alcaraz, Marcinkowska [24] Godemann, Haertle [25]
2015	Launch of UN Agenda 2030 and establishment of SDGs	Provides a framework for scholarly contributions to sustainability	Caballero [26] Hujo [27]
2020	Establishment of the European School of Sustainability Science & Research (ESSSR)	Coordinates initiatives in sustainability science education and research across Europe	Filho, Sierra [28]
2021	Quality Assurance Agency [QAA) and Advance HE Education for SD Guidance	Jointly published in 2014 and updated in 2021 by QAA and Advance HE, this guidance provides a framework to help UK HEI staff incorporate ESD within their curricula. Advance HE has emphasized the critical role of leadership and innovation in embedding ESD across HEIs, as outlined in its foundational frameworks	Martin, Jucker [29] Sterling [30] Fiselier and Longhurst [31] Advance HE [32]

Source: prepared by the authors

2.3 Distinctive practices in sustainability teaching

Effective education for sustainability requires increasing interactions across disciplines that include Indigenous knowledge and values. Western learning models of dominant education paradigms are often limited and flawed by reductionist, anthropocentric worldviews. Therefore, the need to develop a culture of awareness about the role and place for humanity in nature becomes a priority in ST before tackling the more pragmatic issues surrounding the quest for achieving sustainability, thus demanding education and learning that shift towards ecocentrism [52].

Furthermore, an establishment of living labs among increasing numbers of HEIs exemplifies the more holistic framework that has become better understood for excelling in ST [53]. Along this pedagogically inclusive trajectory, the university campus and its resources become an ecosystem, which requires ecocentric wisdom and knowledge to remain functional in the long run, allowing instructors and their students to comprehend the tenets of 'health' from the organismal to the planetary level, through a variety of hands-on and field activities [54]. Additional ST practices that include ecological design projects in a campus-built environment were the norm of students' learning in the first sustainability program in the US [14] and should continue to inspire instruction in sustainability.

3 Methods

This study utilised a mixed-methods approach to assess ST in HEIs while evaluating course provisions as a distinct component of sustainability in HEIs. It involved conducting (i) a bibliometric analysis of relevant literature, (ii) investigating case studies of ST practices implemented in a selection of HEIs globally, and (iii) a survey to gather the perspectives of teaching staff on the perceived impact of ST.

3.1 Bibliometric analysis

The initial approach involved conducting a bibliometric analysis based on keyword co-occurrence. This method simplifies the complexity of exploring a specific research topic by revealing clear connections between the various research streams investigated [55]. The analysis was performed using the Scopus database. Scopus is a comprehensive multidisciplinary abstract and citation database covering multiple scientific disciplines, including social, physical, health, and life sciences. Compared to more restricted databases, it offers extensive, comprehensive coverage of peer-reviewed literature, conference proceedings, patents, and other scholarly sources [56]. VOSviewer software, a commonly used software for bibliometric analysis [57], was used to analyse scientific trends. Data collection was accomplished on April 27, 2023.

The keywords used for data collection covered the research topics: sustainability, HEIs, and teaching. Therefore, the configured search string was the following: (TITLE ("sustainability" OR "sustainable" OR "sustainable development" OR "sustainable development goal*" OR "SDG*" OR "2030 Agenda") AND TITLE-ABS-KEY ("HEI" OR "HEIs" OR "Higher Education Institution*" OR "Higher Education" OR "University*" OR "College*") AND TITLE ("teach*").

The sample selection process adhered to the flowchart shown in Fig. 1, which aligns with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [58]. During the first phase (Identification), 770 documents were retrieved from the Scopus database using each key term's "article title, abstract, and keywords" search option without limiting the document type. In the second phase (Screening), the search was refined to include only articles, book chapters, and reviews, reducing the number of documents to 631. Further limiting the selection to English-language publications resulted in 596 documents. A keyword co-occurrence analysis was performed on these documents, revealing five clusters discussed in the next section.

3.2 Case studies

The case study approach allows for an in-depth understanding of a phenomenon and strengthens the analytical conclusions of the research. As evidence is gathered from studies with similar research interests, the theory becomes more robust and applicable across various studies and contexts [59]. Research utilising different case studies can draw on multiple data sources and methodologies, making it an effective method for collecting a large volume of data

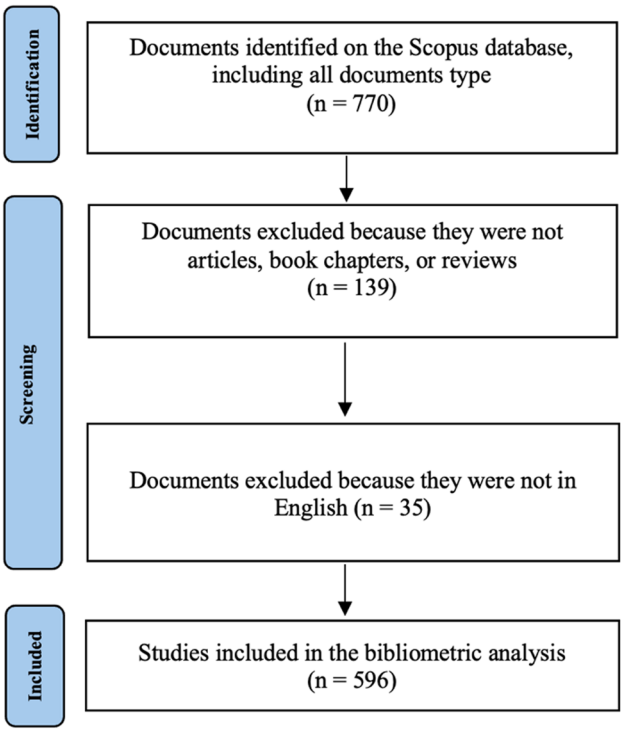

Fig. 1 The process of selecting publications for bibliometric analysis based on PRISMA (Source: prepared by the authors)

[59, 60]. In this context, this study selected 20 case studies focused on ST in HEIs across diverse geographic regions informed by online secondary data and research published in peer-reviewed journals.

The selection of case studies was guided by three primary criteria: (i) the inclusion of HEIs across diverse geographic regions to ensure global representativeness, ii) the implementation of innovative and impactful ST practices as evidenced by published studies, and (iii) the availability of peer-reviewed publications within the last decade that provided comprehensive documentation of these practices. These criteria were established to capture a wide range of approaches, contexts, and challenges in ST while ensuring the reliability and comparability of the data. HEIs were chosen to reflect varied institutional profiles, including differences in size, academic focus, and socio-economic contexts, to provide insights into the adaptability and scalability of sustainability education models.

The chosen publications were analysed using content analysis, a well-established research technique that systematically focuses on the content of studies to derive meaningful insights and draw conclusions. The approach involved an examination of the context, objectives, key findings, and implications of each paper to identify recurring themes related to ST practices, techniques, and impacts in various HEIs. These themes were then summarised, organised in a tabular format, and discussed by synthesising and comparing them. This method facilitated a rigorous examination and interpretation of the textual data within their specific contexts. By employing content analysis, the study aimed to gain valuable insights, deepen the understanding of the phenomenon under investigation, and provide practical guidance for future actions [61].

3.3 Survey

The third approach consisted of an online survey administered between April 27 and June 19, 2023. Content validity and a piloting phase were conducted amongst a careful selection of field experts to ensure they captured all the essential elements we intended to investigate [62, 63]. The choice of the experts was based on professionals working in the field of sustainability in higher education who are considered experts. Moreover, the research team designed the questions based on the literature review conducted in the previous research stage, such as those referred to in Table 2**.** Typical of a study of this nature, closed questions were mainly used for participants to address a series of questions related to the thematic focus. The questionnaire preparation was led by the authors, many of whom have worked together in previous studies and have a track record in successfully designing and using such tools. After preparing a matrix, comments and

Table 2 Case studies on sustainability teaching at HEIs

Case	Region	Objective	Key findings	Implications	Reference
1	Sweden	Assessing master's level students' understanding of SDGs and sustainability	Inclusion of SDGs and sustainability within HEIs to motivate students' sustainable learning experience	Embedding work-integrated learning and real-life experiences as teaching methods improved students' sustainability comprehension	Alm, Beery [44]
2	Global Study	SDGs and ST at HEIs	Assessing the current state of SDGs teaching implementation in HEIs in Europe, Africa, Asia, South America, North America and Oceania	SDGs 4, 11 and 13 were the goals most addressed in teaching. SDGs knowledge is apparent among university stakeholders, but there is a limitation in terms of concrete and practical integration	Leal Filho, Shiel [48]
3	United Kingdom	A university-wide approach to integrating the SDGs into the curriculum	Approaches to embedding the SDGs into the core curriculum	Innovative electronic resources, living lab concept, using community case studies and staff development as approaches to university-wide SDG integration	Willats, Erlandsson [75]
4	Malaysia	ST within elective communication modules of undergraduate engineering programmes using a blended learning approach	Sustainability learning outcomes can be infused within non-technical modules of engineering programmes using technology-enhanced pedagogies	Students' awareness of sustainability knowledge, skills and values, and the sustainability triple bottom were heightened	Sivapalan [76]
5	Malaysia	Infusing sustainability within engineering education programmes to advance holistic sustainability competence development	Sustainability outcomes are best embedded within the engineering curriculum via a holistic approach that combines technical and non-technical dimensions	Students are key stakeholders in determining the successful implementation of holistic sustainability outcomes within engineering programmes	Sivapalan [77]
6	Australia	Views of teachers on ST within HEIs in Australia	Assessing teachers understanding of SD, experiences, and challenges with teaching sustainability online	Online approaches to ST are valuable but pose limitations in terms of student engagement	Shah, Kennedy-Clark [78]
7	Canada	Embedding sustainability in undergraduate learning	Development of a pathways model for university-wide sustainability learning via a three-tier pathways programme	The three-tier pathway focusing on sustainability citizen, scholar and leader through co-curricular activities, a certificate of minor and a capstone project offers a practical pathway to teaching and learning sustainability for students not majoring in SD	Robinson, Ariga [79]
8	United States	Teaching and learning of sustainability within General Education courses	Developing approaches to structuring and ST learning outcomes and exploring their implications for learning	Course designs approaches such as reorientation, development of new unit courses or infusion are possible approaches, and can be used as a strategy to inculcate sustainability literacy among students	Natkin [80]

Table 2 (continued)

Case	Region	Objective	Key findings	Implications	Reference
9	Japan	Promoting interdisciplinarity via sustainability	Integrating sustainability issues in non-environmental courses such as general education to enhance interdisciplinarily teaching and learning	Students' and instructors' communication opportunities were broadened. Instructors were able to develop a keener understanding of sustainability and interdisciplinary education	Liu, Watabe [81]
10	Netherlands	Developing higher education students' sustainability competencies	Exploring the impact of transformative, interdisciplinary and intercultural learning to advance sustainability learning	Structural support is critical to effectively integrate sustainability in higher education teaching and curriculum	Sommier, Wang [82]
11	Europe and North America	Evaluate the curricula of programs granting degrees in sustainability	Core sustainability courses constituted most of the curricula, with bachelor's programs generally being more flexible than master's programs	Shared foundation courses across programs are essential for the development of sustainability as a mature scientific discipline	O'Byrne, Dripps [83]
12	Spain	Assess university faculty's practice, concerns, and the need to embed sustainability education	Project-based learning is the predominant approach for ST, even though its application is hindered by a lack of faculty training	Establishing sustainability as a crucial area of study in a university requires adequate ST materials, study curricula, and institutional backing	Busquets, Segalas [84]
13	Australia	Investigate teaching methods and pedagogical strategies employed by university faculty in teaching education for sustainability	Low adoption of the pedagogies and teaching methods advocated for education for sustainability	The extent to which innovative pedagogical approaches are integrated into education for sustainability can provide valuable insights for shaping its future direction	Christie, Miller [85]
14	Europe and Latin America	Explores faculty experience in implementing sustainability principles and curriculum greening in higher education	The process of conducting action-oriented research, collaborative efforts and the integration of diverse fields of knowledge faced operational challenges	Effective sustainability education necessitates the collaboration of all domains of knowledge to conserve and enhance the environment	de Ciurana and Filho [86]
15	Global Study	Review strategies change agents employ to strengthen their efforts in implementing education for sustainability	Sustainability education is a multifaceted undertaking, with both challenges and achievements in trying to broaden the curriculum	Considering the institutional culture is a crucial aspect of initiatives aimed at transforming the curriculum for education for sustainability	Higgins and Thomas [87]
16	Europe	Compare how three European HEIs incorporate education for sustainable development (ESD) into their academic curricula	Integrating ESD into all academic programs through a thorough revision of the curriculum is an arduous undertaking	Incorporating ESD into academic curricula requires robust, enduring strategies and involvement from university management and various groups within the institution	Holmberg, Svanström [88]
17	Australia	Evaluate the potential of a constructivist-informed pedagogical approach to facilitate authentic transformative learning in sustainability education	Sustainability education curricula encompass a few interdisciplinary approaches and pedagogical practices to promote critical and reflective thinking in students	Education for sustainability requires individuals who can effectively engage with the intricacies of environmental issues and think critically about them	Howlett, Ferreira [89]

Table 2 (continued)

Case	Region	Objective	Key findings	Implications	Reference
18	Global	Examine the utilisation of a systems theory approach in researching and teaching sustainability at the university level	Having a practical and effective approach is essential to achieving sustainability across environmental, socio-cultural, economic, technical, and personal domains	HEIs should create sustainability content that is rooted in values and applicable to various disciplines, with a particular emphasis on carefully evaluating both human and technical aspects when addressing sustainability challenges	Pappas [90]
19	Canada and England	Investigate whether education for ESD keep pace with the rapid progress of sustainability values in business, community, and government	Found a lack of structural changes required to develop transdisciplinary curricula, incorporate fieldwork and real environmental problems for student-centred instruction, and promote diversity in education	HEIs as key components of the formal delivery of sustainability education must provide effective environmental and sustainability learning	Pearson, Honeywood [91]
20	Saudi Arabia	Study the evaluation of sustainability education curriculum and research from the perspective of students	Few courses and student projects across different disciplines prioritise sustainability as a key component of their content or objectives	Incorporating sustainability into the curriculum can equip students with the necessary knowledge, skills, and attitudes to tackle sustainability challenges in their personal and professional lives	Abubakar, Al-Shihri [92]

Source: prepared by the authors based on the study findings

suggestions were made, leading to improvements. A final draft was then pre-tested, with further changes, before a final version was agreed upon and deployed.

The survey participants were recruited via purposive, snowball, and opportunistic sampling techniques from a population of academics involved in ST. In doing so, we took advantage of relevant networks, academic mailing lists, and university affiliations. There were no selection criteria to choose survey participants. The participation was open. More specifically, the invitations were sent to the various networks, and the interested colleagues volunteered to take part and provide answers to the questions posed in the survey. There was no payment or any sort of motivation to engage. The persons who took part did so out of interest, to which the authors are grateful. Before completing the online survey, each participant must adhere to the ethical protocol articulated on the cover sheet, which requires consent. In total, 112 participants responded to the invitation and anonymously completed the survey. A descriptive analysis of these data is presented.

The triangulation of bibliometric analysis, case study reviews, and survey data demonstrate a robust methodological approach that enhances the reliability and depth of the findings. By integrating these diverse methods, the study provides a comprehensive overview of ST in HEIs and allows for the replication of the research in different contexts. The bibliometric analysis uncovers the structural dimensions of the knowledge base, while the case studies and survey tool provide detailed insights into practical applications and perceptions. This mixed-methods approach ensures that conclusions are trustworthy, evidence-based, and applicable to various academic and institutional settings, making it a valuable model for future research.

4 Results and discussion

The focus on assessing course provisions as a distinct component of sustainability in HEIs reflects a critical aspect of institutional sustainability efforts. By evaluating course offerings, HEIs can directly address the knowledge and skills necessary to promote sustainability across disciplines. This approach recognises that education is pivotal in shaping attitudes, behaviours, and practices, influencing societal responses to environmental, social, and economic challenges. Assessing course provisions enables HEIs to identify strengths and areas for improvement in integrating sustainability principles into the curriculum. It serves as a means to promote interdisciplinary collaboration, ensuring that sustainability concepts are embedded across various academic fields, cultivating a culture of sustainability that extends beyond individual courses to permeate the broader institutional essence, and fostering a more holistic approach to sustainability education and practice within the academic community. Consequently, this section reports and discusses the results obtained in assessing the course provisions about addressing ST in HEIs, combining the bibliometrics, case studies and survey data.

4.1 Bibliometric analysis

Education is considered a goal and a key enabler in achieving the SDGs [64]. To effectively address sustainability issues, environmental and sustainability education should focus on imparting action-oriented knowledge [65]. HEIs have an essential role to play in this regard. More specifically, academic staff are considered change agents and embody a pivotal duty in affecting teaching practices that aim at maximising students' learning outcomes in this field [66]. To identify trends in the literature about this topic, a co-occurrence analysis of keywords from relevant studies was conducted, followed by a cluster analysis (Fig. 2). The resulting keyword co-occurrence network revealed five distinct clusters.

The **red** cluster encompasses curricula, innovation, professional development, engineering education, and personnel training. The sustainability curriculum and educators are crucial in raising awareness and promoting the implementation of sustainability concepts [67]. However, several studies indicate that there are barriers to the integration of SDGs into curricula. Leal Filho, Shiel [48] explained that a lack of training and difficulty incorporating SDGs into courses are among the most common reasons for not integrating these into curricula. Moreover, insufficient support from top management is frequently identified as a significant obstacle to implementing education for sustainable development (ESD) in HEIs. These barriers demonstrate the need for institutional support and faculty training to include sustainability in the curriculum.

The **blue** cluster focuses on experiential learning, integrated approaches, interdisciplinarity, problem-based learning and skill, and leadership. The constructivist learning theory perspective, which emphasises interactive learning, can be a practical, didactic approach to ST-related subjects. This approach involves co-creating knowledge between students and teachers [68]. According to this approach, students actively learn while collaborating with their peers and instructors to develop a deeper understanding of SD challenges. The teacher's role is to guide and facilitate this process rather

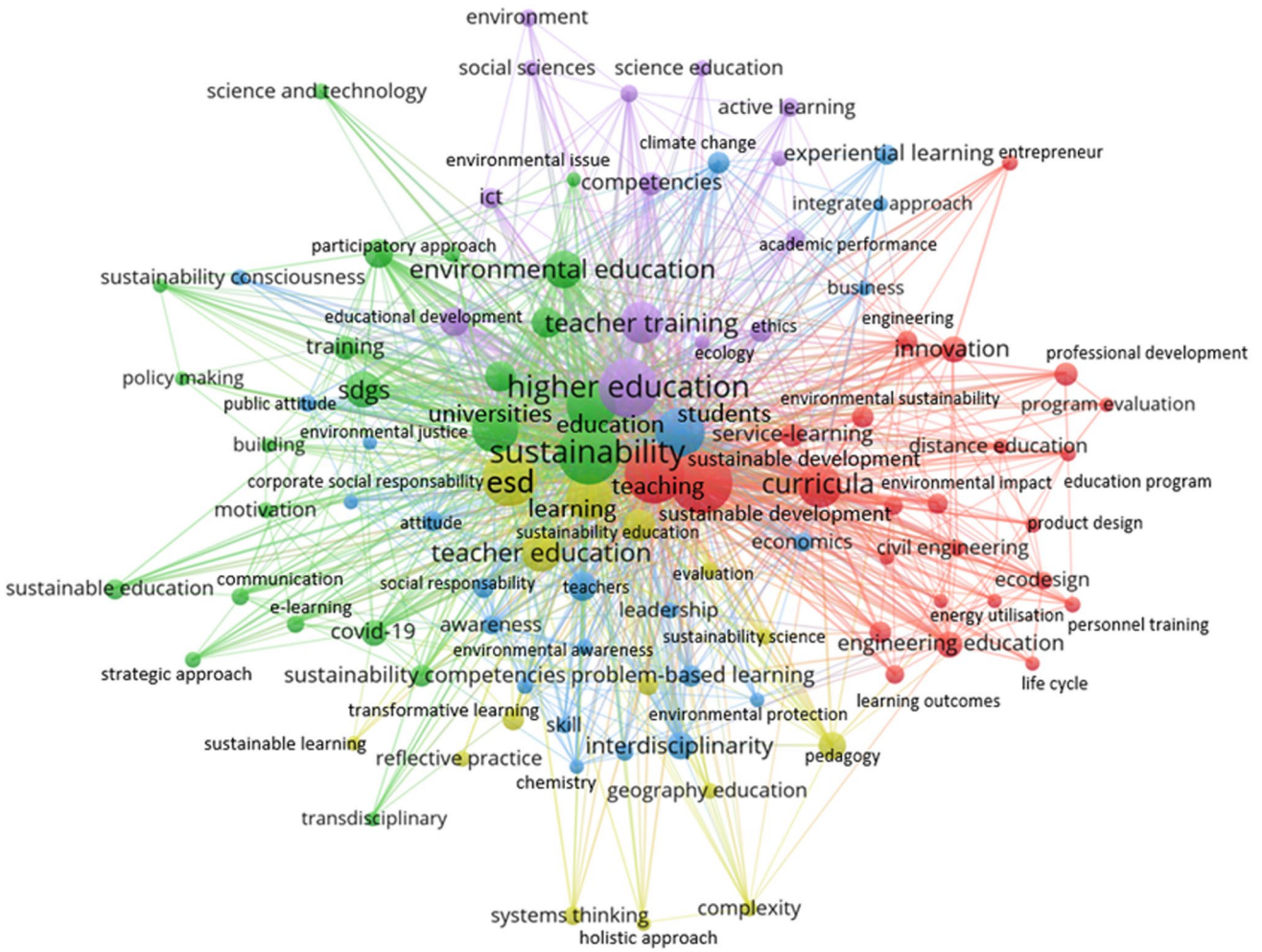

Fig. 2 Keywords co-occurrence network (Source: prepared by the authors based on the study findings)

than imparting knowledge. This strategy fosters critical thinking, problem-solving skills, and a deeper understanding of complex sustainability issues that are relevant today. By adopting this approach, students can develop a more holistic and nuanced understanding of sustainability and become better equipped to address these challenges in future endeavours and when embarking on their professional careers.

The **purple** cluster primarily focuses on enhancing teaching methodologies and educator competencies in higher education. It emphasises the professional development of educators through training in education for ESD, fostering active learning environments, and integrating science education with ethical considerations. This cluster highlights the role of educators as facilitators of transformative learning, where competencies such as systems thinking and interdisciplinary collaboration are developed to prepare students for complex sustainability challenges. Additionally, the integration of information and communication technologies emerges as a critical tool in modernising and improving teaching practices. Teachers are critical in driving societal transformative actions [69]. However, to maximise their impact, teachers' preparation needs to incorporate ESD and promote teachers' competencies in the context of ESD [64]. This approach aligns with the broader push for enhanced teacher training, increased awareness among decision-makers, and greater involvement in cross-curricular and interdisciplinary practices. Additionally, the SDGs can be significant motivators for encouraging academics to integrate sustainability into their teaching. These initiatives can help build capacity and create a generation of well-equipped teachers to tackle future sustainability challenges [48].

The **green** cluster focuses on environmental education, SDGs, HEIs, sustainable education, sustainability competencies, and training, among other topics. According to Baena-Morales, García-Taibo [70], the role of HEIs in the Agenda 2030 is twofold. Firstly, HEIs should incorporate the SDGs into their daily activities, including teaching and research, to promote interest in this area of knowledge. Secondly, HEIs should be agents that facilitate change and raise awareness

among students and communities beyond their campus borders. This reflects that HEIs must be more than just educational institutions but also pillars of social change. Valdivia, del Carmen Pegalajar Palomino [71] further suggest that HEIs must reflect on their social mission and pedagogical effectiveness because they are responsible for generating social impacts, committing to new functions while transmitting knowledge for training and disseminating, transferring, and looking for applications of new knowledge. By embracing these roles, HEIs can make meaningful contributions towards SD and create a better world for all.

Finally, the **yellow** cluster is distinguished by its emphasis on pedagogical strategies and learning frameworks that underpin ESD. It delves into transformative learning theories that promote systems thinking, enabling students to grasp the interconnectedness of environmental, social, and economic systems. It emphasises complexity and critical thinking as key elements for effectively empowering students to address sustainability challenges. This cluster underscores the importance of embedding sustainability across curricula through innovative, participatory pedagogical methods. Educators play a crucial role in facilitating the development of sustainability competencies in their students [72]. To achieve this, Dziubaniuk, Ivanova-Gongne [68] suggest that teaching sustainability may require the employment of constructivist, student-centred, and transformative pedagogies in both offline and online environments. These pedagogies transform students' attitudes and behaviours towards SD issues and concepts. In this regard, systems thinking is a fundamental element of ESD. Students can problem-solve sustainability issues effectively by understanding the interconnections between different dimensions (environmental, development, social, economic, and cultural) and the complexity of systems and situations. These ideas reinforce the importance of educators in promoting sustainability competencies and implementing pedagogical strategies that foster meaningful change towards a sustainable future [73].

4.2 Case studies analysis

ST in HEIs assists in preparing the next generation of leaders and professionals to address SD challenges [74]. This subsection presents and discusses 20 exemplary case studies on ST in HEIs worldwide. It discusses real-world examples of how HEIs across diverse geographic regions have implemented ST practices and their implications. The diversity in the selected case studies, ranging from HEIs in developed to developing countries, allowed for a comparative analysis of ST practices under varying socio-economic and environmental conditions. This approach highlights both universal and context-specific strategies, contributing to a clearer understanding of how ST can be tailored to meet diverse institutional needs and regional challenges.

The selected case studies were from many countries and ranged from 2005 to 2022. Their analysis revealed common themes centred around SD teaching and the SDGs' perspectives on the need to include elements of SD within teaching and learning (including challenges) and pedagogies. Interestingly, these emerging patterns align with the clusters from the bibliometric analysis already presented in the previous subsection.

The analysis of the case studies suggests that HEIs view the inclusion of SD concepts and goals as pivotal for spurring sustainability literacy among undergraduate and postgraduate students. Employing SD within academic programmes in HEIs can support students and prepare them to address the sustainability challenges they will face along their career paths and future workplaces. Besides this, the integration of SD is also instrumental in broadening competencies, comprehension, and communication skills in sustainability [80, 81, 92].

Programmes and modules (both technical and non-technical) in which the incorporation of these elements was effective were engineering and general education [48, 76, 77]. Additionally, undergraduate programmes were more flexible than postgraduate programmes regarding including and using sustainability terms within the curriculum. Findings from the cases reviewed suggest that the teaching of SD should be approached using holistic, interdisciplinary, transdisciplinary, intercultural, and multifaceted approaches [81, 90, 91]. Integrating SD principles within curricula is often perceived as a demanding task. As such, its assimilation within the curriculum is best facilitated through broader educational transformation strategies and the involvement of multi-stakeholder levels, particularly faculty, students, and university administrators.

Pedagogies related to ST in the reviewed cases have taken many forms. Student-centred pedagogies that have proven to be effective in advancing the education of SD in most HEIs include diverse learning approaches (e.g., work-integrated, real-world, project-based, collaborative), in addition to critical and reflective thinking [44, 75, 84, 89]. Besides that, electronic resources, community-based case studies, living labs, co-curricular activities, capstone projects, action-oriented research, and fieldwork have been used to promote the teaching and learning of sustainability at the institutions featured in these cases [75, 86]. In addition, the use of pathways models, shared courses, reorientation of modules, infusion, and

development of new modules are some of the strategies that have been used to advance the teaching of sustainability at the HEIs considered in this work [79, 80, 83].

Challenges associated with the teaching of sustainability at these institutions of higher learning include the lack of practical integration, low engagement among learners, particularly with online education, and the need for adequate teaching materials and institutional support [48, 78, 84, 88]. If these limitations could be reasonably addressed, teaching sustainability within HEIs could be substantially transformed to accelerate students' development of sustainability competencies. This will add to existing efforts, including the use of social networks [93, 94] while bolstering the personal learning environment of students [95, 96] engaged in sustainability education.

4.3 Survey results

This subsection presents the survey results while addressing specific queries to understand how sustainability has been integrated into teaching disciplines and courses worldwide. The survey engaged participants from 38 countries (Fig. 3), with the highest number from the United States ($n = 15$), followed by Nigeria ($n = 12$), the United Kingdom ($n = 12$), Brazil ($n = 9$), Saudi Arabia ($n = 8$), India ($n = 7$), Spain ($n = 6$), Australia ($n = 5$), Canada ($n = 4$), and Portugal ($n = 3$). The rest of the countries either had one or two participants. It is essential to mention that this trend, which is common in studies whose participation is voluntary, may depict a different level of involvement in ST across the globe.

Most participants fell within the age ranges 41 and 50 ($n = 46$), 51—60 ($n = 26$), and 31—40 ($n = 21$). These were underpinned by distinct gender backgrounds, with a slight majority of females ($n = 57$). Among all participants, there were full professors ($n = 25$), associate professors ($n = 29$), assistant professors ($n = 27$), and instructors ($n = 8$), contributing to an array of disciplines within the remit of sustainability.

Sustainability was recognised to be an integral component for several disciplines in this assessment, including *Environmental Studies* (49; 43.8%), followed by *Social Sciences* (44; 39.3%), *Engineering* (26; 23.2%), and Business Studies (25; 22.3%). Areas such as *Humanities* (8; 7.1%), *Biological Sciences* (6; 5.4%), *Agricultural Sciences* (5; 4.5%), *Health Sciences* (3;

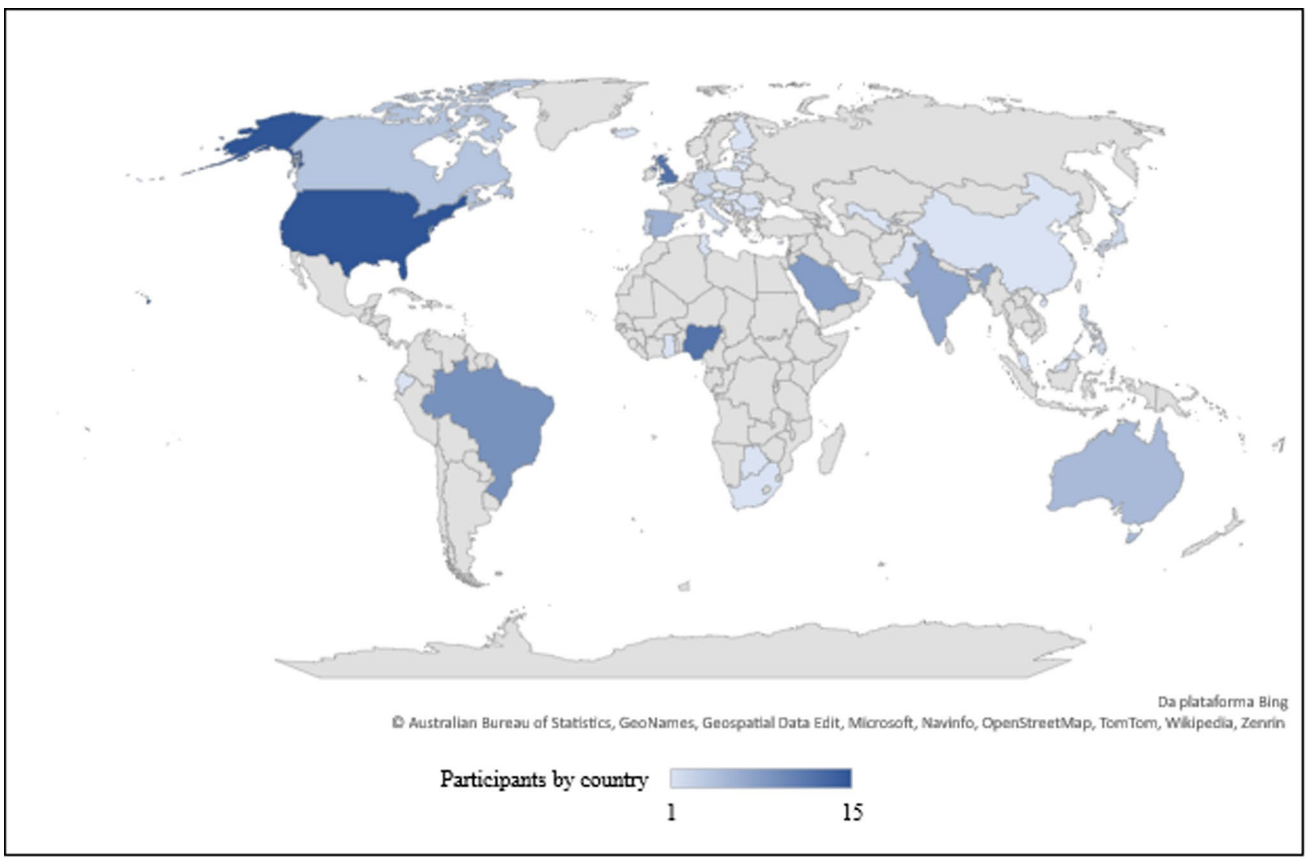

Fig. 3 Countries represented in the survey (Source: prepared by the authors)

2.7%), or *Chemical Sciences* (2; 1.8%) were less mentioned. However, these were followed by a residual characterisation of more specific areas by the respondents, such as *Sustainability*, *Urban & Regional Planning*, or *Built Environment*, among several others, and being selected by one respondent. These choices illustrate areas that could appear marginal and not connected solidly with sustainability when they are, nowadays. However, it is clear from the survey results that most emphasis is given to the environmental and social sciences.

Regarding the role played by instructors in ST (Question: What is your role/s in the teaching of sustainability?) (Fig. 4), many respondents (54; 48.2%) reported being involved in teaching a sustainability course to undergraduate students. Other options were selected, however, with a distinctive answer, involving, for example, "having some responsibility for implementing the university's sustainability sub-strategy", "leading institution-wide work on sustainability education; delivering co-curricular learning on sustainability (workshops, events) and staff development" or "advocate for SDGs within my University", among other less represented answers. Thus, an apparent involvement in ST in various roles emerged from staff within the assessed HEIs. These spanned from teaching activities and guiding students in graduate and undergraduate study programs in sustainability.

Concerning the methods used for ST (Question: What is/are your methods for teaching sustainability?), most respondents reported that "case-study instruction" and "research" were their methods of choice, yielding an equal number of answers in both categories (66; 58.9%). A third highly selected option was "project-based instruction" (63; 56.3%), followed by "lecture only" (46; 41.1%), "co-teaching with other instructors" (37; 33%), "hybrid (mixture of online and classroom) instruction" (31; 27.7%), "weekly seminar" (26; 23.2%), "hands-on activities through lab exercises" (23; 20.5%), "service-learning activities" (22; 19.6%), "on-line (asynchronous) instruction" (21; 18.8%) and "peer-led instruction" (19; 17.0%). The diversity of choices indicates the many approaches selected to address teaching in sustainability and a clear indication of effort and sound creativity in pedagogy for sustainability. Additional answer options, such as: "interactive online exercises", "workshops and events outside of the classroom", or "creative practice-based design research exploration", received a single answer.

Table 3 reports the most representative strategies for integrating sustainability into teaching (Question: How has sustainability been integrated into your teaching?). These results acknowledge a straightforward search for different perspectives in creating awareness about sustainability. Interestingly, some of these opt for less common approaches, like "Various forms of art expressions (poetry, music, photography, painting, etc.)", thus aiming at contributing to different aspects of promoting behavioural change. Less reported answers (1 out of 112) were: "Student-centred, activity-based pedagogy", "Personal behaviour change projects; links to volunteering on campus", "International immersive experiences in other countries", or "Theorizing using Indigenous/local concepts and communication patterns".

Four central answers were collected concerning the effects of ST experience by students (Question: What do you think are the effects/impacts of your sustainability teaching on your students?) (Table 4). These outcomes included minor choice proportions (1/112), for example, "become a sustainability advocate", "view their major subjects through a sustainable development lens", "furthering research and knowledge in sustainability discourses", or "collaborating/continuing to engage on policies and regulations with impact", which highlight the consequences of efforts in fostering sustainability awareness in students' behaviour in the achievement of societal transformation [97, 98].

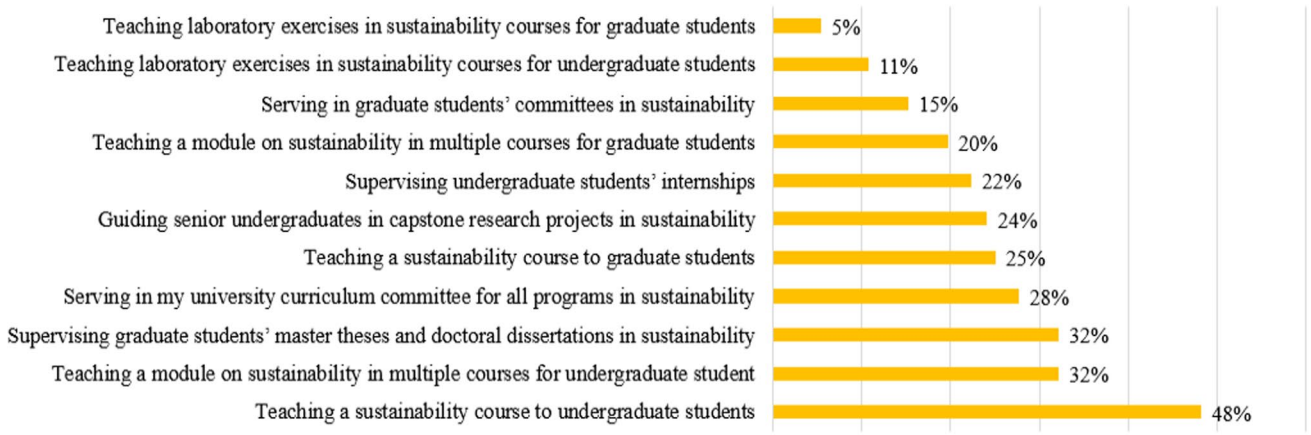

Fig. 4 Teaching staff's roles in sustainability teaching (Source: prepared by the authors based on the study findings)

Table 3 Approaches of integrating sustainability into teaching ($n = 112$)

Variable	*n (%)*
Case-studies	86 (76.8)
Research	71 (63.4)
Project-based instruction	69 (61.6)
Guest Lectures	53 (47.3)
Local sustainability event reports by students	33 (29.5)
Service-learning activities	26 (23.2)
Fostering students' engagement and leadership in campus government	26 (23.2)
Hands-on activities through lab exercises	22 (19.6)
Various forms of art expression (poetry, music, photography, painting, etc.)	12 (10.7)
Letter writing to local newspaper editors	4 (3.6)

Source: prepared by the authors based on the study findings

Table 4 Self-reported effects of sustainability teaching, as perceived by students ($n = 112$)

Variable	*n* (%)
Enhancing interest to want to learn more about sustainability	97 (86.6)
Increased aspirations to 'make a difference' in making their communities more sustainable	87 (77.7)
Take personal action to change their own life-style towards sustainability	72 (64.3)
Pursue professional careers in sustainability	67 (59.8)

Source: prepared by the authors based on the study findings

Table 5 Estimated students' attitudinal change when these are taught about sustainability teaching ($n = 112$)

Variable	*n* (%)
Students' interest in sustainability has increased	93 (83.0)
Students' aspirations to pursue more knowledge in sustainability	80 (71.4)
Students' desire to pursue careers in sustainability has increased	66 (58.9)
Students' groups/committees engaged in making their campus and community more sustainable have become well-established	33 (29.5)
Students' groups/committees engaged in making their campus and communities have been formed	27 (24.1)

Source: prepared by the authors based on the study findings

The reported changes in students' attitudes toward sustainability since being exposed to the teaching are presented in Table 5 (Question: What has changed in your students' attitude toward sustainability since being exposed to your teaching?). These data from the five most selected choices suggest that an effective behaviour change towards community engagement occurs when sustainability is taught. This finding is similar to insights advanced by Mbah, Shingruf [99] and Godfrey and Feng [100].

In addition to analysing existing approaches to ST at different HEIs and for various disciplines, as well as perceived impact, this survey quantified pointers to future opportunities and challenges in sustainability education, with some of the insights resonating with those expressed by few authors [65, 101, 102].

When respondents were asked how likely they envision the growth of ST at their university in the next ten years (Question: How likely do you envision the development of sustainability teaching at your university in the next ten years?) (Fig. 5), many respondents selected the "likely" option (52%) and the "extremely likely" option (26%). Some respondents (16%) took a neutral position when answering this question, whereas 3% selected "unlikely" and 4% "extremely unlikely".

Regarding the challenges to ST (What are the constraints (if there are any) to teaching sustainability at your university?) (Fig. 6), lack of instructors with expertise (52%), inconsistent institutional support (51%), rigid curricula (44%), and lack of internal start-up funding for sustainability research (43%) were the most frequent answers. These findings agree with the ones from Al-Nuaimi and Al-Ghamdi [103]. These results are on a convergent trajectory compared to those presented already in the bibliometric analysis. Their intersectionality is also substantiated by actions and programs developed by the HEIs that were considered case studies. Such a triangulation of the results enhances the trustworthiness of the data.

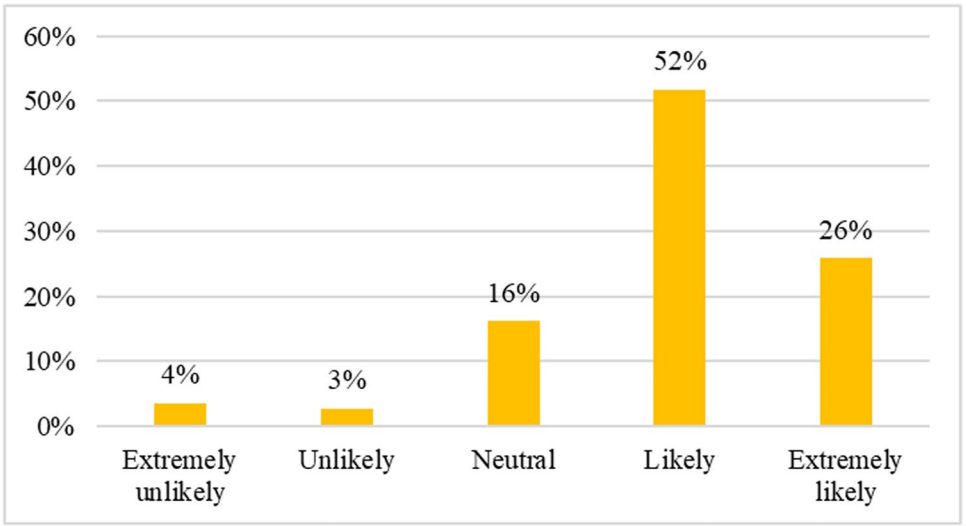

Fig. 5 Respondents' perception about the growth of sustainability teaching at their HEIs in the next 10 years (Source: prepared by the authors based on the study findings)

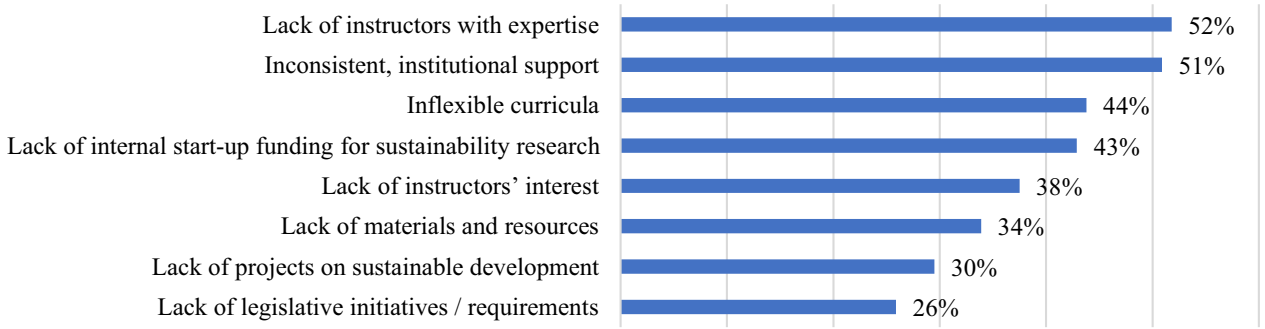

Fig. 6 Respondents' perception of the challenges to teaching sustainability (Source: prepared by the authors based on the study findings)

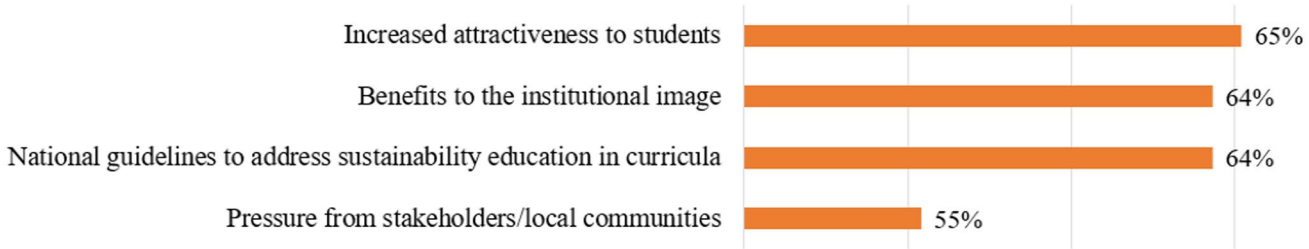

Fig. 7 Respondents' perception of the drivers for strengthening sustainability education at their HEIs (Source: prepared by the authors based on the study findings)

Among the drivers that could enhance sustainability education at HEIs, most of the responses clustered around four variables, as shown in Fig. 7 (Question: What are/could be distinctive drivers for strengthening sustainability education a step further at your university?).

Therefore, the outcomes of this study can be used to assist policymakers, managers, and students in understanding how to contribute to achieving an educational transformation towards sustainability within the context of HEIs. Transitioning towards sustainability in HEIs will make society greener and healthier, serving as an example for many other institutions, as Mohammadi, Monavvarifard [33] highlighted, as there still needs to be a more systematic effort to map this connection effectively. The practical implementation of sustainability policies in universities is strongly dependent on the willingness and commitment of the leadership and students to engage in sustainable activities. Understanding the current state of ST within HEIs can pave the way for a more sustainable future in human communities Leal Filho, Caughman [104] while enabling the same to lead towards a successful implementation of the SDGs, fulfilling specific requirements [105], thus advancing sustainability in higher education, a step further [106].

5 Conclusion and recommendations

This paper reports on a study assessing ST's current impacts on HEIs. The rationale is that ST has been gaining significant momentum and generating positive impacts on various levels. The data collection used a multi-methods approach, which entailed a bibliometric analysis, the assessment of a set of case studies, and an international survey conducted with teaching staff from HEIs in 38 countries, making this study one of the largest ever undertaken on the topic.

The evidence gathered illustrates four main trends. The first, derived from the bibliometric analysis, is the identification of themes such as environmental education, SDGs, HEIs, sustainable education, sustainability competencies, and training (green cluster) and ESD, teacher education, transformative learning, systems thinking, holistic approach, complexity, and pedagogy (the yellow cluster) as prominent ones in connection with ST. The second trend, derived from the case studies, shows that HEIs across diverse geographic regions are implementing ST practices by using tools such as provisions for new curricula, evaluation of current practices, and the development of competencies. These approaches indicate that students have the potential to gain a deeper understanding of the interconnectedness of global issues and the relevance of adopting or adapting sustainable practices. The third trend derived from the survey demonstrates that many teaching methods are currently deployed to enhance students' learning about sustainability. These include the use of case studies and research-related tools.

Moreover, "project-based learning" is emerging as a popular didactic tool. Finally, the paper has shown that interest in sustainability issues is increasing, which illustrates how important it is to develop appropriate teaching methods further. The paper's novelty lies in its approach to evaluating sustainability education's effectiveness and broader impacts on HEIs. It offers a unique approach by integrating assessments across multiple disciplines, showing how ST impacts students´ education. Furthermore, the study tracks the impacts of the sustainability literature, providing insights into how sustainability education shapes students' professional prospects. Finally, the paper shows the status of sustainability education across different HEIs and countries, offering a broader perspective on how it is implemented into practice. The findings have two implications for theory and practice. First, they showcase various approaches to enhancing the impact of sustainability education. Second, they offer novel insights into how ST is implemented at HEIs, potentially shaping future educational strategies and policies.

However, this paper is not exempt from limitations. The first one is that the bibliometric analysis used a scanty number of search strings that could only cover some topics associated with the theme, ending in April 2023. Moreover, the set of case studies needed to be more significant to account for all modalities of teaching sustainability being used globally. Finally, the survey involved participants from 38 countries, and some regions, such as Africa, needed to be better represented. Other studies may consider collecting complementary information, such as those related to demographics and individual profiles of respondents. Still, they also need to make sure they comply with the current data protection procedures, both international ones and the procedures used in their countries. Despite these limitations, this report is valuable to the literature by highlighting the current focus on SD issues within higher education, particularly course offerings. It illustrates the importance of further research on the topic. Moving forward, some measures which may be used to maximise the impact of ST in university curricula should be considered:

- Employ sustainability courses across multiple disciplines and departments, such as engineering, business, social sciences, and humanities. This approach will expose and, eventually, enable students from different backgrounds to better understand and address sustainability challenges from diverse perspectives.
- Integrate sustainability courses into the core curriculum, making them mandatory for all students regardless of their major. This will ensure that all graduates understand sustainability principles and challenges, regardless of their chosen field.
- Provide training and incentives for faculty members to develop and teach sustainability courses. Faculty academic development programmes can also help educators incorporate sustainability topics more effectively into their existing courses and encourage the creation of new classes dedicated solely to sustainability.
- Provide students with hands-on learning opportunities, including sustainability projects, internships, and community engagement. These experiences enable students to apply theoretical knowledge in practical settings, deepening their understanding and commitment to sustainability principles.
- Establish partnerships with businesses, non-governmental organisations (NGOs), and governmental agencies to create real-world projects and research opportunities for students. These partnerships will assist HEIs tailor their sustainability courses to address current and relevant issues.

- Encourage teaching-research linkages. HEIs can support research projects, initiatives, and competitions focused on sustainability, contributing to the knowledge base and attracting more students.
- Implement sustainable practices and infrastructure on campus. HEIs can lead by example through green buildings, renewable energy sources, waste reduction programmes, and sustainable transportation options. Such initiatives foster a culture of sustainability among students and faculty.
- Encourage student-led sustainability initiatives. Students should have a platform to voice their ideas and actively participate in sustainability-related activities, promoting a culture of environmental responsibility.
- This list of items needs to be more comprehensive. In addition, there is a need to support efforts in teaching, a matter which some research centres and networks such as the Research and Transfer Centre "Sustainable Development and Climate Change Management"[1] at the Hamburg University of Applied Sciences in Germany, the European School of Science and Sustainability Research (ESSSR),[2]UK Consortium on Sustainability Research (UK-CSR),[3]the Inter-University Sustainable Development Research Programme (IUSDRP),[4]and the European-North American Sustainability Research Consortium (ENASRC)[5] are trying to encourage, delivering research results that may be used in support of teaching.

By implementing the measures outlined here, HEIs will maximise the impact of sustainability courses in their curricula, fostering a generation of graduates who will become better equipped to tackle the pressing sustainability challenges in their future careers and private lives. Moreover, to assess whether ST is practical, clear parameters are essential. These benchmarks help evaluate whether students acquire the knowledge, skills, and values needed to address environmental challenges. Parameters such as students' understanding of ecological principles, ability to apply sustainable practices in real-world contexts, and engagement with community or global sustainability efforts are crucial. Additionally, measuring behavioural changes, critical thinking, and collaboration skills can reveal if ST translates into impactful action. With defined metrics, it is easier to gauge the success of educational programmes in fostering a sustainable mindset and driving long-term environmental solutions. It should be emphasised that the recommendations for policy-makers presented here are derived from the literature, case studies, and survey results. Together, they provide a sound basis for implementing these recommendations in practice.

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Data availability All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate According to the Association of Medical Ethics Committees in Germany, this type of study does not need to be reviewed by an Ethics Committee in Germany.

Consent for publication Were obtained from all participants.

Competing interests The authors declare no competing interests.

[1] Available at: https://www.haw-hamburg.de/en/ftz-nk/.
[2] Available at: https://esssr.eu/.
[3] Available at: https://www.mmu.ac.uk/research/research-centres/ecology-environment/groups/zero-carbon-sustainable-futures/UK-CSR.
[4] Available at: https://www.haw-hamburg.de/en/ftz-nk/programmes/iusdrp/.
[5] Available at: https://www.haw-hamburg.de/ftz-nk/programme/european-north-american-sustainability-research-consortium/.

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