

Policies and practices for sustainability transformation in higher education institutions

Edited by

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Policies and practices for sustainability transformation in higher education institutions

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Editorial: Policies and practices for sustainability transformation in higher education institutions

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KEYWORDS

sustainability, higher education, competences, culture, pro-environmental behavior, "green" strategy, values, experiential learning

Editorial on the Research Topic

Policies and practices for sustainability transformation in higher education institutions

Education that supports sustainable development based on the UN Sustainable Development Goals (SDGs) is a necessity for Higher Education Institutions (HEIs). This research topic sought to provide an overview of Higher Education (HE) policies and educational practices that highlight how Education for Sustainable Development (ESD) and the SDGs can be integrated in HE, to assess their impact and consider future avenues. Among the contributions received, two literature reviews highlighted gaps and suggested ways to implement sustainability as an Whole-Institution-Approach. First is a bibliometric review on ESD by [Umar et al.](#) which highlighted a concentration of research from Europe and the United States, with limited representation from Asia. The majority of studies focus on curricula, campus operations, and educational practices, but few conceptualize HEIs as entities with measurable sustainability performance. Limited attention is given to leadership, change management and green human resource management. Additionally, much of the literature focuses on reported practices and intentions rather than evaluating outcomes or long-term impacts.

The second study by [Sanchez et al.](#) is a systematic literature review that was conducted to clarify the terms environmental literacy (EL) and sustainability literacy (SL) and their links with ESD and Environmental Education. The authors found that SL is a more complex concept compared to EL, encompassing social, environmental and economic dimensions, and that it is less well integrated into HE. In addition, SL is strongly associated with positive ESD outcomes, and the conclusions of this study suggest that it can be used as a framework for curriculum design, learning outcome selection and ESD impact evaluation.

Another group of contributions focused on the two-way link between values and higher education policies and practices. The study by [Wei and Chen](#) showed the effect of higher education policies on value systems such as policy goals, policy instruments and their effectiveness. Policy objectives in China were observed to be categorized based on ideology, education, research and technology, and culture. Proper education policies enhance ESD through the promotion of green and low-carbon education and prioritizing nature, while

integrating science and innovation. Through a goal-tool-effect qualitative approach, the concept of sustainable development among students and their value system based on creative thinking and problem solving for innovation and adaptation was investigated.

Sacher et al. investigated six HEIs in Pakistan and found that faculty members' environmental consciousness and biospheric values significantly influence pro-environmental attitudes. Social influence increases the link between biospheric values and pro-environmental attitudes. These findings have implications for policy and practice in HE in that HEIs should cultivate a culture of biospheric values and establish dedicated "green teams" to promote these values across the academic community. This will then enable academics to integrate these values into curriculum design and educational practice, influencing the formation of pro-environmental behaviors institution-wide.

Similarly, Bravo et al. explored the factors that influence environmental sustainability in a Peruvian HEI. Their Structural Equation Modelling revealed that a pro-environmental culture is the most significant driver of sustainability, while document management and service satisfaction play supporting roles. The study highlights the need for HEIs to foster environmental values, invest in digital infrastructure and commit to sustainability to lead in advancing the SDGs.

Two studies focused on the perceptions of educators and students of ESD integration in HE. Annelin and Boström emphasized educators' need for cross-disciplinary collaboration to address complex sustainability challenges. A student-centered, transdisciplinary approach is seen as essential for meaningful learning. The authors also highlighted the importance of values-based education and intrapersonal reflection that supports personal growth. They offered a sustainability competence support framework that can help HE educators integrate ESD into their teaching and help increase the impact of their educational programs.

The study by Abdullahi et al. sought to explore how ESD influences university students in Somalia for integration. Their questionnaire revealed that students had a positive perception of sustainable development and were aware of the effects of environmental challenges such as the loss of biodiversity and its impact on the planet. The study also reported the use of eco-friendly options for ethical consumption and businesses supporting environmental stewardship in Somalia.

Finally, three contributions reported on specific approaches for ESD implementation pedagogies and student behaviors related to air travel.

López-Santiago et al. explored the impact of Service-Learning Projects (SLPs) on engineering students' self-perceived development of soft skills relevant to sustainability. While causality cannot be confirmed, their results show significant positive associations between SLP participation and improvements in competencies such as creativity, confidence, and collaboration. Rooted in experiential learning theory, SLPs enable students to apply their academic knowledge to real-world environmental challenges in rural communities.

Similarly, Shen et al. examined the incorporation of biodiverse edible school practices into educational curricula at Universities in Taiwan and Malaysia. Their cross-institutional research highlights how experiential and place-based learning can promote student engagement with biodiversity, food systems, and sustainability. The study provides a scalable approach to embedding the SDGs into HE through interdisciplinary pedagogy and campus-based initiatives.

Prandner and Hasengruber investigated the climate awareness and travel behaviors of international students in Austria. Their analysis revealed that student attitudes are influenced by conflicting behaviors, self-assessed ability to act, and the prevailing institutional culture. The study highlights a significant policy gap; while universities actively promote internationalization, they often lack comprehensive strategies to address the environmental impacts of academic mobility. The authors propose systemic reforms, including the integration of climate literacy into international programs and the realignment of institutional strategic planning to support low-carbon travel.

The academic contributions to this Research Topic emphasize the importance of further aligning strategy, policy and practice in HEIs with sustainability frameworks and values that promote an Whole-Institution-Approach. Priority should be given to a pro-environmental culture, enabling academics and students to develop relevant competencies and pro-environmental attitudes through experiential and place-based approaches that take into account and address the environmental and climate impacts of complex behaviors.

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Interdisciplinary perspectives on sustainability in higher education: a sustainability competence support model

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After several decades of work toward elevating sustainability education, many have called for a transformation of the education system to create timely action. Teachers, students, organizational leaders, and many other stakeholders have voiced their dissatisfaction with their experience of sustainability education. Some say we can do more to create real action for sustainable futures. We investigate what, how and why lectures across disciplines at universities in different countries work with sustainability education. We conduct interviews and dialogs with teachers across disciplines to uncover interdisciplinary perspectives on sustainability education and how to move forward. The emerging reflections provide insights about transformations in the strategies and systems, and how to implement sustainability education. There is also a call for reuniting diverse intrapersonal and values thinking between stakeholders to support transformations in sustainability education. Furthermore, participants imagined the future as a creative space where collaboration across disciplines facilitates a student-centred transdisciplinary experience with real-world practice. This study provides insights into the mindset of teachers across disciplines and countries. A sustainability competence-based support model about the current sustainability education discourse is developed.

KEYWORDS

sustainability in higher education, sustainability competence, transformative learning theory, didactics, interview, interdisciplinary

1 Introduction

In 2015, under the guidance of UN, 273 countries agreed on 17 sustainable development goals (SDGs). The SDGs have created a helpful pathway to guide organisations, such as universities, through their own targets and goals for a sustainable future. [UNESCO \(2017\)](#) have recognized an important relationship between education for sustainable development (ESD), the key sustainability competencies (KSC) described in [Wiek et al.'s \(2011\)](#) framework and the ability to attain the 17 SDGs. There is a call for action in education to develop students' competencies to work with the sustainability problems we face now.

Internationally, universities have been working to integrate sustainability not just in their education but across campus developing learning labs ([Hald, 2010](#)) and a whole school approach ([Mogren et al., 2019](#)). The demand for ESD has been placed on the general education community to integrate ESD into ongoing present modules, courses and programs across disciplines. The reasons for why teachers must deliver ESD is clearly outspoken by several stakeholders, for example institutions such as UNESCO and state education authorities

(Swedish Council for Higher Education, 2021), teachers, students and university leaders (Leal Filho et al., 2020). Teachers have been given the freedom to identify what and how sustainability should be taught. In order to do this work cooperation and exchange of ideas and resources is needed.

Space for creativity in sustainability education (SE) has been discussed (Hart et al., 2009; Clark and Button, 2011; McCrory et al., 2020), and a call for less add-on lectures about sustainability (Wals and Benavot, 2017; Barth et al., 2023) since it puts little emphasis on the importance of the transdisciplinary knowledge that SE embodies. Transdisciplinary knowledge (Scholz and Steiner, 2015) includes interdisciplinary knowledge and practical knowledge in the process of inquiry of sustainability challenges; and interdisciplinary knowledge is derived from different disciplinary science that provide different perspectives and understanding of the knowledge. To be able to help students to delve deeper into the sustainability challenges faced, students need to build capacity in sustainability competency through richer transdisciplinary activities (Backman et al., 2019; Alm et al., 2021). Community learning labs (Hald, 2010; Macintyre et al., 2020; Holmén et al., 2022) are one example of how universities have been working to enable richer engaging activities that can apply transdisciplinary approaches to sustainability education. Such learning spaces provide scientific and practical knowledge experiences for several stakeholders.

Many advocate for a student-centred experiential learning approach (Ely, 2018; Backman et al., 2019; Öhman and Sund, 2021). Experiential learning provides a space to prepare students for real-world problems and is not a new approach at many universities, however real-world problems often require an interdisciplinary approach. This involves many higher education teachers reassessing how they have been practicing the art of SE, to transform the language of teachers toward an interdisciplinary language of sustainability science (Brundiers et al., 2020).

SE questions what we teach, why we teach and how we teach it, as a sustainability discourse (Seatter, 2017). To facilitate a transformation in the SE discourse from a political position guided by the UN toward a position situated in knowledge of transdisciplinary sustainability science, it is time to support higher education teachers to share, learn and collaborate teaching experiences. We ask what has been experienced by teachers to teach sustainability, how do teachers practice sustainability education and imagine a future of SE, and why teachers implement SE.

In this article we investigate the findings from an action research project that has created and participated in different events across university campuses in higher education internationally. In the next section we discuss the theoretical background to the work conducted in the project. Section 3 provides insights from practicing higher education teachers and we conclude the article with a model about the sustainability education discourse across universities.

2 Transdisciplinary didactics for sustainability education: transformative learning theory

Transdisciplinary SE provides scientific and practical knowledge about complex sustainability challenges that require interdisciplinary scientific inquiry as well as practical understanding (Scholz and Steiner,

2015). Interdisciplinary SE includes the concepts and knowledge that combine different disciplinary perspectives to provide a more holistic scientific approach to the learning experience. Knowledge from practice also provides multiple and diverse stakeholder real-world perspectives on complex sustainability challenges. Together, science and practice provide a transdisciplinary sustainability learning space.

Didactic is a theory about what, how and why learners' build capacity to transform through the tools of knowledge and skills (Öhman and Sund, 2021; Mård and Hilli, 2022). As knowledge is taught about what sustainability concerns in each discipline, teachers are increasingly aware of a need to include interdisciplinary, multi-disciplinary and transdisciplinary (Barth et al., 2023) approaches to teach what sustainability is about from a scientific and practical perspective. How teachers teach sustainability can be quite diverse, using different pedagogical approaches (Lozano et al., 2017) within the disciplinary norms. Why teachers teach through sustainability or why they are resistant to the practice of SE could be due to our different feelings toward SE (Shephard and Furnari, 2013), which presents a diverse intrapersonal thinking toward sustainability science.

Furthermore, transformative learning theory explains learning that transforms values through intra-personal self-awareness that creates an understanding of our ethical responsibility (Sterling, 2010). Transformations in SE include the need for a holistic integration and a built-in approach (Wals, 2014) of sustainability in higher education. For transformative learning to be successful, the institution must put in place the principles and policies that lead the teachers toward transforming sustainability education toward a transdisciplinary approach and teachers become facilitators of co-created learning.

Many universities have applied different principles and policies in line with aspects of the sustainability perspective or sustainable development in their education system, which reveals support through sustainability leadership (Leal Filho et al., 2020). Higher education transformations toward student-centred learning that can challenge traditional mindsets and promote creativity (Lozano, 2006; Barth et al., 2007; Baumber, 2022) requires adapting how teachers teach from the role as teacher to a role of learning with students – co-created transdisciplinary learning. The sustainability competence of teachers and students therefore build capacity to transform practices to be able to act on sustainability challenges (Brundiers et al., 2020; Redman and Wiek, 2021).

Students and teachers recognize and understand sustainability's wicked problems (Lönngren and van Poeck, 2021). Transformative learning requests a space for students to consider life-long learning for sustainability. Facilitators engage with students through more active, inspiring and solution-based activities (Eka Putri et al., 2023). Interdisciplinary activities, such as anticipatory practices (Sharpe et al., 2016), and art in sustainability teaching (Clark and Button, 2011; Heinrich and Kørnø, 2021) are increasingly called for but not often applied. A transdisciplinary approach to sustainability learning can provide the knowledge and skills students and teachers need to transform SE (Scholz and Steiner, 2015; Baumber, 2022).

3 Method

We conducted interviews and facilitated dialogs with teachers to learn from their experience teaching sustainability in their different disciplines. Open question interviews were conducted among

participants to let information about higher education experience emerge (Alvesson, 2003). We identified several questions based in research (Cebrián, 2017) to design an interview guide (see [Supplementary Appendix](#)) that could help elicit information about the three main research questions: (1) what teachers experience to teach sustainability education, (2) how have teachers captured opportunities to build student capacity for sustainability, and (3) why teachers implement SE? Sub questions included probes into the teachers' understanding of sustainability and evaluation of SE work.

3.1 Participants

We sought out teachers that work at universities on an international scale that are responsible for courses on a program because we wanted to understand what might have changed over several years. The sample followed the snowball approach (Mweshi and Sakyi, 2020) through known contacts (seeds) at Umeå university and in the Baltic University program initiative that are directly involved in SE initiatives. We also began our search for participants with teachers who work in an environment where SE is emphasized but do not specifically teach on an SE named course or program. Those that were recommended by interviewees that had participated were then contacted, which included several universities in Sweden and Finland and then Germany and the UK and the Netherlands. This approach has led to a large international project that is taking part in several cooperations on an international scale. In total, emails were sent to 67 teachers that work across all faculties and several disciplines¹ in Sweden, Finland, Germany, Poland, Latvia, Greece, England, the Netherlands, Canada, the US and Australia. The experience of the teachers in higher education is a range of between 3 years to 40 years, and teacher roles ranged from PhD students to full professors, including adjunct professors, administrators, sustainability leaders and pedagogical development roles. The authors acknowledge that the snowball approach to sample selection has its limitations and can explain why the participants may present certain perspectives that differ compared to teachers based at universities in locations that are not represented in this study.

3.2 Data collection

We conducted the interviews and facilitated dialogs between 2020 and 2023, using Zoom and face to face, and each took between 60 min and 90 min long. The length of time was influenced by discretion of the researchers, pragmatic reasoning and the number of details being elicited (Alvesson, 2003; Creswell, 2006). There were 26 interviews that were recorded on Zoom, and transcribed using the software called Trint. Consent was given to record interviews and use the information for research. Other dialogs were documented by note taking. Interviews and dialogs were conducted in English, but sometimes in Swedish to

help participants in Sweden feel comfortable to talk freely. The authors are proficient in both languages. Both researchers participated in the data collection and reflected on the experience together.

3.3 Data analysis

The inductive and emergent thematic analysis follows recommendations in research (Alvesson, 2003; Denzin and Lincoln, 2011). First, we took notes during interviews which revealed emerging themes that were coded manually. Interviewer discussions after each interview helped to recognize patterns emerging (Alvesson, 2003). Second, listening to the recorded interviews helped to confirm and reveal new themes (Rowley, 2012; Leedy and Ormrod, 2013) that were manually coded. Third, the software called NVivo was used to upload transcripts and organize the codes by the emerging themes.

We applied the cluster analysis in NVivo and found that “knowledge” and “time” is needed to “teach students sustainability” [themes of support and lack resources] and “to teach something different” and through “good research” [themes of knowledge-based sustainability science, didactics and practice]. Also, to “change business” we “need to question what we know” and teachers “want” to integrate “sustainability well in a course to actually be a part and mean” something and emphasize that it is “important people discuss courses and meaning” in SE [themes of facilitation support, transformation through action and sustainability science, shared collaboration].

The themes that emerged and confirmed by participants and the cluster analysis were then established as “support” and the “lack of resources,” especially time that we frame as strategy and systems thinking; also, themes of “didactics in practice” that we frame as implementation thinking, teacher “attitudes” revealed intrapersonal and values thinking and “collaboration” as interpersonal and future thinking, to create interventions for a sustainability science transformative education system. The coding scheme was confirmed by a line by line reading of the transcripts and then comparing the codes between participants (Rowley, 2012; Leedy and Ormrod, 2013). What emerged by the manual coding is the application of the key sustainability competencies that frame the discussions revealed by the participants. Each researcher cross reviewed the analysis to test the trustworthiness of the emergent themes and data was collected over several years to provide a varied perspective from different participants.

For anonymity, each participant was given a coded name, for example, P1 = participant number 1. The cites chosen for our discussion in section 4 represent the emerging themes that the participants gave during the interviews and were verified by continuing dialogs with participants at different universities. The interview responses were also verified by participating teachers to assess our interpretation of the responses. The translation of the Swedish speaking interviews into English was conducted when both researchers had come to an agreement about the information and meaning behind the chosen response data quotes used in the paper.

4 Results: a dialog with teachers in higher education

After listening to many teachers in higher education during interviews, project presentations, workshops and other collaborations

¹ Art, history, literature and language, philosophy, law, religious studies, anthropology, economics, geography, political science, psychology, sociology, biology, chemistry, physics, earth science, computer science, mathematics, architecture, design, business, education, engineering and technology, environmental science, forestry, media, library, and medicine.

at universities, we have developed a thematic presentation of the narrative. The following results will provide perspectives about how SE has been experienced in the higher education systems at different universities across several countries. The analysis is organized to answer the three research questions: (1) what teachers experience across disciplines to teach sustainability, (2) how have teachers captured opportunities to build student capacity for sustainability, and (3) why teachers implement SE?

4.1 What teachers experience across disciplines to teach sustainability

When listening to teachers discuss their experience with teaching sustainability education, it became apparent that the participants were applying their systems and strategic thinking competence to sustainability education. While thinking about the education system that sustainability education is applied within, teachers provide insight into the different strategies that have been applied and the strategies that are preferred. Teachers that participated in this study have called for a renewal of guidance by sustainability education leaders and innovative methods to deal with time restraints.

4.1.1 Strategic thinking: renew guidance

There are several international groups that provide guidance toward transforming education to a sustainability perspective, for example the principles for responsible management education (PRME) and the UN's sustainable development solutions network (SDSN). There are also several national and local initiatives that can help guide teachers through their work to transform SE in their subjects. Despite the efforts made by many, teachers can struggle to find the guidance and leadership required for applying sustainability education. While reflecting on the sustainability education strategies, several participants pointed out a need for more guidance from outside their personal network, saying:

We personally know some people that are doing research on certain things in certain areas, and we can talk to them. But what if we make it a bit more formal by saying that, you know, for questions related to that, you may have these people that you can talk to or you need some guidance when it comes to teaching sustainability related issues. You may have a discussion with them that could be in a very nice way to also kind of have a better team when it comes to teaching certain phenomena (P3).

Guidance only being provided from personal networks is not sufficient and there is an outspoken need for direction. "From above, you can give more support and also directives that sustainability should become a natural part of our education" (P 21). Evans (2015) finds that when there are visionary leaders in position at the administration of universities transformations on a transdisciplinary level will be most successful. Support from sustainability education leaders is on demand and organising formal support to facilitate capacity building in sustainability teaching is recommended.

The system of sustainability education can differ tremendously between universities across countries, some have been able to create full learning labs dedicated to sustainability education, while others feel that they do not know how to integrate sustainability into their

education. Some participants point out that guidance about what to expect from the next class of students is lacking in the system of educational programs, saying.

To know what the knowledge of students is, the background knowledge of students who are coming to you, to your course... you do not know if they [the students] already have had some introduction... this fragmented nature of the way we teach sustainability that it's usually used just like a small thing here, a lecture here and you do not know how sort of the overall progression of learning looks like with students...there's a fragmentation of sustainability learning (P9).

Formative assessments (Andrade, 2019) can help teachers to plan and provide lessons adapted to the students' needs. Several of the participants also called for a whole school approach as a strategy, for example "I think if we had kind of a more common understanding as a school, how we want to teach about it and how to teach about it, and then any kind of guidelines that we could have, almost some kind of teachers' manual" (P18). Guidance from the whole school could provide a strategy to achieve a sustainability perspective integrated in a sustainability science curriculum for transdisciplinary learning (Barth et al., 2023). We have experienced that there is a clear voice from all countries that asks for more formal support to guide SE transformations, support which is considered vital in the abilities of teachers to create transformations in their teaching activities (Henderson and Tilbury, 2006; Copsey, 2018).

There is some variation in how the interviewees perceive the level of support that already exists in different countries. There are perceptions of countries that have better support by the laws and policy that have been set. Participants in countries that have installed policies and laws on SE perceive that support is not given to create space to practically apply teaching. Participants in countries that have little law or policy support for SE find they have the space to create practical teaching opportunities with support between teachers, and instead ask for guidance from above to bring these initiatives to scale. Thus, the systems and strategies applied to SE can vary across countries, but all teachers perceive a need for support and guidance from management and between teachers and universities. Sustainability education leadership that facilitates teaching practices has been lacking across all disciplines on an international scale.

4.1.2 Systems thinking: restore time as the actor (innovator)

Reflecting on the education system, most participants have discussed lack of time as a challenge. Many universities create a system where teacher training hours are rewarded, and the planning is created around a specific number of hours applied to different university duties. There is a difference between disciplines within universities about how the working hours are delegated to teaching hours, research hours and other activities such as community engagement and meetings. The lack of time to train, to reflect, to adapt and create is very present in higher education, where work overload and overtime is expected and considered a norm in the culture of academia. If a teacher teaches 100 percent of their work time or more (overtime/work in their free time), when do teachers get to train, learn, adapt create build or find the space to transform their education for sustainability. This concern indicates a perspective on time in

sustainability education that is probably one of the reasons why sustainability as an add-on lecture is still the norm found in education today.

While reflecting on the higher education system of time and expectations for development, a participant explained,

I do not always have the time to prepare as much as I would like to. But I mean, that's a resource issue as well. You have to prioritize. Do one course at a time. And I can feel that sometimes what I'm talking about feels a bit outdated because so much happens in the area, but I do not always have the time to keep up...when I tried to bring these issues up [integrating sustainability education], people do not have time and then the meeting is over and then we do not talk about it. So, I mean, that approach [bottom-up] has not really worked. So, I think we need firmer top-down approach as well (P12).

This evidence represents a system developed to cope with a lack of resources in higher education. Sustainability leadership is not just needed in the policies driven from above, but also sustainability leadership for SE is a common discussion across all disciplines. A lack of resources indicates that teachers need to develop an approach to SE through systems thinking, by reflecting on what universities do have and creating interdisciplinary support where students can benefit from knowledge from different perspectives (Scholz and Steiner, 2015; Baumber, 2022). In order to help teachers to feel comfortable to take the risk to try something that they are not an expert in, requires a transformative mindset and a willing to work with the co-created curriculum approach (Bovill, 2020). Support for the teachers can come from active listening that can generate ideas for the teachers to connect what they already do to the sustainability perspective. An efficient approach that may not seem like time taking could be required. Evident in a reflection, a participant acknowledged how a lack of time and knowledge can be intertwined, saying,

I think that, or I want to think that nobody's against sustainability in our [workplace], with our colleagues, because it's well-educated people that should know better. But I think that in a lot of cases, it's time and knowledge...It's not that people do not want to. It's time to rethink and integrate it in a good way. When people are already swamped with work, to be honest (P6).

Since lack of time has become such a problem for these teachers, there is sense that even if there is a will the teachers have not been able to find space in the system to analyze where and how they can implement SE. One answer to seeing time as a restraint on building capacity could be eased by interdisciplinary support and input by practitioners, since efficiency in time and knowledge could transfer between disciplines to provide space to apply transdisciplinary SE. Furthermore, some participants revealed the lack of importance emphasized on SE, since training for SE would take time away from other work.

I think it's always about the fact that we have limited time. We have limited resources. Then I think it boils down to it taking too much time from other things or taking too many resources from other things that you also have to do (P11).

Several participants resonated with the suggestion that the university system expects too much from teachers in terms of the activities demanded in order to keep their job or climb the professional academic ladder; “publish or perish” is a common reiterated phrase, but nothing about teaching SE or your out. Hence, SE leadership is needed to inform and engage, encourage and create action for a transdisciplinary approach to higher education. Although some sustainability learning labs have begun a more inclusive whole institution approach to education for sustainability (Hald, 2010; Holmén et al., 2022), many teachers still lack such support networks. All participants have mentioned to us that they feel there are not many teachers that share the passion for SE and therefore find it difficult to organize courses or programs, and holistic learning or living labs that can provide such learning spaces are considered an even bigger challenge within the current university system. Many participants do not find they are given the right resources to support the work necessary for transformation of their educational practices.

However, some say “just do it!” (P25) and “Stop talking about time!” (P10) and indicate that sustainability education should be incorporated no matter the resources or time to work or resistance in the education system. An interdisciplinary approach to SE could help develop teachers' capacity to transform mindsets toward collaborative teaching programs that provide the needed knowledge environment for student sustainability learning. Therefore, there is some differentiation in how engaged and driven teachers are to develop their SE no matter what time they have for work or other activities.

It was apparent that strategic and systems thinking challenges for support and time were common across disciplines and universities in different countries. If time is the actor in this challenge, how do we transform teacher mindsets to consider time through an alternative lens (Facer, 2022). Innovations in how time is perceived and how time is used as well as how time drives transformations can be considered to adapt within the education systems or develop new educational systems. Future research can pursue these topics to find out more about what international transdisciplinary support networks can provide in terms of guidance, collaboration and resources that can implement SE transformation without needing more time. Also, how can time be used to benefit the needs of teachers and students in sustainability education. Moreover, future research could study why the actor of time is so urgent, uncertain and unsustainable across disciplines and nations.

4.2 How teachers practice sustainability education and imagine future teaching

When we discussed how teachers teach sustainability with the participants, there is great enthusiasm in engaging implementation thinking about how to inspire students into action to work with the sustainability challenges. There are many similarities practices across different countries that teachers wish to keep doing due to the success and engagement created with students. However, there is also a common understanding that some practices need to be renounced so that space is provided for a better learning environment for all students.

4.2.1 Implementation thinking: practices to keep and renounce

The participants have pointed out the availability of courses about SE provided for teachers at their university, but in most cases it is not mandatory for teachers to train in sustainability education. Courses on SE can help teachers to reflect on what they are doing and how they can develop their work as well as inspire new approaches. Several participants point out that they thought teacher education and training activities that can provide opportunities for reflection and innovation for implementing into lesson plans is needed.

To transform sustainability more effectively in higher education, researchers point out that there is a need to develop pedagogical approaches (Lozano et al., 2017; Backman et al., 2019) not just about sustainability but for sustainability (Persson et al., 2023). Several researchers (Wiek et al., 2011; Wals and Benavot, 2017; Brundiers et al., 2020) also recognize that we need to be able to teach for sustainability in a way that can enable students to act on the sustainability challenges we face; to work on creating solutions for a sustainable future (Browne et al., 2020). Holdsworth and Thomas (2015) have found that applying an interdisciplinary approach coupled with a holistic framework can help teachers develop their sustainability education. Some examples of pedagogical activities disclosed by participants of this study include experiential approaches that benefit from a practical understanding, for example:

The literature, cases and examples we give creates a ground for discussions that helps to influence the students. It is quite important to choose something that is interesting and guest lectures that come from the practical world gain more interest from students than researchers as teachers. It is important that the course works on follow-ups to the guest teachers' points to keep the knowledge flowing about current practical points. What are the negative consequences and what can we do better? (P13).

Experiential activities can create opportunities to learn and contribute to society's sustainability challenges through real-world learning practices. It is evident that academics across participating nations include out-reach activities in the activities planned for SE to build capacity in implementation competency. Some lectures informed us that they have designed capstone projects where students work with organizations that have proven to develop intrapersonal thinking competencies for sustainability, visible in the reflection work set for students that take part in these experiential activities.

A common discussion we had with participants is that there are different perspectives about whether the teacher teaches a course that includes sustainability, teach a course about sustainability, or whether sustainability is a pedagogical approach applied to teach. One participant explained:

It's the balance, because it's a lot of things in each course that we want to teach them, that I want them to have with them and to really let them dig into it, but still not take over the entire course because it's not a course in sustainability... it cannot be the only thing we need to think about when we are planning... and there are several other factors that are also important (P16).

While some teachers still struggle with how they can teach about sustainability, others build capacity for sustainability through

the pedagogical activities and resources they use to develop the students' competence in sustainability. Some participants pointed out that integrating SE into the education system will be a natural learning curve process that needs to solidify in real, tangible applications with each subject. A participant explains their experience, saying:

Teachers should not be left to include sustainability... gender was important 20 years ago... it was good that the department was focusing on, for example, female researchers and there should be similar tangible programs for sustainability. People who research on sustainability should be awarded and students... promoting, also financing research projects, and systematically including our own research in teaching, would be good. I mean, make it tangible. Not only promises and ideas (P7).

Tangible application of the sustainability perspective requires a transformation of mindset in how sustainability science can be taught. It is no longer an additional application of material that teachers need to apply, but a perspective on science with a transdisciplinary approach (Salovaara et al., 2020). Sustainability competencies are something that enables the student to act for a sustainable future, to transform societies and take on their ethical responsibility (Sterling, 2010).

Some participants in the Netherlands, the United Kingdom, Sweden, and United States have shared with us about how they have implemented creative approaches to teaching, becoming facilitators (rather than the role of teacher) and providing students with the space to co-create learning activities. The activities include real-world experiential support but also traditional discussion and literature-based study. The systems are described as flexible that can also control for university norms, such as expected learning outcomes, program goals and set text literature.

Several participants across countries have discussed a reluctance to share ideas, resources, tools used in the classroom. Some have even discussed the intangible patent on their own ideas, material and classroom material, suggesting ownership over pedagogics. However, some have revealed more open approaches and believe in shared resources for all teachers. Thus, approaches to SE practices differ between nations due to national academic norms. The competence to implement SE is similar across disciplines, where most participants mentioned how there are only a few that really get involved and thus there is much room for improvement and a need to transform mindsets of teachers in each discipline to be able to implement SE on a transdisciplinary scale across universities. Future research could investigate what practices can facilitate the international application of sustainability education, how can transdisciplinary knowledge be best applied in teacher learning activities across nations, and why applying alternative creative and flexible transdisciplinary practices in SE can be met with resistance.

4.3 Why teachers implement sustainability education

As we discussed the teachers' own interest toward SE their intrapersonal and values thinking competencies showed diverse perspectives across countries and disciplines. It is widely regarded (Brundiers et al., 2020; Redman and Wiek, 2021) that attitudes and

interests influence self-awareness and the mindset that builds intrapersonal thinking competency. The teachers' intrapersonal thinking and implementation brings meaning to SE that can then build student capacity for sustainability competence. When we asked participants about what they would change in SE, the participants future thinking revealed that they would like opportunities to collaborate and use creative innovations in SE.

4.3.1 Intrapersonal and values thinking: reunite with diversity

The expectations from policies made at management in departments and at the main university governing body can be faced by a group of teachers that have diverse attitudes, interests and values toward the sustainability perspective. During interviews, we noticed that some feel that they should or must implement sustainability, while others feel it's not natural or it's not 'my' subject. Other teachers are completely comfortable with the demands of policy or law to integrate SE into the curriculum, for example one participant said, "we need to make teachers realize that it is important" (P2). However, it was revealed that many teachers feel alone in their work to teach SE. For example,

I take one course at a time and try to focus a bit more on developing that one, but we can do that in a more strategic way and a joint way, rather than just me doing it all by myself when I'm basing the choice of where to go and what to do on my own knowledge and values, rather than the strategy of the school overall (P26).

This is an example of how teachers question their own influence on the SE they can provide, showing that self-awareness and resilience is a fundamental capacity needed in higher education. This first stage approach to SE where the teacher experiments with what they know can have its positive effects, to start from somewhere there is a safe space (Holmén et al., 2021). However, to take the next step and transform SE the teacher needs support to feel comfortable to experiment with new interventions. "There is certainly support that I'm not aware of for this teaching sustainability, but it's very much up to the individual teacher" (P20). Support from collaborative groups to know how to teach for sustainability is lacking (Persson et al., 2023).

One obstacle to transforming SE is the different interests that teachers hold themselves. If a teacher holds an opposing position on what is taught and how it is taught, they may find it hard to see the benefits of why they teach sustainability. This was indicated by participants that said:

I think it might be the interest. People have different interests in sustainability ... I think the clarity from above can also become clearer. There is a trade-off here. The academic freedom that we should have and then the one that slips it into everything that we do at the university, regardless of whether it is research, teaching or going to meetings or whatever (P14).

If higher education teachers have a lack of incentive (Cho, 2017) and argue for academic freedom (Hugé et al., 2016), it can be difficult to persuade teachers to educate for sustainability when their attitude toward it is reluctance, negative or in disagreement. Teachers feel they

need to communicate these diverse values and capabilities for intrapersonal reflexivity and be heard. Transforming teachers' mindsets toward a transdisciplinary approach where diverse knowledge can emerge could help bridge this divide in SE values. Transformative learning encourages new ways of reflecting and understanding the complex challenges of sustainability and requires collaboration and support (Baumber, 2022). Another participant points out:

It would be interesting to hear other people's perspectives on how sustainability can be incorporated into it [a course], because I do not see that it's always a natural fit, although I have not thought that much about it, but you know. Perhaps we should. Perhaps we have to, but I do not see that it's always a natural bedfellow. In some areas, of course, it is perfect, you can talk about anything (P4).

It is apparent that the capacity for inner development differs between participants of different disciplines. Those in the humanities and especially art and music find self-awareness and reflecting on a sustainability mindset is a natural experience, while those in mathematics, chemistry and physics have shown less engagement with their own capacity to work with SE. Another participant explained their position through their understanding of sustainability as a political agenda, "The 24 goals. Is it 24 goals of the UN? Teaching sustainability seems very politicized to me" (P22), showing a disinterest in how many UN SDGs there are and showing a disliking in the politics of how Greta Thunberg has been used or how activists behave, the participant continues:

"What I want to say is I do not ever want to be doctrinal. This is why I do not like the whole Greta movement, because to me it's doctrinal. I mean, if I may elaborate on that, the way she's dealing with this current issue, she's a mouthpiece for whomever. She has influence over millions of young people. And I think she's the anti-Trump actually. I think they are both as dangerous as each other" (P22).

The nature of sustainable development as a political movement, derived from development diplomacy (Bolis et al., 2014; Moomaw et al., 2017) has created an overwhelming emphasis on the values of one type of sustainability. Several participants point out that they have experienced a resistance to the term transformation or students as change-agents, since it holds a political opinion that some believe academics should not hold (Shephard and Furnari, 2013; Hugé et al., 2016). However, the value of transformational learning has its background in understanding diverse cultural values and sustainability science has a value base where transdisciplinary knowledge exchange is emphasized (Sprain and Timpson, 2012). Although the scientific values of sustainability should be understood by teachers, through a scientific dialog, sustainability as a science has not been emphasized as much as the UNs SDGs (Bendell, 2022). A teacher set in the sustainability science approach explained their position,

If someone is trying to change a text description or a learning outcome related to sustainability, I'm not accepting it, really. It will not be accepted unless it's covered in some other way. Which is

then an improvement, probably, but taking something out related to sustainability will not fly (P5).

This complex environment of values conflicts can hinder the transformation of the education process. The values of sustainability may be misinterpreted when thinking only through the UN's SDGs. Teachers have their own values as well as work within a system of values and a community of different values, for example "some people might not want to, or they do not feel confident, so they need this kind of, you know, encouragement" (P1). Teachers also have their own personal attitudes and self-awareness. For example, one participant suggested "I think we need to make it interesting for people to work with" (P2), implying that SE is not interesting enough to put effort into transforming the existing education. Comparatively, a teacher in the arts states "I think it is art that will save us. It is art that connects us, helps us to understand, to feel, to connect, communicate and enjoy life" (P24). Teachers' attitudes and knowledge of sustainability can affect their ability to transform SE (Jones et al., 2010). The diversity of teachers' attitudes, interests and values across disciplines creates a complex environment where collaboration needs to be encouraged.

4.3.2 Futuring and interpersonal thinking: imagining creations

Transforming education so that students can act on what they know is of primary concern to the participants of this study. Teachers talked about how there is a need to develop a network of local, regional, national and international colleagues for SE to enable a learning space for students that can act on the transdisciplinary of sustainability challenges. When we discussed what the teachers thought would help them transform their education for sustainability, participants replied "Maybe just sit together and talk about it because it's kind of seems like one of those things you kind of talk about informally, but how you would actually do it creatively" (P8). Also,

I would like collegial discussions, or workshops or seminars or something for the teachers ...support of my colleagues. I mean, if we were to discuss and develop these things together, that would be a great leap forward. And then we can also have directed development issues that focus like I do now by myself (P15).

Although workshop and seminar series are often created and ongoing in most higher education institutions, the problem of having no time to attend comes up again. Several participants point out how there are low attendance rates for seminar series about SE already provided. Since many of these participants also noted that they do not know about such opportunities, it seems that information dissemination across campuses and between universities is lacking. Explained well in a participant's response,

If there was a possibility of creating and maintaining a sort of pedagogical community which is interested in this [sustainability education], and questions, deeply and wants to explore together how we can improve teaching...how could we develop our teaching in order to make things work? So, a sort of community of this kind would be interesting (P17).

And when asked about how to act on these ideas, participants revealed that creating a space for experimentation, where teachers can easily access information and collaborate on different scales, locally, nationally and internationally. A safe space to try ideas and experiment with new activities in the classroom (Holmén et al., 2021). For example,

There needs to be some kind of action and one action that has been done is like drawing it [sustainability education] into the different courses. But I think that a page on the Internet that provides tips and tricks and discussion, and that each section or someone responsible that is really good at different parts could come up with ideas on that subject. How to integrate sustainability into a subject... we create a hub of examples on how it can be done. Both integrating in different topics, but also sustainability in general... How do you do it in class? Depending on subject, because it's different, depending on subject (P8).

Practical and flexible resources in a coordinated open access environment requires collaboration, the will to share and support each other in a reciprocal relationship. This work to practically implement activities with students has also had a varied response. Some participants have talked about the difficulty of incorporating different practices when traditional practices need to also be taught, such as lab work and the use of different tools and materials. A space where ideas are shared could inspire different disciplines and how to adapt to include different activities. A participant disclosed,

Creating these pockets of experimentation and freedom. Because the thing is also when you do this, especially if you want to do something new, you want an environment where you can experiment and play and introduce things. And of course, within the existing structures that might be challenged. Could it mean like designing your courses? Could it mean, creating more space within existing courses? (P19).

There have been several examples of teachers who imagine a future where teaching has transformed. The futuring method (Sharpe et al., 2016; Liveley et al., 2021; Czerniewicz and Cronin, 2023) has proven to be a useful technique to help teachers imagine what is wanted and backcast to how teaching is experienced now, and then consider the changes in structure and behavior in order to achieve the imagined future. A technique and practical tool that can also be applied in many different student class contexts. There have been several successes in universities around the world (Hald, 2010), but many still call for guidance to sustainability education. Participants from all disciplines have discussed that they need support between universities on an international scale and believe that this could help to facilitate the imagined transformation in higher education.

5 Discussion and conclusion

In dialog with practicing university teachers on an international scale we listened to many experiences that call for reinforced support and collaboration to be able to create a space for the transformation

of sustainability in higher education. Add-on lectures are not sufficient, students need more (McCorry et al., 2020). Reflections on what we have been teaching, why we must continue this work and how we can achieve this have provided insights into the present state of SE and its imagined future.

We identified themes in the narrative about support and guidance, practical teaching inspiration and innovative time solutions, collaboration and facilitation of open resources, and most importantly action that can transform SE toward a student-centred approach. It is apparent that there is a relation (see Figure 1) between the support that can be provided by management and the support that can be shared between lectures across subjects, departments and universities on an international scale (strategy-interpersonal). Also, support to provide the imagined space to facilitate co-creation, student-centred learning and the transdisciplinary sustainability science approach (strategy-futures). In order to apply such transdisciplinary approaches (strategy-implementation), teachers discuss the inspiration of how some schools have abandoned the traditional approach to the higher education system and designed new schools (Ecoverities, 2018; LIS, 2024), while others have applied alternative approaches within the traditional education system (Hald, 2010).

Some teachers have brought up the complex connection that SE has with political agendas and suggest inspiration and shared resources between universities is needed to be able to apply sustainability didactics from a non-political perspective (values-implementation). In a call to open up a space for facilitation lectures ask to reconcile the diverse values and intrapersonal feelings toward sustainability education in order to better collaborate (values-interpersonal). Across these diverse teachers there is a common call for guidance from management in a whole school approach and

sustainability leaders across departments, disciplines and universities to share practices, knowledge and other resources with compassion (system-intrapersonal).

In order to implement transformations in SE teachers across countries have noticed some practices are not working and some practices that have been used for many decades have been well fitted to the SE approach (systems-implement). Teachers are inspired by the learning experiences that have applied a transdisciplinary approach and many have discussed how sustainability didactics can help this process (futures-system) but recognize the complex nature of teaching across disciplines in current education systems.

To conclude, teachers reflected on the different types of guidance that direct sustainability in higher education. Some teachers disclosed how useful the policy and legal directives can be as a support since it can help with resistance from students or colleagues. Others commented on the dialog about sustainability science as an interdisciplinary knowledge approach to create dialog for SE support. Hence, the guidance and support from legal directives, institutional goals, visions and missions and departmental management policy can help drive the work of SE (Persson et al., 2023), but much more support from sustainability education leaders is needed from a sustainability science basis to create a transformation of the education system.

Several constraints were revealed including the lack of resources in terms of time to develop courses, competencies in sustainability and being left alone to do the work. Many teachers talked about the feeling of being left alone leads to risks in the workplace due to diverse values and management approaches. Participants call for time to create space for a dialog supported in sustainability science to overcome the challenges faced in transformations of teaching sustainability education.

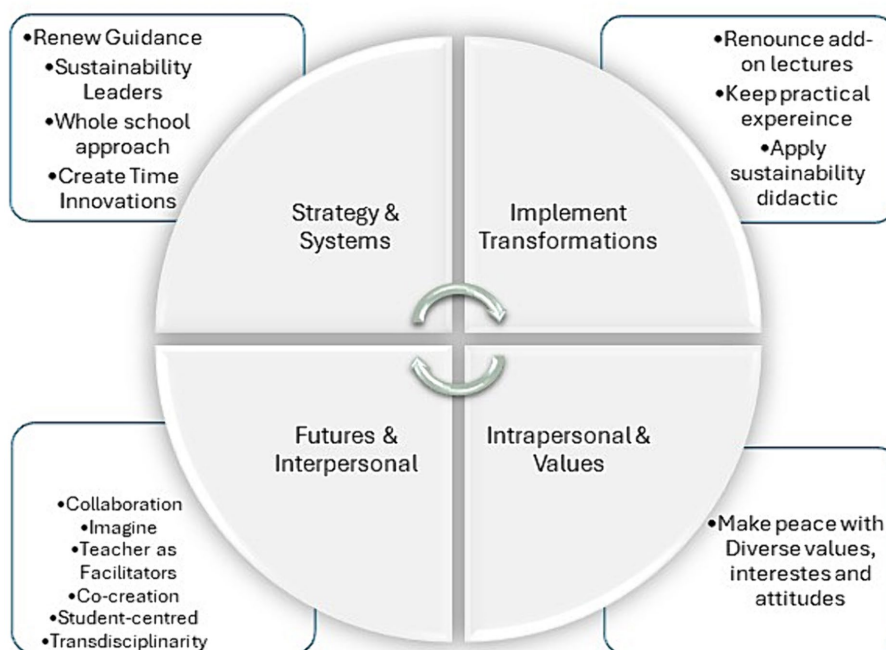


FIGURE 1
Space to facilitate transformations in sustainability education.

Across disciplines teachers shared common capacity to apply systems, strategic, interpersonal and futures thinking. However, they also signaled that their approach to provide SE through these competencies have different approaches and apply different theories. This indicates that there is room for an interdisciplinary approach where collaboration could provide knowledge from these different perspectives across disciplines and combine to create new knowledge as teachers and students learn from each other in sustainability science inquiry.

The discussion also revealed that teachers differ in their values, intrapersonal and implementation thinking competencies across disciplines. For example, engineering and business teachers are well experienced in implementation competency building and include practice in their SE, and teachers in the arts, literature and sociology find it is common to apply intrapersonal competencies since self-reflection activities are the norm. There is evidence to suggest that different disciplines work with values, intrapersonal and implementation competencies to different extents, some not at all touching on these competencies. Hence, there is a great possibility to learn from each other through interdisciplinary collaborations in SE. Teachers in higher education commonly train in pedagogics to improve their teaching. It would benefit SE if teachers could also train in different disciplines to improve their knowledge across disciplines.

Sustainability values are widely described as political and are regularly considered controversial in higher education. There is a need to move away from the idea that sustainability values are only a political notion, and instead move toward sustainability as a transdisciplinary science. Teachers who collaborate on an interdisciplinary scale to teach and to learn across disciplines, and of course, from practice, can provide a transformed sustainability education.

Data availability statement

The datasets presented in this article are not readily available because the interviews are anonymous. Requests to access the datasets should be directed to alice.annelin@umu.se.

Ethics statement

Ethical approval was not required for the studies involving humans because no sensitive information is obtained and therefore does not need to have an ethical review board approval according to Swedish law under the Act (2003: 460). The studies were conducted in

accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. G-OB: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsus.2024.1416498/full#supplementary-material>

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A decade in review: bibliometric analysis of sustainable performance trends in higher education institutes

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The sustainable performance of higher education institutes (HEIs) is key to efficiently manage educational institutes in the long run, to get financial aid from the government, and to keep the interest of stakeholders in the institutions. Researchers have focused on examining the impact of a sustainable curriculum, sustainable teaching methodologies, sustainable campuses, and tools for assessing sustainability in HEIs in past literature. The present bibliometric analysis, combined with network analysis, aims to explore the literature to identify research gaps in the field of sustainable performance or sustainability performance of HEIs. We have employed a Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram to analyze the results obtained from Scopus, Web of Science (WoS), and EBSCOhost databases. A bibliometric analysis using Biblioshiny web application and VOSviewer software was performed on the 263 articles included in the study after screening. The results revealed that the annual growth rate of publications is increasing, indicating that the sustainability performance of HEIs is gaining momentum after the introduction of the Sustainable Development Goals (SDGs) in 2017. The production of articles in the field is highest from advanced European countries and the United States, but only a few articles are published from Asian countries. The authors with the highest number of publications and the most cited research article in the field are Leal Filho and Wals, respectively. Authors keywords in HEIs (or institutions) not only have a strong link with sustainability, sustainable education, green campus, and sustainability assessment but also have a small network with sustainable performance, green knowledge sharing, green knowledge management, green human resource management practices, green teams, change management, and organizational commitment. These findings can be used by future researchers to identify unexplored research areas in different contexts.

KEYWORDS

HEIs, higher education institutes, sustainability, sustainable performance, Bibliometric analysis

1 Introduction

Sustainability has gained tremendous momentum in recent years and has received significant attention in a variety of fields, including education, business, agriculture, manufacturing, and transportation (Larivière and Smit, 2022). Higher education is also confronting a number of challenges related to sustainability. Therefore, higher education institutions (HEIs) have responded to these challenges by taking many initiatives for incorporating sustainability. HEIs have started addressing these challenges by planning and seeking solutions to modify and transform the way they perform business activities related to environmental performance, economic performance, and social performance.

Many HEIs have promoted sustainability and are actively engaged in preparing students to understand global challenges and provide solutions to these challenges based on the principles of sustainability. This can be accomplished by reducing the institution's environmental footprint, actively engaging with the communities, and imparting good governance (Lewis et al., 2021). In recent years, a growing body of knowledge has been developed toward higher education in order to implement a sustainability curriculum, campus practices, and outreach activities (Weiss and Barth, 2019; Menon and Suresh, 2020). Incorporating sustainability principles in HEIs is critical for improving the university's image, reputation, and study quality. The universities with the highest rankings are those that have a long-term vision for their students' development and have established a culture of sustainability (Salvioni et al., 2017; Singh et al., 2023).

The focus of research has been on sustainability in HEIs (Shriberg, 2002; Vargas-Merino et al., 2024), education for sustainability in HEIs (Figueiró et al., 2022), sustainability reporting in universities (Rosa et al., 2024), and Sustainable Development Goals (SDGs) in HEIs (Leal Filho et al., 2023). To the best of our knowledge, very few research studies have been devoted to the sustainable performance of the HEIs as business entities. The literature reviews on sustainability in HEIs mainly include internationalization efforts in HEIs through sustainability (Leal Filho et al., 2023), tools for assessing sustainability in HEIs (Singh et al., 2023), digital transformations in HEIs (Benavides et al., 2020), SDGs in HEIs (Serafini et al., 2022), evaluating service quality and performance of HEIs (Camilleri, 2021), organizational change management in HEIs (Rieg et al., 2021), carbon footprint in HEIs (Valls-Val and Bovea, 2021), knowledge management in HEIs (Quarchioni et al., 2020), and graduate employability and competence development in HEIs (Abelha et al., 2020). To the best of our knowledge, no literature review has been conducted yet to explore the sustainability performance of HEIs. Therefore, the following research questions have been developed:

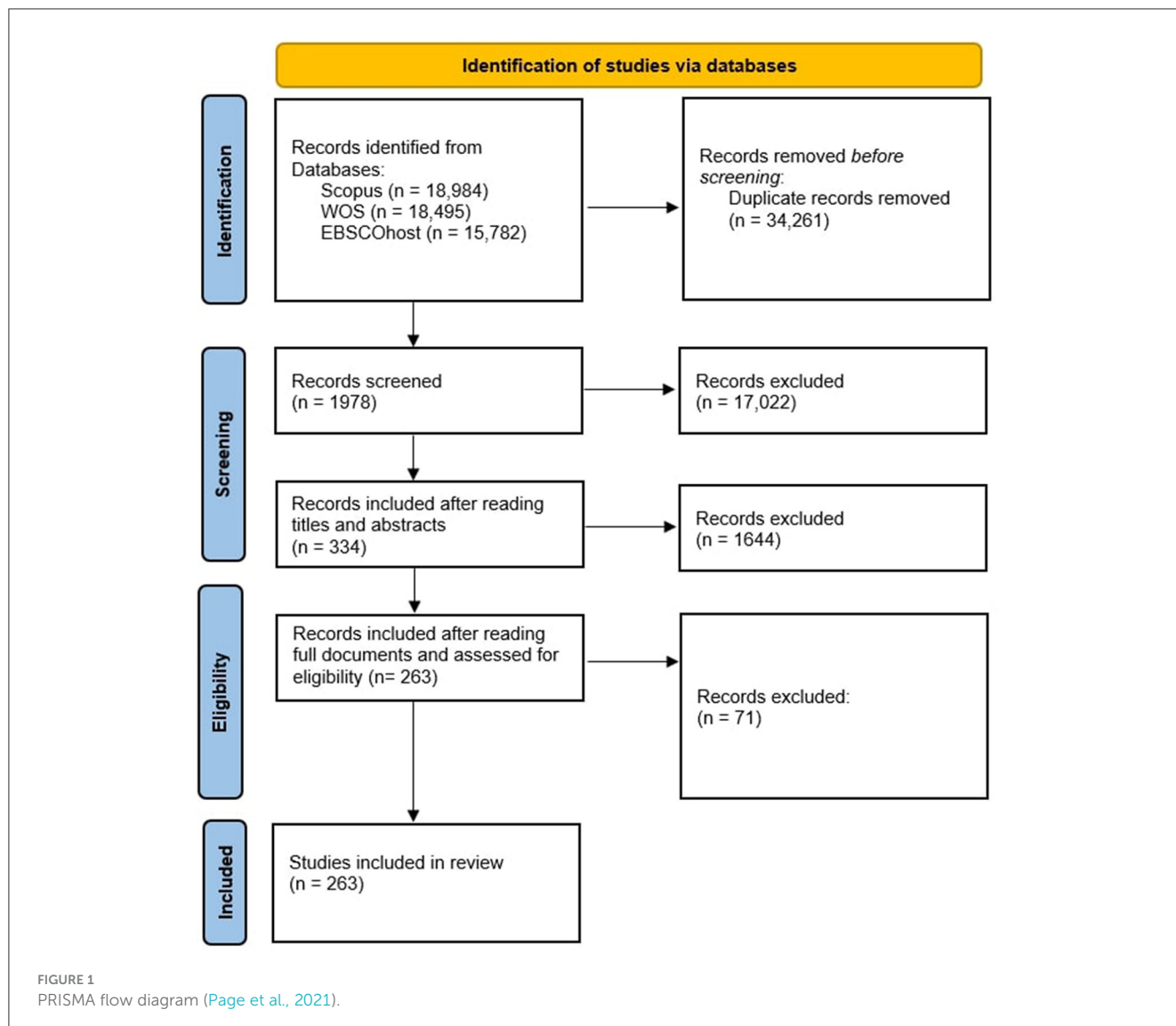
- RQ1: What is the current trend in research for sustainable performance of HEIs?
- RQ2: Which theories and research methods are used to explain the sustainability performance of HEIs?
- RQ3: What is the influence or relationship of different fields on the sustainable performance of HEIs as reflected through keyword analysis?

2 Methodology

The study has adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement based on a 27-checklist item protocol and a four-phase flow diagram to confirm the transparency, robustness, and reliability of the search method (Page et al., 2021; Liberati et al., 2009) as provided in Figure 1. A bibliometric analysis using R package was carried out on 263 research articles selected by the PRISMA 2020 flow diagram. The choice of bibliometric study using PRISMA was made on the bases of the following reasons: (a) The quantitative analysis of the data obtained from bibliometric studies has higher accuracy, is easily interpretable, and provides a higher level of understanding of a specific field (Zhao et al., 2023; Iqbal et al., 2022) and (b) a bibliometric analysis conducted on the databases considering peer-reviewed journals is a reliable approach. In the present study, we have considered the articles relating to sustainability performance in HEIs from three world-wide renowned databases that are used by the research community: Scopus, Web of Science (WoS), and EBSCOhost. The Scopus and WoS databases are accepted as the world's leading and competing citation databases (Hassan et al., 2021; Zhu and Liu, 2020). The EBSCOhost database not only provides basic and advanced search options but also offers reliable and peer-reviewed content for specific searches (Wood, 2012). In addition, these databases provide a broad set of data that include the economic sciences and management sciences. Zemigala (2019) conducted a bibliometric analysis to investigate the number of articles and their total citations from top publishing educational centers or institutes by region in the field of sustainable development. The currently available bibliometric analysis in the literature lacks the identification of sustainable performance in HEIs. The present bibliometric study aims to address research gaps of bibliometric analysis in the sustainable performance in HEIs.

2.1 Timeline

After the introduction of concerns about sustainability and the role of higher education in sustainability by the UN Conference on the Human Environment in 1972, the concept of "sustainable development" became internationally known in 1986 (Amaral et al., 2015). In HEIs, even student unions started pressurizing universities in Canada for higher sustainability in higher education (Elliott and Wright, 2013). The philosophical studies about sustainability challenges in HEIs started in the first decade of the 21st century (Hassan et al., 2021). In the present study, we limited the time period to the last 10 years (i.e., from 2014 to the March of 2024) because the number of relevant publications through our searches in the databases before 2014 were only two to three per year. Other reasons for gathering literature review of the last 10 years are the following: (a) consideration of the most recent articles and (b) the expectation of higher number of publications due to activities and interest in sustainability at HEIs after the introduction of the 17 Sustainable Development Goals (SDGs) by the United Nations Organization (Pradhan and Mariam, 2014).



2.2 Search strategy

A search of the WoS and Scopus databases was carried out with the different search phrases and Boolean operators (“OR” and “AND”) as follows: “Higher Education” OR “Higher Education Institutions” OR “HEIs” OR “University” (Trevisan et al., 2024), AND “Sustainability” OR “Sustainable Performance” OR “Sustainability Performance” (Alejandro-Cruz et al., 2019; Saulick et al., 2023). The number of search results on the WoS and Scopus databases were 80,323 and 18,984, respectively. The filters in search engines of all the databases were used to include the last 10-year research publications in the business field as search results show two to three articles per year before 2014 that focuses on the sustainability performance of HEIs. The other criterion for the inclusion is the articles published only in English. Data obtained from all three databases (i.e., WoS, Scopus, and EBSCOhost) were merged into a single file in RStudio to remove duplicate data and to retain only the unique results in a single Excel file with .csv extension. The resulting Excel file contained 1978 unique publications. In the next step, after reading the titles

and abstracts of the publications, irrelevant research articles were removed from the list and a list of 334 articles was retained and used for further screening. In the last step, 71 research articles after a thorough reading of 334 articles were excluded as being irrelevant to the research questions of the study. Finally, 263 research articles were included for the systematic literature review, bibliometric analysis, and network analysis. The bibliometric analysis and network analysis were performed using R software’s Biblioshiny application for bibliometric analysis and VOSviewer software for network analysis.

3 Results

The study employed a bibliometric analysis to summarize the research studies on sustainability in HEIs available in the literature in the last 10 years. The main findings of the research in the field of sustainability in HEIs are summarized in Table 1 using 263 articles obtained after screening results from the WoS, Scopus, and EBSCOhost databases. According to the bibliometric analysis, a

TABLE 1 Main findings of the study.

Description	Results	Description	Results
Main information about data		References	15,021
Timespan (2014:2024)	263	Keywords plus (ID)	563
Sources (Journals, Books, etc.)	17	Authors' keywords (DE)	848
Documents	263	Authors	949
Annual growth rate %	17.46	Authors of single-authored docs	13
Document average age	3.34	Co-Authors per Doc	4.03
Average citations per doc	23.84	International co-authorships %	32.32

total of 263 articles, with an average of 23.84 citations per article, were published across 17 journals over the last 10 years. The total number of authors who contributed to these articles is 949, and most of them have written only a single article, indicating that such authors most probably have not adopted the field for continuous improvement of sustainability performance in HEIs. The total number of authors' keywords is 848 for all the publications. The current trends of publications, theories, and methodology and the relevance of different fields with sustainable performance of HEIs are presented in subsequent sections.

3.1 Current trends of publications

The current trends in the field are reflected through the annual growth rate of publications, the number of citations in each journal, Bradford's law to identify the most prominent journals, a network analysis for most relevant countries, authors, and documents, and the most relevant affiliations.

3.1.1 Annual growth rate

The number of publications per year, as shown in Figure 2, depicts a continuous trend of increase in publications, with an annual growth rate of 17.46% from 2014 to March 2024. However, an exceptionally high increase in publications was observed in 2021 in that decade, which may be associated with an increase in the interest of the research community and other stakeholders in sustainability in HEIs due to the COVID-19 pandemic (Crawford and Cifuentes-Faura, 2022). The second and third highest number of articles were published in 2023 and 2022, with 48 and 37 articles, respectively. It can be observed that 25 articles have been published by the first quarter of 2024, and the number of articles in the relevant field at the end of 2024 is expected to exceed the number of publications in 2021. The number of articles in 2019 and 2020 were 28 and 22, respectively. There is a decreasing trend of number of articles published from 2018 onwards as only 16 articles were published in 2018, 17 in 2017, and eight in 2015.

The least number of articles published in the field of sustainability in HEIs was in 2016. A major reason for the increasing trend in the number of publications is this field of study has been sustainability in HEIs gaining the attention of scholars because of the growing interest of governments and stakeholders of HEIs for making their institutes more sustainable by adopting sustainable practices, sustainable curriculum, sustainable teaching methods, and sustainable buildings. This field of study is garnering attention in both developed and developing countries at the same time (Nguyen et al., 2022).

3.1.2 Most relevant journals

The total number of citations for the 263 selected articles in the field of sustainability in HEIs obtained from the 17 journals was 6,271. The distribution of the number of articles and their total citations for different journals is provided in Table 2. These results show that three journals published articles that were cited more than 1,000 times. Among them, the *Journal of Sustainability* ranks first, with the highest number of publications and the total citations being 104 and 2,378, respectively. The *International Journal of Sustainability in Higher Education* ranks second, with the number of publications and number of citations being 87 and 2010, respectively. The third rank is obtained by the *Journal of Cleaner Production* with 35 articles and 1,292 citations. The *Journal of Environment Development and Sustainability* is ranked fourth with 10 articles and 242 citations, whereas the *Journal Environmental Education Research* is ranked fifth with only four articles and 133 citations. The rest of the 12 journals have the total number of articles ranging from one to three and citations ranging from 0 to 100 (for details see Table 2).

3.1.3 Bradford law

The majority of the publications were focused on a very small number of sources, whereas the remaining journals had published fewer than three articles related to sustainable performance in HEIs. Bradford's law categorizes the core sources. It demonstrates that "if the journals containing articles on a given subject are arranged in descending order of the number of articles they carried on the subject, then successive zones of periodicals containing the same number of articles on the subject form the simple geometric series $1:n:n^2:P$ and Bradford called the first zone, the nucleus of periodicals particularly devoted to the given subject" (Alabi, 1979). The "core zone" is the very first zone, which consists of four journals with 236 publications, including *Journal of Sustainability*, *Journal of Cleaner Production*, *Sustainability Science Journal*, *International Journal for Sustainability in Higher Education*, and *Environment, Development and Sustainability Journal*. The second zone comprised of only 24 articles, as shown in Figure 3, including articles from *Sustainability Science Journal*, *Environmental Education Research Journal*, *Higher Education Journal*, *International Journal of Educational Management*, and *Studies in Higher Education*. The rest of the sources have very few citations. The *Journal of Cleaner Production* has the highest total link strength among all the sources.

Annual Growth Rate

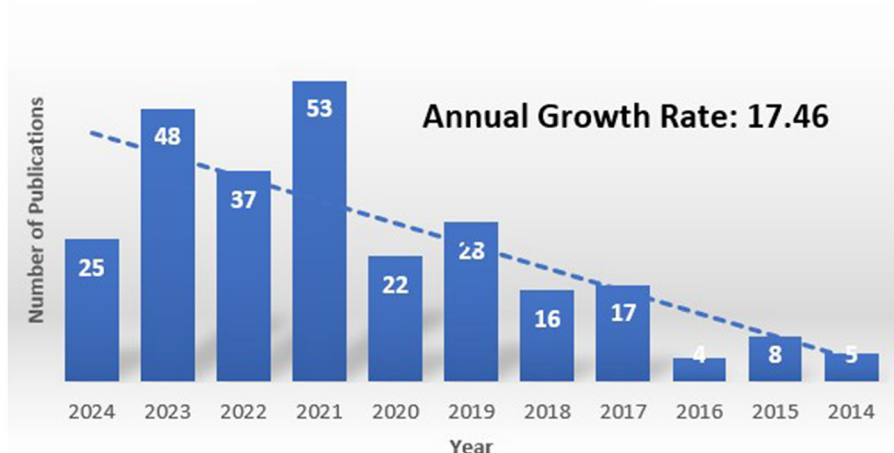


FIGURE 2
Annual growth rate per article.

TABLE 2 Number of publications per journal.

Source title	Doc.	Citations	Source title	Doc.	Citations
<i>Sustainability Switzerland</i>	104	2,378	Industry and Higher Education	2	20
<i>International Journal of Sustainability in Higher Education</i>	87	2,010	International Journal of Educational Management	2	17
<i>Journal of Cleaner Production</i>	35	1,292	International Journal of Sustainable Development and Planning	2	1
<i>Environment Development and Sustainability</i>	10	242	Journal of Teacher Education for Sustainability	2	1
<i>Environmental Education Research</i>	4	133	Frontiers in Education	1	1
<i>International Journal of Management Education</i>	3	62	Higher Education	1	0
<i>Studies in Higher Education</i>	3	48	Journal of Sustainability Science and Management	1	0
<i>Sustainability Science</i>	3	46	Sage Open	1	0
<i>Cogent Business and Management</i>	2	20			

3.1.4 Most relevant countries

A network analysis was performed for determining the total number of articles from different countries in the field of sustainability in HEIs (see Figure 4). The highest number of articles (i.e., 43) in the field were published from Spain with total citations and a total link strength of 1,470 and 42, respectively. The second highest number of articles (i.e., 37) in the field were published from Brazil, with total citations and a total link strength of 691 and 78, respectively. UK is ranked third with respect to the number of articles (i.e., 33) and citations (i.e., 1,302), and Germany ranks fourth with a total link strength of 68 for 30 publications with total citations of 735. There have been 23 documents published from Portugal in the field of sustainability performance of HEIs with total citations of 733 and total link strength of 54. The United States and Malaysia have published 16 and 13 articles in the field, with 496 and 418 citations and total link strength of 44 and 39, respectively. Thailand and Japan have the least number of publications, i.e.,

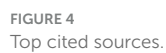
three from each country with 120 and 28 citations and a total link strength of 21 and 17, respectively. Canada, Saudi Arabia, Italy, Sweden, and the Netherlands are among the most relevant countries, with the number of publications being 10, 13, 14, 12, and 9, respectively.

3.1.5 Most relevant authors

We have also determined the number of documents in the field of sustainability in HEIs by authors (see Figure 5). According to the results, Leal Filho from Hamburg University is the author with the highest number of articles (i.e., 15) in the relevant field. Salvia from Hamburg University of Applied Sciences has published the second highest number of articles (i.e., six) related to sustainability in HEIs. The authors Brandli and Frankenberger have published five articles each in the field. Four publications have been authored by Azelterio and Lealand Lozano, whereas Antunez and Avila have



FIGURE 3
Bradford law.



number of documents of an author was set at one. From the results, 955 authors met the threshold. The most cited authors are Alexio and Leal as both of them have 386 citations for only

Documents by author

Compare the document counts for up to 15 authors.

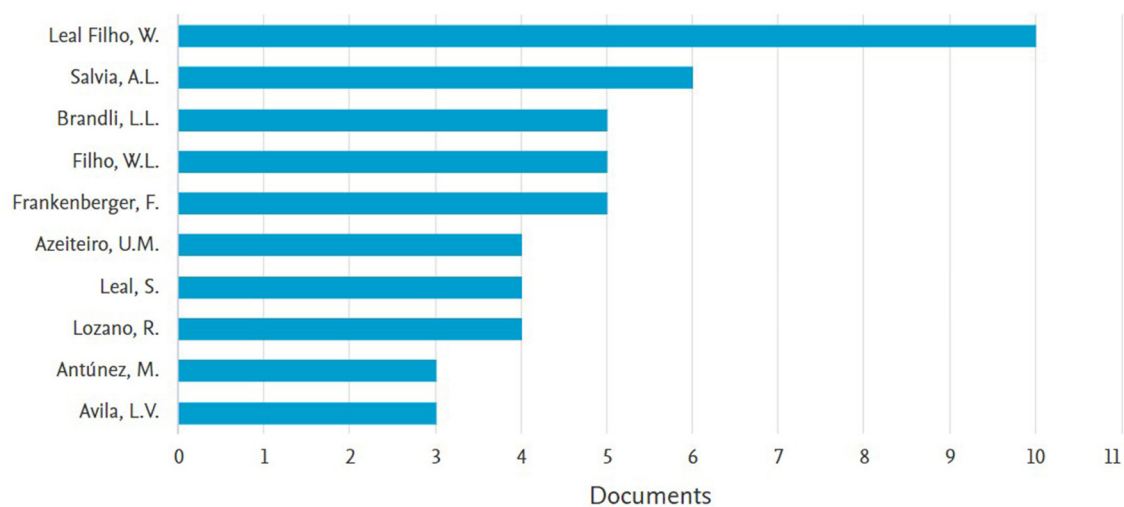


FIGURE 5
Documents by authors.

Most Relevant Affiliations

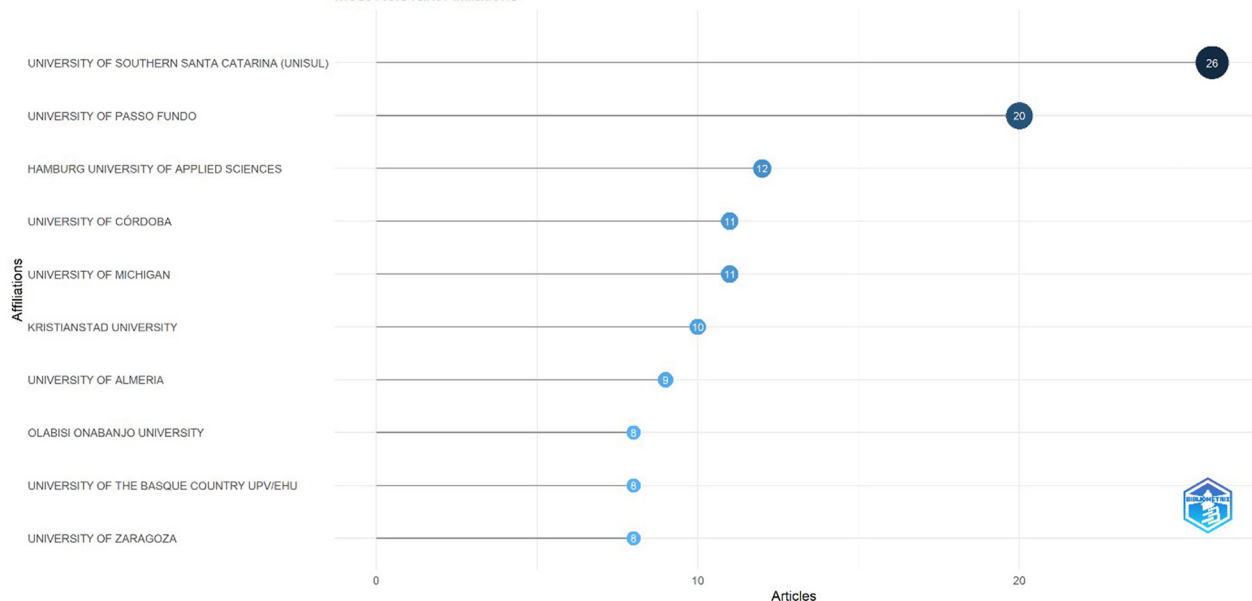


FIGURE 6
Network analysis of citations by authors.

four publications with a total link strength of 222. Leal Filho has the highest total link strength of 225 for 10 publications with 225 citations. Azeiteiro has 279 citations for only two publications with a total link strength of 145. Salvia and Brandli, respectively, have 220 and 207 citations for six and five documents with a total link strength of 148 and 82. Guera, Paco, and Frankenberger are among the most significant authors in the field with a total link strength of 106, 105, and 90.

3.1.6 Most relevant documents

The citation analysis with relevant titles, citations, contributing authors, and year of publications for the first 10 articles is presented in Table 3. The most cited article in the field was published by Wals (2014), with 327 citations interlinked with other authors, and Abbas et al. (2019) and Aleixo et al. (2018) are the second and third most cited authors, with 296 and 275, respectively. Among the most recent research, Brundiers et al. (2021) obtained a highest

citation of 264 from other authors and has a dominant cluster in the recent 5 years. [Too and Bajracharya \(2015\)](#) have 213 citations preceding [Leal Filho et al. \(2015\)](#) who have 191 citations for their publication. [Mulà et al. \(2017\)](#) and [Ceulemans et al. \(2015\)](#) have 184 and 156 citations, respectively, for the publications. Among the top 10 authors, [Dagiliute et al. \(2018\)](#) and [Lozano et al. \(2019\)](#) have the least number of citations, i.e., 149 and 145, respectively.

3.1.7 Most relevant affiliations

The list of most relevant affiliations include 477 universities and institutes from which a remarkable number of research articles were published ([Figure 7](#)). The University of Southern Santa Catarina is the most prominent university with 26 publications. Hamburg University of Applied Sciences, University of Cordoba, and University of Michigan have published 12, 11, and 11 articles, respectively. Kristandad University and University of Almeria have contributed 10 and 9 articles, respectively. Additionally, nine publications each have come from Olabisi Onbanjo University, University of the Basque Country UPV/ EHU, and University of Zaragoza. However, although the prominent institutions are presented in [Figure 7](#), there are several universities from UAE, India, Pakistan, Malaysia, Thailand, and China that have published research articles in the field of sustainability performance of HEIs.

3.2 Theories and methodology in most relevant document

A meticulous analysis revealed that very few have focused on measuring sustainability performance or sustainable performance in HEIs specifically. The appreciable increase in the number of publications in the field of sustainability in HEIs in the timeline points out that the importance of sustainability development is garnering attention globally. [Table 4](#) represents the authors, year of publications, source title, methodology, and theories employed for the most cited publications measuring the sustainable performance of HEIs. [Iqbal and Piwowar-Sulej \(2022\)](#) have employed the upper echelons theory and used the Sustainability Tracking, Assessment and Rating System (STARS) scale to measure the sustainable performance of HEIs through a survey questionnaire method. The Decision Making Trial and Evaluation Laboratory (DEMATEL) approach is used to evaluate the sustainable performance of a green university ([Wu, 2021](#)). Effective management and leadership approach is used in the research to measure the effect of servant leadership on the sustainable performance of HEIs as an organization through a survey questionnaire ([Abbas et al., 2021](#)). The researchers have used the ability, motivation, and opportunities (AMO) theory to predict the relationship between green HR practices and environmental (sustainable) performance of HEIs and collected data using a five-point Likert scale through a questionnaire ([Muhammad Ali and Nisar, 2023](#)). [Adenle et al. \(2021\)](#) have used the analytic hierarchy process as a performance of HEIs. The sustainability performance measurement (SPM) model is used in a case study by an Italian university to analyze the implementation of sustainable performance in the

TABLE 3 Citations per document.

Document	Total citations	Authors	Year
Sustainability in higher education in the context of the UN DESD: A review of learning and institutionalization processes	327	Wals	2014
The impact of social media on learning behavior for sustainable education: Evidence of students from selected universities in Pakistan	296	Abbas et al.	2019
Conceptualization of sustainable higher education institutions, roles, barriers, and challenges for sustainability: An exploratory study in Portugal	275	Aleixo et al.	2018
Key competencies in sustainability in higher education—toward an agreed-upon reference framework	264	Brundiers et al.	2021
Sustainable campus: engaging the community in sustainability	213	Too and Bajracharya	2015
The future we want key issues on sustainable development in higher education after Rio and the UN decade of education for sustainable development	191	Leal Filho et al.	2015
Catalyzing Change in Higher Education for Sustainable Development: A review of professional development initiatives for university educators	184	Mulà et al.	2017
Sustainability reporting in higher education: Interconnecting the reporting process and organizational change management for sustainability	156	Ceulemans et al.	2015
Teaching sustainability in European higher education institutions: Assessing the connections between competences and pedagogical approaches	145	Lozano et al.	2019
Sustainability at universities: Students' perceptions from Green and Non-Green universities	149	Dagiliute et al.	2018

university ([Cavicchi and Vagnoni, 2018](#)). The sustainability of HEIs is measured through green human resources management (GHRM) practices and mediation of strategic excellence in Iraqi institutes by administering a survey-based questionnaire and strategic excellence model ([Mohammed and Faisal, 2023](#)). The supply chain management theory was employed to explain the relationship between top management support and private university sustainable performance in Malaysia by using a quantitative survey-based questionnaire ([Govindaraju et al., 2019](#)).

3.3 Keyword analysis

Keywords are used to describe the research field and relevance of the research fields with each other so that other researchers can easily discover the relevant document through an online

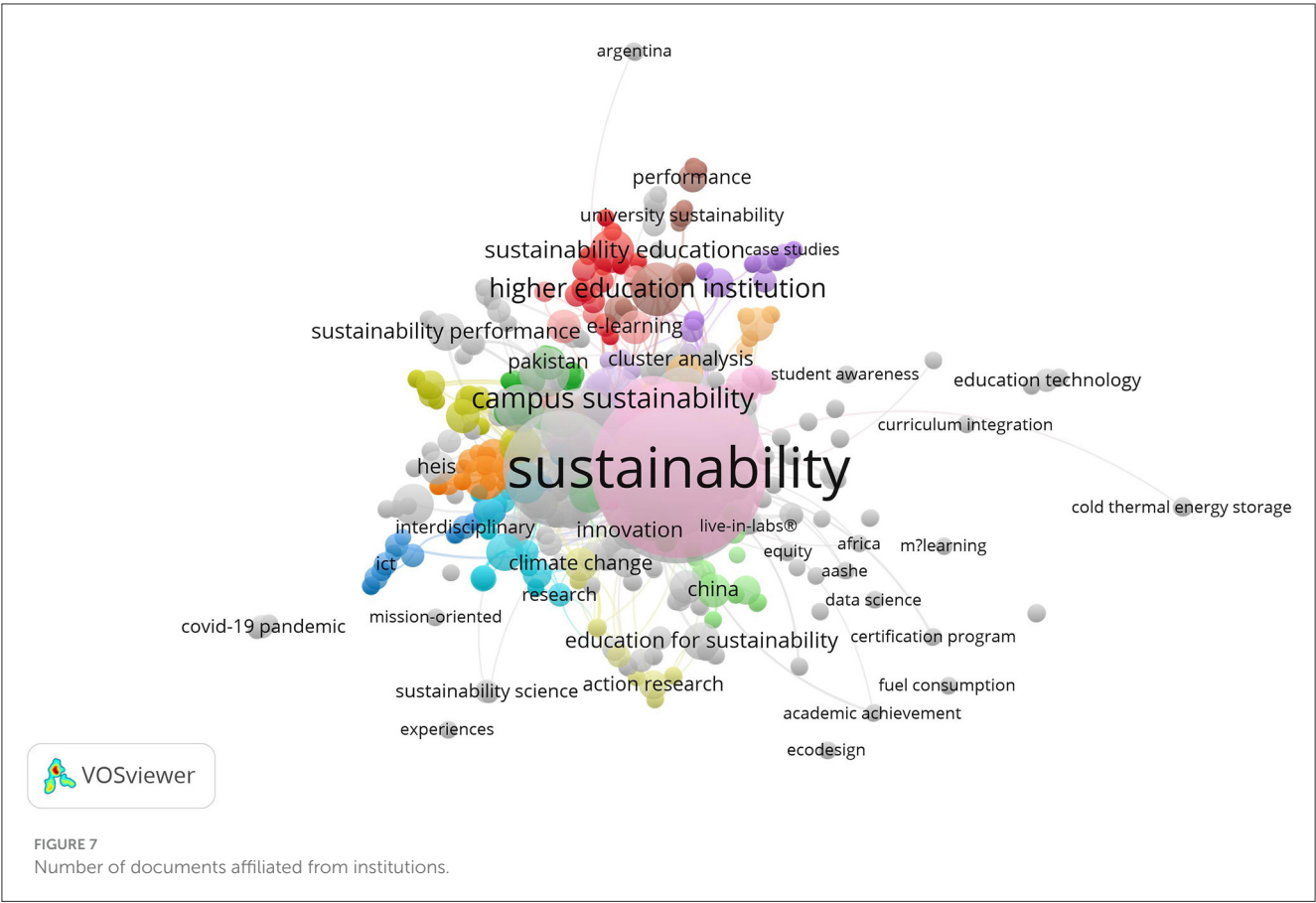


TABLE 4 Theoretical framework and research methodology used by authors in sources.

References	Citations	Source title	Methodology	Theory
Iqbal and Piwovar-Sulej (2022)	50	International Journal of Sustainability in Higher Education	Quantitative (Survey questionnaire)	Upper Echelon Theory
Wu (2021)	20	Ecological Chemistry and Engineering	DEMATEL approach	Not mentioned
Abbas et al. (2021)	18	International Journal of Productivity and Quality Management	Quantitative (Survey questionnaire)	Effective Management and Leadership Model
Jehan et al. (2020)	16	International Journal of Human Capital in Urban Management	Quantitative (Survey questionnaire)	AMO Theory
Adenle et al. (2021)	15	Environmental and Sustainability Indicators	AHP	Campus Sustainability Appraisal Framework
Cavicchi and Vagnoni (2018)	12	Journal of Accounting and Organizational Change	Case Study	SPM Framework
Mohammed and Fisal (2023)	10	Journal of Applied Research in Higher Education	Quantitative (Survey questionnaire)	Strategic Excellence Model
Govindaraju et al. (2019)	3	International Journal of Supply Chain Management	Quantitative (Survey questionnaire)	SCM Theory

search (Iqbal et al., 2022). However, bibliometric analysis uses both “authors keywords” and “keywords plus” as units of analysis, yet “authors keywords” is considered a more comprehensive research methodology and Campus Sustainability Appraisal Framework to measure sustainability in representing the content of the document and therefore used more frequently as a unit of analysis instead of “keywords plus.” Keyword co-occurrence is a highly effective method for visually representing the organization of scientific

information. It allows for the identification of prominent areas of research and helps to detect patterns within a certain topic.

3.4 Network analysis

A co-occurrence analysis with “Authors keywords” as a unit of analysis was performed with a minimum co-occurrence of

one, as shown in Figure 8. The data show “sustainability” as the authors keyword with the highest frequency of occurrence, that is, 103 times. The second most frequent authors keyword was “higher education,” with an occurrence score of 82 and “sustainable development” ranks third, with an occurrence score of 52. The authors keyword “higher education institutions” has an occurrence score of 43, taking the fourth position. The fifth and sixth positions are assigned to “education for sustainable development” and “sustainable development goals,” with occurrence scores of 29 and 26, respectively. University, SDGs, campus sustainability, sustainability reporting, and sustainable campus are among the prominent authors’ keywords in the network analysis.

There are a total of 53 clusters with a minimum cluster size of five. The details of small clusters are provided subsequently to identify the gaps in the literature. Furthermore, keywords analysis shows that organizational change management, university leadership, and sustainability keywords with small cluster sizes are linked together in the first cluster, which consists of 53 items. Cluster 2 has 37 items and fewer links of higher education institutions have been found with servant leadership, economic growth, e-learning, and organizational commitment. Sustainable organizational performance is interlinked with organizational commitment, green teams, and servant leadership. There are a small number of linkages among green organizational performance, green knowledge sharing, green innovation, HEs, job satisfaction, and sustainable leadership in the third cluster with 34 items. In the fourth cluster (with 32 items), the links exist among environmental sustainability, sustainable universities, HEIs, change management, green human resource management, green knowledge management, and decision support framework. The keywords interconnected in the fifth cluster include links among green university with performance measurement, resource management, stakeholders, and sustainability office. Similarly, the sixth cluster has links of higher education with green organizational performance, green knowledge sharing, green innovation, job satisfaction and sustainable performance. Sustainable university is interconnected with developing countries, assessment systems, higher education, green campus, and sustainable development. Combining all the results shows that higher education institutions have a strong link with sustainable performance, sustainability performance, sustainability reporting, sustainable university, governance, agenda 2030, and public university.

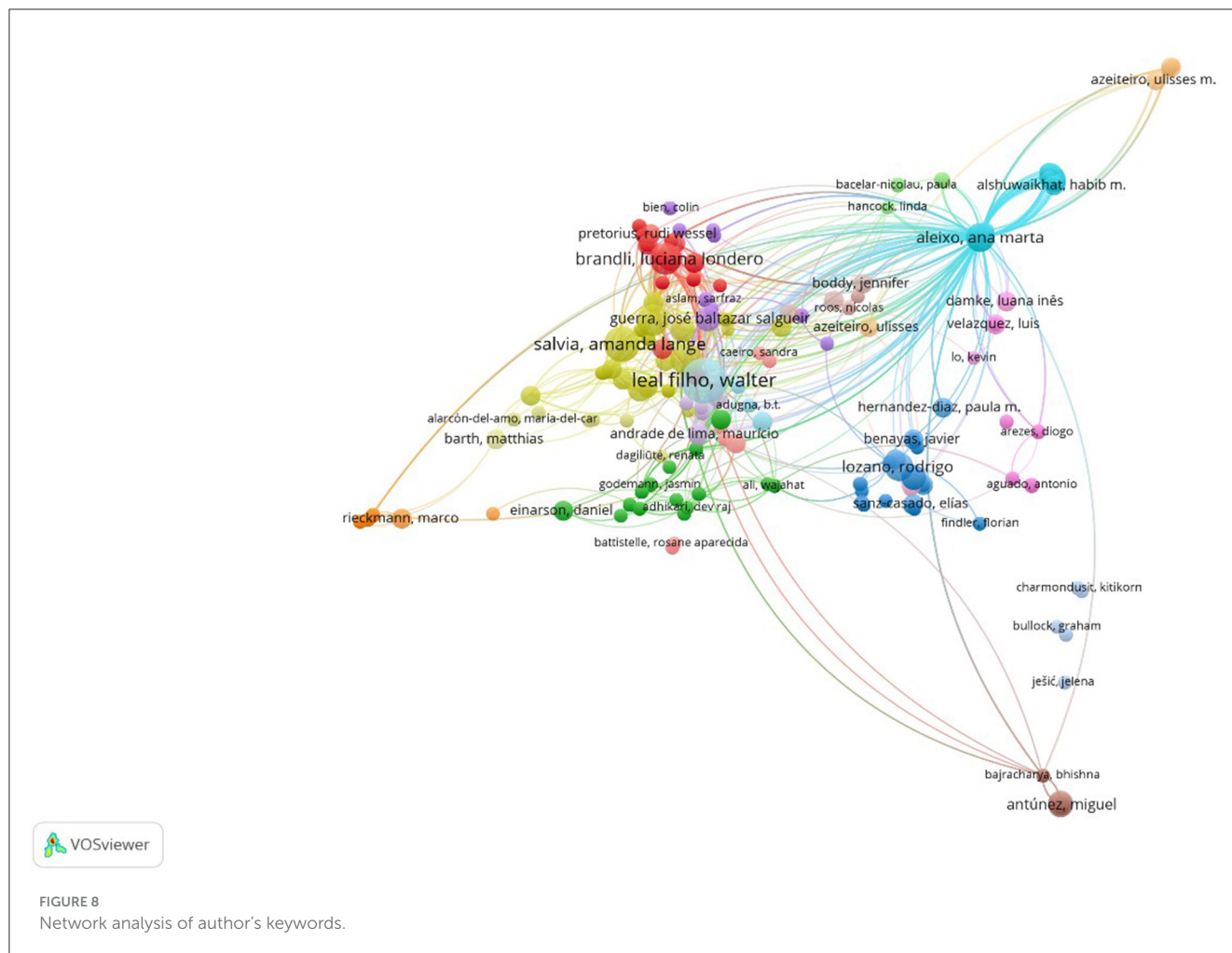
4 Discussion

Sustainable performance and HEIs have been studied independently for the past few decades. Sustainability in HEIs or at campuses has gained extensive attention in the recent literature due to its critical role in ensuring the attainment of the goals of a sustainable society. Many researchers have focused on case study as a research methodology to gain insights into the lifecycle assessment of HEIs (Jürgens et al., 2023), the context and concept of HE for sustainable development (Adhikari and Shrestha, 2024), incorporating sustainability in the curriculum of mechanical engineering (Habek et al., 2024), and universities adopting sustainability transfers to transform regions (Demele et al., 2021). Other researchers have examined the role

of SDGs and sustainability teaching at universities (Leal Filho et al., 2019), the influence of mobile learning on sustainability in HE (Al-Rahmi et al., 2022), administration perspective adopting sustainable practices in Greek universities (Platitsa et al., 2024), and sustainable practices at HEIs in Asia (Leal Filho et al., 2022).

A research study focused on the integration of sustainability into the curriculum of legal education in Latvia (Jekabsone and Ratniece, 2024). Cotton et al. (2023) have investigated the impact of climate change curriculum on campus and compared on-campus and on-website sustainability images. Another study found a positive effect of green content assessment of curriculum on eco-labeling in HE (Okanović et al., 2021). However, there are very few studies that have been dedicated to investigating the sustainable performance of HEIs as a business entity. Specifically, Gutiérrez-Mijares et al. (2023) have reviewed the methods for assessing sustainability performance of HEIs. Future researchers should explore different dimensions of sustainable performance that can be used to measure the impacts of different variables on HEIs so that sustainable performance on HEIs as a business entity should not be neglected. Some researchers have measured the sustainable performance of property development companies in Malaysia (Bakri and Abbas, 2020), dairy industry in Pakistan (Shoaib et al., 2022), hotel industry in Australia (Patiar and Wang, 2016), and petrochemical industries in Saudi Arabia (Althnayan et al., 2022). Although the sustainable performance of HEIs in the education industry has been measured through green campus, campus sustainability, and or sustainable building models, very few articles have focused on exploring the sustainability performance of HEIs as a business entity. This phenomenon has gained pace during post-COVID-19 period when many private HEIs have to shut down their businesses because of poor sustainable performance. Research has shown that HEIs that have focused on sustainable performance of HEIs were able to operate and pursue their business activities even in the period of economic crises. Therefore, it has been suggested that HEIs should opt to achieve sustainable performance in this highly competitive and rapidly changing global market.

Bibliometric analysis and network analysis of country production over time shows that most of the researches originate from European and developed countries like the United Kingdom, Germany, Portugal, and the United States as well as from the developing country of Brazil. There are very few studies conducted in Asian countries like Malaysia, Thailand, Japan, and Saudi Arabia. Moreover, studies that have been conducted in developing countries are not remarkable in terms of citations or their impact on other researchers. Therefore, future researchers should explore the factors contributing to the sustainable performance of HEIs in Asian countries with a more robust theoretical framework. The slow growth rate of research in the sustainable performance of HEIs is attributed to the period of adoption of sustainability practices in HEIs before the introduction of SDGs 2030 Agenda for Sustainable Development by the United Nations. After the introduction of SDGs in 2017 by the United Nations, the research focus on sustainability in HEIs relatively increased, yet the increase in the number of publications in the field is not very impressive. The growth rate of publications has skyrocketed during COVID-19 (2021) and has been continued at a remarkable pace in 2022, 2023, and until March 2024. The geographic concentration of



the research publications is in the developing country of Brazil and in some developed countries like Germany, Spain, and The Netherlands. However, there are only few studies focusing on the assessment of sustainable performance in HEIs in developing countries; however, no prior research can be located in the field that measures the sustainable performance of the HEIs as a business entity. Therefore, future studies should fill the gap in the literature by exploring the factors contributing to the sustainable performance of HEIs as a business entity. The bibliometric analysis combined with network analysis for the sustainable performance research in HEIs has identified the key issues and areas of research neglected previously. There are five units of analysis that are most commonly used in bibliometric analysis: annual growth rate, authors, sources, territory or geographical location, and theme or keywords. This research helps identify the key research areas for HEIs to achieve and or maintain their sustainable performance and also helps to identify gaps in the literature. Researchers in the future can use the findings of this study to initiate new research projects on the topics that have rarely or never been researched in the past. The current growth of research publications indicates the interest of all stakeholders of HEIs in this field who can provide funding for such projects, influencing policymaking, interventions, and developments for sustainable performance of HEIs. The higher concentration of publications in the developed countries in

the West shows an urgent need to initiate such studies in Asian and African countries as well, where a small number of studies have been focused on sustainability in the past literature. The network analysis shows that sustainable performance, knowledge sharing, green teams, change management, servant leadership, green human resource management, organizational commitment, and developing countries have rarely co-occurred on a level similar to higher education institutions, higher education institutes, green campus, and HEIs. These findings can be used by future researchers to adopt a framework that has been studied not so frequently in different contexts.

5 Conclusion

The bibliometric analysis integrated with network analysis in a study presenting the scientific mapping of sustainable performance of HEIs extends the understanding of the field by analyzing current trends in the literature. The contribution of this study is exploring the sustainable performance of HEIs from an entirely new perspective. The results show that the growth of publications shows that there was a surge in the number of articles published after 2016, and this growth rate reached its peak during the COVID-19 period. The list of most relevant

countries includes 69 territories among which Spain and UK have published the most cited articles. The top 20 countries that have published articles are from Europe, Asia, and South Africa. There is a gradual increase in the number of institutions publishing articles in the field with an increase in the annual growth of publications, which confirms the development of the research field of sustainable performance of HEIs. Specifically, the most relevant authors have published in the year 2021 and, in subsequent years, the number of publications has increased. Thus, this study has helped to identify the key areas, assessment tools, theoretical frameworks, and research methodology adopted in the past studies to visualize the origin of the field and when and how it has evolved.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SU: Conceptualization, Writing – review & editing, Supervision. JA: Conceptualization, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. MB: Conceptualization, Resources, Writing – review & editing. KM: Conceptualization, Supervision, Writing – review & editing. WW: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The impact of education for sustainable development on university students' sustainability behavior: a case study from undergraduate students in Somalia

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Education plays a crucial role in moving towards a sustainable future. The United Nations Decade of Education for Sustainable Development has advocated education for sustainable development (ESD) to promote global sustainability. UNESCO supports ESD as a way to provide society with the knowledge, skills, values, and attitudes needed for sustainable living. While considerable progress has been made in many developed countries, particularly in higher education institutions, and to some extent in developing countries, similar success has not been observed in Somalia's higher education establishments. This study examined the influence of ESD on university students' conduct in Somalia. Through cluster sampling, 251 students from SIMAD and Hormuud Universities in Mogadishu were chosen to participate by completing a questionnaire. The research revealed a significant positive connection between ESD and students' behavior. The findings emphasize the importance of integrating ESD into higher education curricula to encourage cultural norms that endorse environmentally friendly practices. This investigation offers valuable insights for academics, policymakers, and businesses seeking to advance sustainability within educational settings and beyond.

KEYWORDS

sustainability, SDGs, education, higher education, student, behavior, Somalia

1 Introduction

The United Nations (UN) Agenda 2030 states that global transformation and universality are necessary for sustainable development. "Universality" refers to sustainable development, which calls for meeting global issues such as inequality between nations, climate change, and regional economic, social, and environmental goals. Governments and international organizations must address these complex concerns to enable necessary "transformative" changes in the way of life and environmental protection (Bastianoni et al., 2019). Education

plays a crucial role in sustainable development and the environment. Global environmental discussions are well-documented through international events such as the United Nations Conference on Human Environment in 1972, the Intergovernmental Conference on Environmental Education in 1977, the World Conference on Environment and Development in 1987, the United Nations Conference on Environment and Development in 1992, the International Conference on Environment and Society in 1997, and the World Summit on Sustainable Development in 2002 (Manteaw, 2012).

It has been observed that education, in all its various forms from elementary to tertiary levels, plays a distinctive and pivotal role. The global initiative for sustainable development is likely to experience significant growth due to the UN Sustainable Development Goals (Shiel et al., 2016). Education for sustainable development (ESD), also known as Education for Sustainability, is a concept aimed at comprehending and reshaping educational systems to foster sustainability within higher education institutions. Its goal is particularly centered on shaping the mindset, values, and actions of future generations (Zguir et al., 2021). However, various strategies are essential to guarantee that ESD develops appropriately locally while considering notable cultural differences (Wals, 2014). Since education is included explicitly in at least five SDGs, it is possible to argue that education and all the other goals are intimately related (UNESCO, 2017).

The increasing number of academic programs focused on sustainability from global universities reflects the modern prominence of sustainability and environmental science (Wiek et al., 2011). Changes in behavior are necessary to achieve sustainability objectives since they have a substantial impact on humans. In this sense, people's consumption patterns—which include the need for necessities like food, fuel, water, wood, minerals, and materials—are fundamental. There is broad consensus that resource overuse and environmental degradation cause irreversible changes to our world. Home consumption contributes 50–80% of global land, material, and water usage and about 60% of greenhouse gas emissions (Ivanova et al., 2016). According to UN Food and Agriculture Organization (FAO) estimates, one-third, or around 1.5 billion tonnes, of the food produced worldwide is wasted (FAO of the United Nations, 2013). Furthermore, as population growth and resource demand increase, it is predicted that in <15 years, the water demand will exceed the availability by 40% (Programme UNE, 2017).

In addition to reducing environmental problems, limiting unsustainable behaviors encourages sustainable development. Therefore, education is critical because it can change people's behavior. It is often acknowledged that influencing students' views toward the environment depends on providing them with suitable attitudes, values, responsibilities, and abilities from an early age (Mahat et al., 2017). According to Geng et al. (2017), teenagers and young adults are more open-minded, more accessible to teach sustainable activities, and more likely to encourage others to adopt sustainable practices (Geng et al., 2017). Furthermore, students are the next generation of decision-makers, educators, and policymakers responsible for environmental management (Joshi and Rahman, 2017; Tan and Lau, 2009).

Although ESD existed before the SDGs (Hjorth Warlenius, 2022), it has emerged as a pivotal instrument within the present SDG agenda to reorient learning toward a more sustainable world

and tackle economic, social, and environmental challenges (Stein et al., 2022). Several universities have started implementing several principles to help administrators in higher education find and implement complex solutions for future responsible management. These principles also ensure that students receive the education necessary to support sustainable development and lifestyles (Borges et al., 2017). On the other hand, higher education's importance in advancing ESD is widely acknowledged (Liu et al., 2022). Higher education institutions (HEIs) are recognized as critical players in the SDGs' advancement due to their diverse contributions to research, pedagogy, campus administration, and community engagement. In addition, they facilitate the integration of knowledge from other fields, and develop the interdisciplinary abilities necessary for developing a sustainable future in subsequent generations (Oyedepo et al., 2020). Higher education also helps students enhance their multidisciplinary cooperation, anticipatory skills, problem-solving ability, creative thinking, and social responsibility—all critical for accomplishing the Sustainable Development Goals (SDSN, 2020).

In the Somali setting, it is crucial to prioritize education on sustainability. Somalia encounters distinctive environmental obstacles such as deforestation, desertification, and the effects of climate change that endanger the livelihoods and welfare of its people (Melesse and Obsiye, 2022). Sustainability education should be integrated more extensively than solely acquiring knowledge, entailing a transformative, participatory learning process that aligns behavior with knowledge (Hammer and Lewis, 2023). However, this research is timely and significant as it coincides with Somalia's efforts to rebuild its higher education sector, presenting a crucial opportunity to embed sustainability principles that will influence the country's future development. Aligning Somali higher education institutions with international sustainability standards is essential amidst the global push for sustainable development.

This research aims to fill a significant gap in the study of how ESD influences student behavior within Somali higher education institutions. Despite global recognition of the importance of sustainability education (Nejati and Nejati, 2013), there is limited empirical evidence on its impact in Somali contexts, especially in post-conflict settings like Somalia. The novelty of this study lies in exploring how ESD integration affects university students' adoption of sustainable practices at SIMAD and Hormuud Universities, aiming to provide insights that can guide future sustainability initiatives tailored to these educational settings. Understanding these dynamics is essential for addressing the region's urgent environmental and socio-economic challenges while promoting long-term sustainable development.

2 Literature review

Since the 1972 UN Conference on the Human Environment, higher education institutions have actively pursued initiatives to promote sustainable development (Amaral et al., 2015). The academic focus on students' sustainability abilities progressively expanded over many years (Wu and Shen, 2016). In Spain, researchers investigated the correlation between adopting sustainable consumption and seven competencies: self-regulation, leadership, perspective, humility and modesty, kindness, and appreciation of beauty. They demonstrated

that cultivating ethical competencies through education promotes the adoption of sustainable consumption practices among students (Okubo et al., 2021).

Sustainable development is mainly integrated into higher education in two ways. The first one is to include it throughout all school curricula, and the second is to train staff and students to become sustainability experts (Liu et al., 2022). Curriculum change, regional and worldwide partnerships, and sustainable campus initiatives have been organized to endorse ESD in higher education institutions (Vaughter et al., 2013). Universities have promoted sustainability initiatives in their academic programs and infrastructure (Findler et al., 2019). An increasing focus is placed on cultivating students' proficiencies in systems thinking competency, anticipatory competence, normative competence, strategic competence, and interpersonal competence (Cebrián et al., 2020; Cebrián and Junyent, 2015; Liu et al., 2022).

University students must receive education to understand and address social, environmental, and economic challenges while promoting collaboration to execute coordinated initiatives (McNall, 2011; Weber and Duderstadt, 2012). From an educational perspective, this involves establishing meaningful human connections that result in significant learning to address socio-environmental challenges during the academic journey (Núñez, 2014). Universities have a significant impact on shaping the behavior of their students, utilizing resource use competitions and sustainability programs conducted on campus (Filho, 2011). Achieving sustainable development demands more than just environmental initiatives; it requires a fundamental shift in human behavior to address today's pressing sustainability issues (Badwan et al., 2022). It also requires a profound understanding of individuals' decision-making processes, actions, thoughts, interactions, beliefs, and attitudes (United Nations, 2016).

Berchin et al. (2018) outline six approaches that higher education institutions use to embrace sustainability, including setting institutional agendas for sustainability, conducting research, teaching sustainable practices, managing campus operations sustainably, engaging in outreach activities, and disseminating knowledge. They also emphasize the promotion of recycling behavior, critical thinking skills, innovative technologies adoption and fostering open dialog among science professionals, industry experts and society members. Barros et al. (2020) highlighted the significance of educational institutions prioritizing changes in the behavior of students and instructional staff to advance sustainability efforts. Also Ahamad and Ariffin (2018) emphasized that simply imparting knowledge about sustainable behaviors to students is inadequate because earning a university degree does not guarantee their adoption of such behaviors.

UNESCO coordinates the development of policies and strategies for integrating ESD into national education systems on behalf of governments and global stakeholders (Hjorth Warlenius, 2022). Despite their key role, numerous academic scholars have questioned their perspective regarding the behavioral change as result of ESD. This argument is based on the premise that this outcome is intrinsically more conducive to instruction-based learning (Syed-Abdullah et al., 2023). Scholars continue to be concerned that when behavior modification becomes the objective, the fundamental learning processes, and motivations for doing so may be called into question (Syed-Abdullah et al., 2023). Such a concept, Bourn and Soysal considers education to be fundamentally transmissive. The term

"transmissive" refers to actions or behaviors that are generated in accordance with a predetermined set of knowledge, skills, and values that are promoted by industries, special interest groups, governments with preferred messages, agendas, ideologies, or consumer preferences (Bourn and Soysal, 2021).

An additional factor is noteworthy to our investigation. Syed-Abdullah et al. (2023) emphasize that an extensive body of literature indicates that individuals rarely change their behavior according to a logical impetus. This further exposes the weaknesses of transmissive approaches, as the literature also indicate that learning and understanding are not enough to inspire a commitment to sustainable behavior (Shehzad et al., 2024). Experts on ESD argue that pre-established educational outcomes would restrict the opportunity for independent thought and reflective self-determination regarding academic achievements (Syed-Abdullah et al., 2023). Therefore, the search for rational solutions within a broader context is highly important (Kvamme, 2020). Considering this concept, literature emphasize that imparting knowledge and fostering critical thinking skills are crucial components of a transformative education (Alam, 2022).

Experts advocating for a transformative approach to ESD emphasize that behaviors are influenced by processes of social reproduction, social efficiency, and confronting global injustices, which demands proper judgment in determining which ethical values are right or wrong within specific contexts (Kvamme, 2020). For instance, recycling has been characterized in numerous studies as an environmentally beneficial practice that warrants promotion (de Leeuw et al., 2015). According to Hopewell, Dvorak, and Kosior, "in the first instance, methods that reduce the use of materials in products can reduce the amount of material entering the waste-management system" (Mourshed et al., 2017). According to this perspective, endorsing recycling may inadvertently reinforce mis-educative behavior, because, from a lifecycle analysis perspective, first minimizing material consumption is more advantageous.

Madar et al. (2019) and Syed-Abdullah et al. (2023) provide valuable insights by differentiating between transmissive and transformative approaches of ESD. The transmissive ESD encourages "well-informed and proficient behaviors and thought processes," whereas the transformative ESD, advocates for "developing the ability to think critically beyond experts' opinions and investigating the inherent contradictions in sustainable living." Although they acknowledged the significance of both approaches, they contend that transformative ESD is more crucial because our long-term prospects will be determined less by our obedience to training in doing the "right" thing in the present and more by our capacity to analyse, question alternatives, and negotiate our decisions (Madar et al., 2019).

On the other hand, teacher quality in integrating sustainability concepts into classroom activities in many developing countries has been commonly criticized, leading to teacher sustainability education reform in many countries. For instance, Thailand has numerous initiatives and schemes to enhance the education system, particularly in training both student teachers and qualified educators. These initiatives prioritize enhancing competent professional skills, addressing global challenges, and mastering technological utilization (Vermeulen et al., 2014). Teachers must possess the necessary knowledge, awareness, competency, and appropriate behavior to create learning opportunities for their students, as they are essential

in facilitating understanding and awareness of sustainability within the educational system.

In addition to improving teacher quality, various studies have been undertaken on campus sustainability to measure and improve the environmental impact of educational institutions. For example, research has focused on measuring the carbon footprint of student and teacher transport, promoting the use of energy-efficient modes of transportation like bicycles or public transport, and encouraging practices such as turning off lights in empty classrooms (Barros et al., 2018; Jain et al., 2013). Concurrently, researchers like Marinho et al. (2014) and Geng et al. (2013) have emphasized activities aimed at reducing water usage, improving water treatment in universities, and promoting tree planting, respectively. These efforts highlight the importance of addressing practical sustainability challenges on campus. Additionally, alternative methods aim to identify the primary obstacles to integrating sustainability-related subjects into academic curricula (Andrades Peña et al., 2018), ensuring that both theoretical and practical aspects of sustainability are incorporated into education.

To understand the multidisciplinary nature of sustainability challenges, students must engage in experiential learning facilitated by pedagogical methods that enhance their connection to real-world scenarios (Banos-Gonzalez et al., 2018). In this regard, researchers have proposed various methods for learning, including social constructive pedagogy, experiential learning, field-based travel courses, outdoor adventure trips, and more (Badea et al., 2020). The literature review highlights that the subject gains attention beyond academia, inspiring considerable debate due to the lack of consensus. Furthermore, it serves as a focal point for numerous studies, particularly concerning the attitudes and behaviors of university students regarding the implementation of ESD principles.

3 Materials and methods

The research was conducted at SIMAD University and Hormuud University in Mogadishu, Somalia, involving undergraduate students from the Faculty of Economics. These faculties were chosen due to their focus on areas related to sustainability, including resource management, environmental economics, and corporate social responsibility. Given that these subjects inherently involve aspects of sustainability education, the study considered economic students as a suitable cohort for investigating the impact of sustainability education on behavior. As of the 2023/2024 academic year, there is a total student population of 750 across both faculties. Further information about data collection and analysis methods will be provided below.

3.1 Item development

The questionnaire of this study contains five sections addressing concerns about the environment (CE), the culture of the environment (CUE), warning (W), reuse (R), and a section intended for respondents' demographic background. These sections draw upon items adapted, revised, and added from previous studies (Ahmad and Ariffin, 2018; Boca and Saraçlı, 2019). The chosen objects correspond to four components of ESD: enhancing quality of life, ensuring environmental protection, resource efficiency, and addressing the

demands of future generations (Ahmad and Ariffin, 2018). These four components is aimed to ensure that the questionnaire is inclusive. There are 10 items in the independent variables (CE, CUE, W) and three in the dependent variable, namely student behavior (R). The total number of items was adjusted accordingly after subsequent validity and reliability tests were taken.

3.2 Item validity and reliability

Before distributing the questionnaires to the sample population, the questionnaire was content-validated and tested for reliability. Item content validity was assessed using the item content validity index (I-CVI). This process involves a team of experts indicating the relevance of items contained in a questionnaire (Polit and Beck, 2006). Therefore, the questionnaire was distributed to four academicians with expertise in or relevant to ESD. They were requested to rate, comment, and suggest item improvements.

After receiving comments and suggestions from the experts, revision was made. The experts' comments and suggestions were considered, and the questionnaire items were revised accordingly (Lynn, 1986). Among the suggestions was to remove a few items that showed duplication, and adjustments were made to the structure to align with the experts' recommendations. Subsequently, the items were adjusted to 17, including the demographic items as encouraged.

Later, a pilot test involving 20 respondents was undertaken to confirm the reliability of the questionnaire. The internal reliability and consistency of questions were tested using Cronbach's alpha. Cronbach's alpha values for all four sections have acceptable internal consistency (CE, CUE, and W) and (R).

3.3 Sampling size and method

The sample size was determined using the Bin Ahmad and Binti Halim (2017) formula, where an additional 5% of the sample size was added to account for potentially incomplete questionnaires. A total of 267 self-administered questionnaires were disseminated via Google Forms among undergraduate students across Faculties of Economics at SIMAD and Hormuud Universities. We received 251 responses out of the 267 we targeted. The selection process for the study population involved cluster sampling, whereby faculty staff provided information regarding the total number of students enrolled in each faculty. Participation in the study was entirely voluntary, and the criteria for inclusion required that participants be currently enrolled undergraduate students in the Faculty of Economics at either SIMAD or Hormuud University; graduated students were not allowed to participate. Students were approached in the classroom to complete the questionnaire fully. The confidentiality and anonymity of the responses provided by the participants were strictly maintained.

3.4 Data analysis and results

The study utilized structural equation modeling with SmartPLS4 to assess both the measurement and structural model (Henseler et al., 2015). The researchers of this study investigated the proposed paths and confirmed the findings. Structural equation modeling using

SmartPLS4 encompasses a range of statistical techniques for examining potential relationships between independent and dependent variables (Lee et al., 2011). It is characterized by two sets of linear equations: the structural model, which elucidates the connections between constructs, and the measurement model, which illustrates the interactions between a construct and its observable indicators. The researchers selected SmartPLS for two primary reasons: firstly, PLS is a more suitable approach for our investigation as it is exploratory in nature. Secondly, it has gained significant recognition across scientific disciplines recently (Sarstedt and Cheah, 2019). Utilizing hypotheses testing in research to uncover causal relationships was commonly considered appropriate (Restuputri et al., 2021).

3.5 Research model

The diagram in Figure 1 describes a research model that is developed based on the study's objectives, hypotheses, and existing literature. This model encompasses various important variables including environmental concerns (CE1, CE2, CE3, and CE4), cultural environment (CUE1, CUE2, and CUE3), attitudes toward environmental warnings (W1, W2, and W3) as well as the practice of "reuse" with its three components (R1, R2, and R3). The research employs Structural Equation Modeling to examine the eco-friendly behaviors of university students and explore the causal connections between their environmental attitudes and their real actions. The SEM framework integrates both behavioral aspects along with attitudinal ones. Additionally, the research model incorporates provisions for testing three hypotheses which are detailed in Table 1.

4 Findings of the study

4.1 Demographic profile

Based on the demographic information provided by the participants, it can be observed that 54.2% of the sampled respondents identify as male, while 45.8% identify as female. Concerning age

groups, 86% of the sample consists of participants aged 18–22. Concurrently, 14% of the respondents were between the ages of 22 and 25. All participants in our study were undergraduate students who had recently completed secondary education, and none were older than 25.

Regarding marital status, the study's sample was predominantly composed of single respondents, at 96%. Married respondents constituted a mere 4% of the total. As indicated in Table 2, most research participants (70% of all respondents) were in the last years of their bachelor's degree, while 30% were in the first years of their bachelor's degree (Diploma).

4.2 Assessment of the measurement model

Using SmartPLS 4, a confirmatory factor analysis was employed to validate the psychometric properties of the instruments (refer to Table 3). The assessment of the measurement model included average variance extracted, composite reliability, discriminant validity, and convergent validity. Table 3 demonstrates that most factor loadings for the variables' measuring items were ≥ 0.70 , except for one item. Furthermore, both "average variance extracted" and "composite reliability" values exceeded 0.50 and 0.70, respectively, for all latent variables in the research study. These results indicate strong reliability and validity of the research measurement model with factor loadings surpassing 0.70, as well as AVE and CR values exceeding their respective thresholds across all study variables.

Table 3 presents the findings of confirmatory factor analysis that support the psychometric characteristics of the assessment tools. The measurement model was assessed using average variance extracted, composite reliability, discriminant validity, and convergent validity. The results in Table 3 indicate that the factor loadings for the items measuring variables were consistently above 0.70. Moreover, both "average variance extracted" and "composite reliability" values for latent variables exceeded 0.50 and 0.70, respectively, across all research variables, demonstrating high reliability and validity of the research measurement model with strong factor loadings exceeding 0.70 as well as AVE and CR values surpassing thresholds for all study variables.

The fact that each latent variable differs from the others shows that the test is discriminately valid. This statement supports the idea that the measurement model captures different aspects of the phenomena

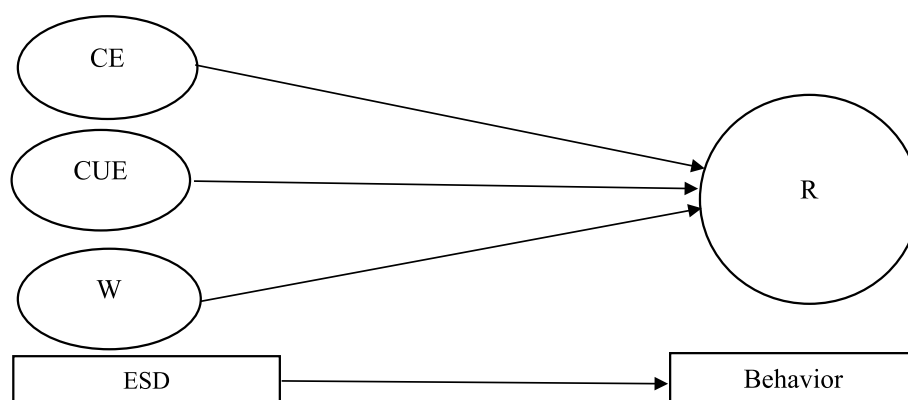


FIGURE 1
Research model. Source: by author.

TABLE 1 Hypotheses tested by the attitude of students.

H1: Students' attitudes to the concern of the environment have a significant effect on their reuse behavior.
H2: Students' attitudes to the cultural environment significantly affect their reuse behavior.
H3: Students' attitudes toward warning significantly affect their reuse behavior.

TABLE 2 Demographic characteristics of respondents (N = 251).

Character	Frequency	Percent
Gender		
Male	136	54.20%
Female	115	45.80%
Age (in years)		
18–22	216	86%
22–25	35	14%
Marital status		
Single	241	96%
Married	10	4%
Education		
Diploma	75	30%
Bachelor	176	70%

under investigation (Rönkkö and Cho, 2022). It proves that the questions successfully evaluated the intended constructs and supported the validity of the research tools. It suggests that the items chosen are appropriate for measuring the variables in this study.

Table 4 illustrates the utilization of the Fornell-Larcker criterion by the researchers to evaluate discriminant validity. The outcome presents the associations between the latent constructs in the study model. The Fornell-Larcker criterion involves comparing a construct's square root of Average Variance Extracted to its correlations with all other constructs, where each construct's AVE must exceed the squared correlation with any other construct for it to pass the test of discriminant validity construct (Fornell and Larcker, 1981). With support from the Fornell-Larcker criterion indicating discriminant validity and no instances of cross-loading surpassing corresponding loadings, this investigation favors discriminant reality as evidenced in Table 4.

The Heterotrait-Monotrait Ratio (HTMT) is one of the most valuable indicators for measuring discriminant validity when employing SmartPls4 (Henseler et al., 2015). The HTMT values in Table 5 support the conclusions drawn from the Fornell-Larcker criterion. The values for the complete model in this investigation were 0.9 or less, as shown in Table 5 and Figure 1. These results suggest that the measurement model possesses discriminant validity, thereby strengthening the overall reliability of the measurement model (Figure 2).

4.3 Assessment of the structural model

The findings of the study are displayed in Table 6. The structural pathways were evaluated using the Bootstrapping technique, and

5,000 sub-samples were utilized to examine the proposed connections. The β -coefficient, t -value, and p -value were employed to validate the suggested associations. The overall model adequacy was assessed utilizing the coefficient of determination, R^2 . As indicated by Figure 3, the R^2 indicated a 0.795% variation in student sustainability behavior due to all independent variables studied in this research such as concern for the environment, cultural environment, and attitude toward environmental warnings. In general terms, student conduct in higher education shows a positive and significant connection with concern for the environment ($\beta=0.277$; $p=0.027$), cultural environment ($\beta=0.310$; $p=0.017$), and attitude toward environmental warnings ($\beta=0.530$; $p=0$).

The findings of this study support the acceptance of all three hypotheses, indicating a statistically significant positive correlation between concerns about the environment, cultural environment, warning attitudes, and the sustainability behavior of university students in Somalia. These findings align with previous empirical support for the perception that education for sustainability has a positive correlation with university students' adoption of sustainable practices (Boca and Saraçlı, 2019).

5 Discussion

This study investigated how ESD affects the behavior of university students in Somalia. The study's results emphasize the importance of education for sustainability in developing sustainable behaviors among university students in Somalia. The structural model confirmed that sustainability education (including environmental concerns, cultural environment, and warning attitudes) significantly correlated with university students' sustainability behavior (specifically, reuse behavior). Higher education institutions are crucial in advancing sustainable development through significantn-campus activities that positively impact the environment and society (Badea et al., 2020). The involvement of students in sustainable practices promotes their attachment to the campus community, extends their desire to participate in campus initiatives, and facilitates a significant change through their behavior (Krasny and Delia, 2015).

Our research shows that students' perceptions of sustainable development efforts on campus positively affect all items of sustainable behavior investigated. These findings align with the broader literature, highlighting the importance of sustainability education in shaping sustainable practices. The correlation between individual worries regarding air pollution and the willingness to participate in environmental stewardship is robust, consistent with the results of prior research that underscore the significance of perceived personal relevance in motivating environmentally conscious conduct (Steg, 2016). According to research by Kollmuss and Agyeman (2002), people are more persuaded to embrace sustainable practices when they perceive immediate personal advantages or consequences. Therefore, our findings underscore the potential effectiveness of targeted messaging and interventions that emphasize the pressing importance of environmental issues to people's lives.

Moreover, the participants' acknowledgement of global environmental difficulties, such as biodiversity loss, shows a deep understanding of how environmental issues are interconnected and their significant impact on the planet's long-term viability. This finding

TABLE 3 Factor loadings, reliability, and validity.

Factors	Items	Loadings	CR	AVE
CE	Concern about the environment			
CE1	I am concerned about the effects of air pollution on me	0.972		
CE2	I have never had serious concerns about issues like marine pollution	0.919		
CE3	I do not believe that the extinction of animals and plants will destroy the world	0.964	0.978	0.916
CE4	It annoys me to see that factory wastes cause environmental pollution	0.972		
CUE	Culture environment			
CUE1	I will check and switch off unnecessarily used lights	0.773		
CUE2	I will use the back of papers when I am studying	0.817	0.961	0.930
CUE3	I will warn those polluting nature	0.966		
W	Warning			
W1	I will warn those harming trees and flowers in parks and gardens	0.644		
W2	I will warn those in my immediate vicinity to	0.791	0.805	0.582
W3	I will fight those endangering nature	0.839		
R	Reuse			
R1	I buy ecological products, although they are in parks and gardens	0.943		
R2	I am buying products with recyclable packaging	0.882	0.926	0.807
R3	I buy the products of companies that are backing environmental projects	0.868		

TABLE 4 Inter-construct correlation (Fornell-Larcker criterion).

	CE	CUE	R	W
CE	0.957			
CUE	0.947	0.904		
R	0.738	0.711	0.898	
W	0.316	0.261	0.699	0.763

TABLE 5 Heterotrait-monotrait ratio (HTMT).

	CE	CUE	R	W
CE				
CUE	0.816			
R	0.789	0.790		
W	0.509	0.583	0.838	

is consistent with research highlighting the importance of promoting systems thinking and fostering a sense of global citizenship to promote sustainable behavior (Wals and Jickling, 2002). Increasing people's awareness of the impact of their actions on global sustainability can enhance their sense of responsibility and motivate collaborative efforts to tackle urgent environmental issues.

The participants' feeling of prioritizing eco-friendly options, such as ecological products and those with recyclable packaging, demonstrates a rising inclination toward ethical consumerism and responsible consumption. Studies have shown that customers increasingly consider environmental and social factors when purchasing, indicating a shift toward more sustainable consumption habits (White et al., 2019). The results underscore the necessity for policymakers and business leaders to support sustainable production and consumption due to the growing consumer demand for

environmentally friendly options. The participants' support for businesses that endorse environmental activities highlights the importance of corporate social responsibility (CSR) in shaping consumer attitudes and actions (Ahamad and Ariffin, 2018). Consumers are more motivated to support businesses committed to environmental sustainability and social responsibility (Du et al., 2010). Therefore, businesses prioritizing environmental activities enhance their market competitiveness, brand reputation, and sustainability. The study offers significant contributions to academic understanding and practical implementation of sustainable practices in educational environments by shedding light on the determinants of sustainability-related behavior among university students in Somalia.

This research extends current knowledge by providing empirical evidence from a region that has been underrepresented in sustainability education studies. The study highlights the unique challenges and opportunities within this context by focusing on Thai higher education institutions, enriching the global discourse on ESD. The study contributes to understanding how specific components of sustainability education interact to influence student behavior, offering a more nuanced view of the mechanisms driving behavioral change. The findings of the study suggest a requirement for Somali universities to incorporate ESD more extensively into their academic programs. Policymakers and educational leaders should give importance to creating and executing courses and initiatives that integrate sustainability principles throughout various fields of study. Additionally, hands-on activities like projects centered on reusing and recycling should be included to offer practical experience and strengthen theoretical understanding.

Enhancing the quality of teachers through specialized training programs in sustainability education is essential for advancing educational achievements in Somalia. Educators must possess the

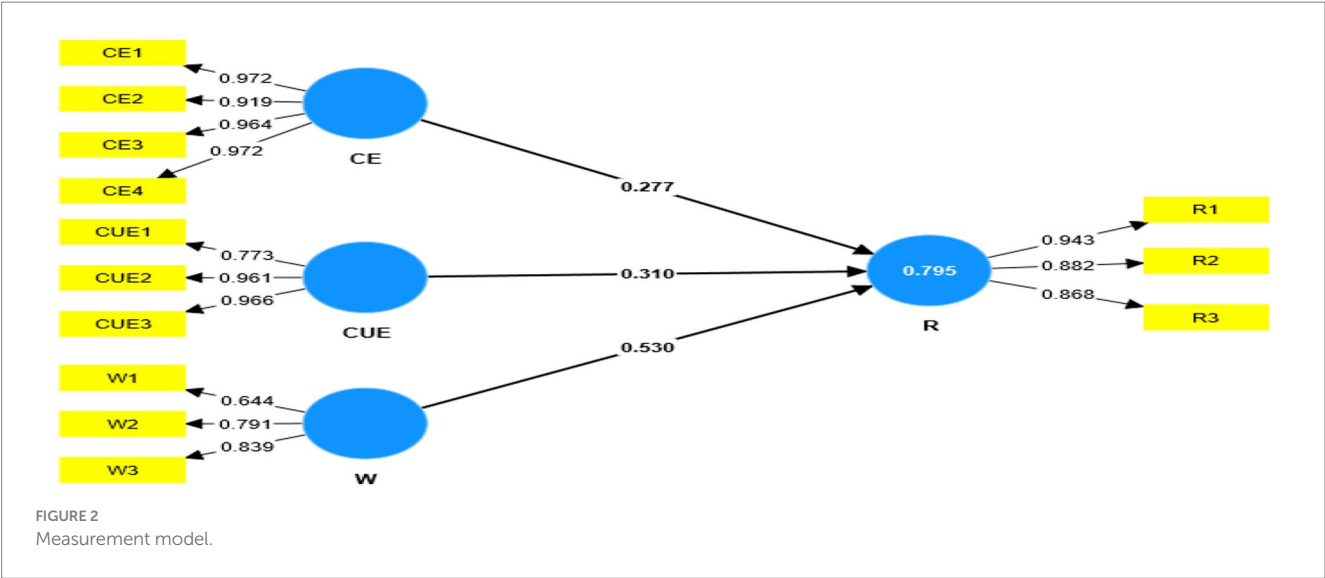


TABLE 6 Hypotheses testing results.

Hypotheses	Relationship	Beta (β)	STDEV	t-value	p-values	Findings
H1	CE->R	0.277	0.125	2.215	0.027	Accepted
H2	CUE->R	0.31	0.13	2.379	0.017	Accepted
H3	W->R	0.53	0.025	21.331	0	Accepted

necessary expertise and skills to integrate ESD into their teaching strategies effectively. These training initiatives should also consider the unique cultural and contextual elements relevant to Somalia to ensure their relevance and effectiveness. Key components of these professional development efforts include organizing engaging activities that cultivate environmental awareness, facilitating workshops to enhance personal and community-level understanding of global responsibility, and encouraging active participation in sustainability projects.

Universities are responsible for championing and supporting on-campus sustainability initiatives involving students in practical, hands-on sustainable practices. These efforts provide valuable learning opportunities for students to apply their classroom knowledge in real-world settings. By promoting student-led sustainability projects, universities can foster a sense of ownership and participation, thus promoting the adoption of sustainable behaviors within the campus community. Integrating project-based learning (PBL) models into sustainability curricula can help students develop critical thinking, problem-solving, and collaboration skills necessary to address complex sustainability challenges.

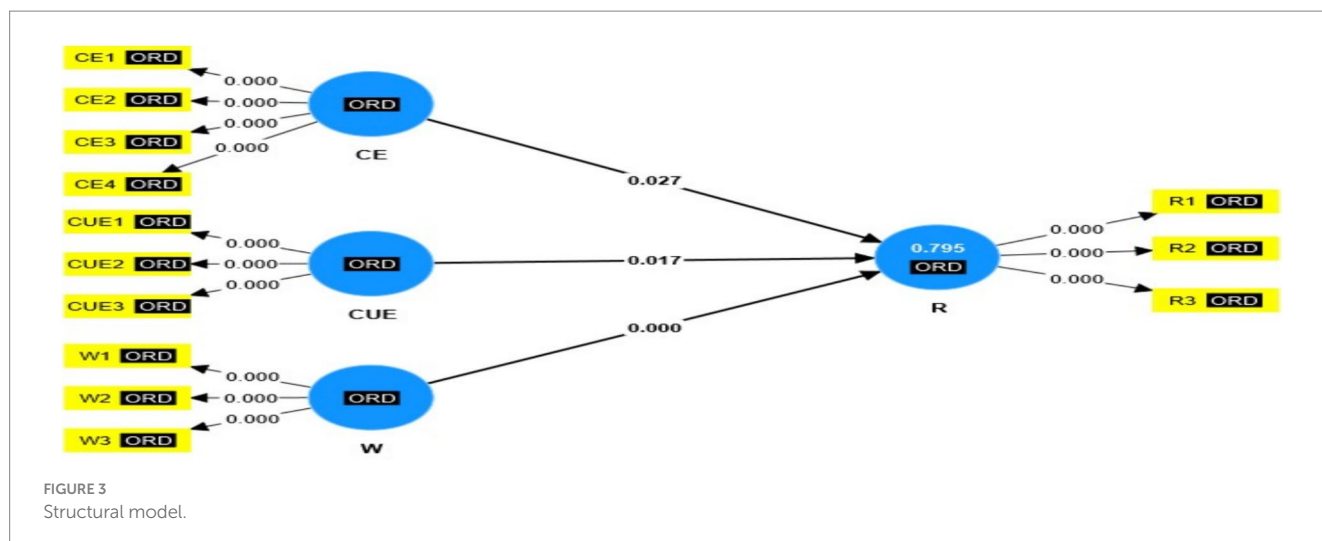
6 Conclusion and policy recommendations

This empirical research examined how ESD influences the sustainable behavior of university students in Somalia. ESD programs have been shown to dramatically impact students' attitudes and behaviors toward sustainability thorough investigation and

examination of many elements. This study emphasizes the significance of including sustainability education in higher education courses. Somali universities have the potential to cultivate a culture of environmental awareness and responsibility among future leaders by introducing ESD to their students. These efforts not only help in the advancement of a sustainable society but also support worldwide initiatives for environmental protection and preservation.

Findings from this study emphasize the importance of continuous research and advancement of ESD programs to guarantee their effectiveness and applicability in tackling environmental, social, and economic issues. Universities can enhance their influence on students' behavior and foster continued positive change in communities by consistently improving and adjusting educational methods (Ahmad and Ariffin, 2018). ESD significantly influences students' behavior toward environmental sustainability in Somalia. However, universities can positively use their infrastructure and expertise to advance ESD in collaboration with other educational institutions, government levels, and the broader community.

The study recommends that higher education institutions in Somalia consider prioritizing sustainability education initiatives. This suggestion stems from the positive connection between sustainability education and students' adoption of sustainable practices. Universities can prioritize these activities by integrating sustainability courses into academic programs and organising extracurricular activities to promote social and environmentally conscious behaviors among students. The study also encourages higher education institutions to explore integrating sustainability ideas throughout all academic disciplines. This holistic approach can equip students with a deep understanding of environmental issues and sustainable solutions. By



adopting a multidisciplinary approach, students can cultivate a comprehensive perception of sustainability, potentially fostering their motivation to integrate sustainability concepts within their fields of study.

Empowering students to initiate sustainability efforts like recycling programs, green initiatives, and community projects can strengthen their connection to the campus community and motivate significant changes in behavior. Universities should foster a culture of sustainability on campus by offering a variety of on-campus activities. Universities should create thorough sustainability strategies that cover energy efficiency, waste reduction, water conservation, and sustainable transportation, involving stakeholders in the execution and oversight. They must also allocate resources toward educational and outreach initiatives to increase awareness and encourage behavioral changes among students, lecturers, staff, and the wider community. The programs should include sustainability workshops, seminars, campaigns, and educational resources to empower individuals to embrace more sustainable lifestyles and activities.

6.1 Limitations and future research

The research was carried out at the faculties of economics in SIMAD and Hormuud Universities. This focus was selected for multiple reasons, despite its limitation on generalizing the results. Firstly, students at these faculties have been introduced to sustainability concepts through specific courses within their academic programs. These courses aim to impart an understanding of economic principles alongside sustainable development practices. By concentrating on students who already possess some knowledge of sustainability, the study aimed to evaluate how this education influences their behavior and establish a clearer link between ESD and behavioral changes. Secondly, the faculties of economics were chosen because economic students often interact with subjects that intersect with sustainability, such as resource management, environmental economics, and corporate social responsibility. These topics naturally incorporate elements of sustainability education, making these

students an ideal group for examining how sustainability education affects behavior.

While this focus restricts generalization of the findings to all university students in Somalia, it provides valuable insights into the effectiveness of sustainability education among a group already familiar with these concepts. In the future, there is an opportunity for broader research covering diverse universities and faculties for comparative analysis of students' perceptions, attitudes, and sustainability behavior. Expanding studies on ESD can deepen cultural impacts on environmental decision-making and support effective strategies in ESD. It should be noted that this study relied on self-reported data possibly affected by response bias and social desirability effects. Future research could incorporate mixed methods involving qualitative and quantitative tools better to understand the underlying relationship between ESD and sustainability behavior. The sustainability and cross-cultural research fields may yield ineffective strategies for addressing environmental problems prevalent in our society. Investing in targeted professional development programs can equip Somali educators with the necessary knowledge and skills to effectively integrate ESD into their teaching. Such programs should address the technical aspects of sustainability education and the cultural and contextual factors specific to the Somali context to ensure relevance and effectiveness.

Findings from studies conducted in other developing countries like Pakistan suggest that the implementation of ESD in higher education institutions remains low, and teachers often lack adequate knowledge of sustainability concepts (Vilmala et al., 2022). Similarly, research from the UAE indicates a need to investigate the status of ESD and sustainability literacy among tertiary students, as they are key agents of change in addressing environmental issues. Therefore, designing tailored professional development for Somali teachers can help bridge this gap and empower them to become champions of sustainability education (Rukmana et al., 2023). Integrating sustainability education into Somali classrooms requires a comprehensive approach that considers both the pedagogical and contextual factors. Professional development programs should focus on building teachers' content knowledge and pedagogical skills to

deliver ESD effectively. Additionally, these programs must be designed with a deep understanding of the cultural, social, and environmental realities of Somalia to ensure the relevance and impact of the training.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AA: Writing – original draft. HH: Formal analysis, Software, Writing – original draft. MA: Methodology, Writing – original draft.

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How do higher education policies influence the shaping of sustainable development values in China: a three-dimensional framework

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Introduction: In the face of global challenges, higher education is regarded as an important force to promote the achievement of the 2030 Sustainable Development Goals (SDGs). Existing research has focused on articulating and analyzing the impact of value shaping for sustainable growth in higher education, although articulation and systematic analysis of higher education policy remain lacking.

Methods: Based on the policy tool perspective, this paper constructed a three-dimensional analysis framework by using content analysis and the PMC index model to undertake a thorough analysis of higher education policies published at the central level in China from 2009 to 2024.

Results: This study found that current higher education policies had multiple impacts on the formation of sustainable development values: (1) In the four dimensions of sustainable development proposed by the United Nations, China's higher education policy had shown clear guiding ideology and action direction; (2) In shaping sustainable values, China's higher education policies showed clear progress in three key dimensions; (3) The value and innovation of this study in shaping the values of sustainable development in higher education policies were primarily expressed in the following aspects.

Discussion: This paper suggested a way for optimizing the design of China's higher education policies, providing empirical data and theoretical support for China's higher education policies to better promote the ideals of sustainable development.

KEYWORDS

higher education policy, sustainable development values, policy analysis, content analysis method, PMC index model

1 Introduction

Sustainable development was the organizing principle of global development and concerns the well-being of people and the planet (UNESCO, 2016). The concept of sustainable development was born out of a series of uncertain risks that threatened the future of humanity's perpetual development in the course of human industrial civilization (Li H., 2024). At the World Conference on Education for Sustainable Development (ESD) in 2021, the United Nations Educational, Scientific, and Cultural

Organization (UNESCO) called for a reshaping of education's mission to address the dilemma of education for sustainable development caused by the Neo-collapsing pneumonia epidemic. The Sustainable Development Goals Report 2022 pointed out that the achievement of the global Sustainable Development Goals (SDGs) was in jeopardy, and the 2030 Agenda for Sustainable Development was under grave danger (UN, 2022). In this context, the inclusion of higher education in the 2030 SDGs and its inclusion in the global development agenda as a more important development actor was a positive feature (Roberts and Ajai-Ajagbe, 2013). Higher education was a "key tool" for achieving the SDGs and can bring the necessary transformational momentum to today's world by increasing knowledge, skills, values, attitudes, critical thinking, competencies, systems thinking, responsibility and empowerment of future generations (Leicht, 2024). China's higher education key construction policy was an innovative approach to improve and accelerated higher education development by focusing on the establishment of a set of high-level universities and disciplines (Zhao and Li, 2024). Therefore, higher education policy has an important impact on shaping the values of sustainable development.

This topic has piqued the curiosity and attention of an increasing number of scholars. Cardiff et al. (2024) recommended the application of ESD in language education. According to Chankseiani and McCowan (2021), one of the goals of sustainable development in higher education was equal access to higher education, also known as equity. Fekih Zguir et al. (2021) proposed including Education for Sustainable Development (ESD) and Sustainable Development Goal (SDG) ideals into the curriculum. Nordén (2024) used a qualitative methodology to uncover trans-boundary learning and a shift in how we think about sustainable development by activating intrinsic elements. Thus, it has been discovered that the policy impact analysis and book review on the sustainability of higher education in a certain country are relatively prominent, and the main deficiencies are the single quantitative method of the evaluation system indicators, the heavy subjective evaluation, and the lack of targeted policy recommendations for the sustainability of higher education development (Chankseiani and McCowan, 2021). At the same time, Chinese scholars' attention to this topic is also becoming increasingly visible, Du (2022) clarified the definition of sustainable development of higher education, which contains three meanings: higher education as sustainable development, higher education on sustainable development, and higher education for sustainable development. Ma (2023) expounded on China's practice of higher education for sustainable development in terms of economy, society, ecology, and the international experience achieved. Yuan and Li (2021) anticipated the modernization of China's higher education in 2035, and proposed some proposals for the development of sustainable education in higher education in 2035 under the guidance of relevant policies. Certainly, the development and refinement of higher education to cultivate sustainable development values is maturing over the globe. However, in China's educational practice, these policies remain in the exploratory phase. The existing literature primarily elaborated and analyzed the influence of higher education on sustainable development values. And, there is a distinct absence

of detailed examination of higher education policies. Furthermore, no studies have quantitatively examined higher education policy texts on sustainable development using policy tools as a lens. This represents a significant research gap, with ample scope for growth in this subject.

As a result, based on the perspective of policy tools, this study will use data from relevant government departments to examine sustainable development policies for higher education. It employs content analysis and the Policy Modeling Consistency (hereinafter referred to as PMC) index model to build a framework analyzing policy objectives, tools, and effectiveness. The study applies Nvivo12 and ROSTCM6 to thoroughly investigate the aims, tool structures, and enforcement effects of higher education policy documents. Based on these findings, the study suggests an optimization path for higher education policy to foster sustainable development values, offering theoretical insights for future central government policy making.

2 Research framework

2.1 General ideas

Policy objectives, policy tools, and policy effectiveness are all important components of public policy analysis, regardless of whether they follow a vertical or horizontal basic framework (Yao et al., 2024). As the basic way to implement policies, the appropriate choice of policy instruments affects the sustainability and effectiveness of policy objectives. The analysis of policy instruments helps to improve the understanding of policy formulation (Peng and Peng, 2022). Policy objectives reflect the values and preferences of policymakers, which will also play a role in the selection criteria of policy instruments (Nordén, 2024). Policy effectiveness, in contrast, demonstrates the coherence of policy substance and is an objective reflection of the scientificity of policy instruments and the rationality of policy objectives (Fekih Zguir et al., 2021). At the same time, some studies have found that high-quality policies tend to exhibit stronger characteristics of goal rationality, problem responsiveness and implementation robustness, such as policies with clear goals, scientific tools and efficient effectiveness are more likely to produce positive policy effects in the process of implementation (Cutcher et al., 2020). Many research had examined public policy based on goal-tool-efficacy. For example, from the perspective of tools, Lu et al. (2024) analyzed China's policies related to children's medication to provide reference for the formulation and optimization of policies in the field of children's medication in China. Zhan et al. (2024) investigated the significance of China's ESG policies through the lens of policy tools and provided recommendations for the government's future formulation and optimization of ESG policies.

All of the examples above demonstrated the goal-tool-efficacy dimension, which was an effective tool for interpreting public policies. Thus, in order to investigate the impact of higher education policies on long-term value shaping, this study follows the fundamental principles of the policy science school of public policy analysis. We seek to examine the policy text and undertake specific assessments by contrasting three aspects: policy goals, policy instruments, and policy effectiveness.

TABLE 1 Policy target coding.

Dimension of policy objectives	Policy objectives	Keyword encoding
Ideology	Fostering the concept of sustainable development	Environmental protection, Resource conservation, Ecological balance, Green development, Carbon Neutrality etc.
Education	Promoting green and low-carbon education	Green and low-carbon concept, Environmental education, Course integration, Practical education etc.
Science	Promoting scientific innovation	Independent innovation, Cultivation of innovative talents, International cooperation, Intellectual Property Protection etc.
Technology	Strengthening the construction of ecological civilization	National participation, Green School, Education integration, Ecology etc.

2.2 Policy objective dimension

Policy objectives are the requirements and effects expected to be achieved by policy implementation, as well as the unified consensus of managers' will to act (Lu et al., 2024). Objectives have a specific role in policy creation, unifying the course of action of various sectors and stakeholders, guiding resource allocation, providing criteria for policy evaluation, and increasing policy openness and public participation. Policymakers may guarantee that resources are used effectively, and that policies achieve the desired results by establishing clear policy objectives, improving the knowledge and support of all key parties for the policies, and encouraging policy consensus. Based on the UNESCO series of reports, this study starts from four aspects: ideology, education, science and technology, and culture, and divides the dimensions of ESD policy objectives related four aspects (UNESCO, 2015) identified in the UNESCO reports: fostering the concept of sustainable development, promoting green and low-carbon education, promoting scientific innovation, and strengthening the construction of ecological civilization (Xiong et al., 2023) (see Table 1).

2.3 Policy instrument dimension

Policy instruments are important means adopted by governments to achieve governance goals and improve governance effectiveness (UNESCO, 2015). They are "blueprints or templates for shaping policies," which can be used to test the implementation of public policies based on a set of specific government behaviors, and appropriate policy instruments can have a multiplier effect on the realization of policy objectives (Rothwell and Zegveld, 1985; Linder and Peters, 1990). Rothwell and Zegveld's policy tool theory classifies policy tools into three types: environmental, supply and demand policy tools. Only a balanced use of these three sorts of policy tools can ensure that policy is reasonable and scientific (Blair, 2002). Based on this, this study adopts the classical way of separating the types of policy instruments proposed by Rothwell and Zegveld (1981), i.e., the three dimensions of supply-side, demand-side, and environment-side. Therefore, this study divides the policy tools for shaping the values of sustainable development into three categories of supply-type, demand-type, and environment-type totalling 12 policy tools (see Table 2).

2.4 Policy effectiveness dimension

Policy effectiveness refers to the impact and effect that a policy demonstrates in the course of its actual implementation. The real influence and change that the policy causes in the target group or the social environment. Policy efficacy is one of the most crucial criteria for determining a policy's success. A highly successful policy can better serve the public interest, solve social problems and promote social progress. This study combines the characteristics of higher education sustainable development policies with nine first-level indicators to measure whether these policies support the realization of the Sustainable Development Goals (SDGs). It offers a PMC evaluation method for higher education policies aimed at forming values relevant to sustainable development, and intuitively displays the strengths and shortcomings of these policies by calculating the PMC index value and creating the PMC surface diagram (Li M. L., 2024).

3 Research methodology and data

3.1 Description of the research methodology

Based on the instrument-goal-effectiveness framework, this study employs Nvivo12 software to conduct a content analysis method of keyword analysis data of higher education policy texts. Furthermore, a quantitative literature analysis approach of policy text, paired with the PMC index model, is used to interpret the values of higher education policy that shape sustainable development. The use of mixed research methodology in this study can completely exploit the capabilities of diverse research methods in order to get more accurate conclusions (Carter et al., 2014).

The content analysis is an objective, systematic and quantitative description of the content of communication, in essence, it is an examination of the amount of information contained in the content of the literature and the trends or changes reflected in it (Yang and Hu, 2021). As a popular auxiliary tool for textual econometric analysis, Nvivo qualitative analysis software can assist researchers in capturing data characteristics and patterns, as well as managing data flexibly, allowing them to free themselves from tedious data processing tasks such as classification, sorting, and organization in the past, giving them more time to explore research objects and problems (Gil-Garcia et al., 2018). According to the four

TABLE 2 Types and content of policy instruments.

Tool type	Tool name	Meaning of the tool	Source (of information etc)
Supply-side policy instruments	Capital investment	Provide financial support for low-carbon development through the allocation of special funds in the form of direct capital inputs, the granting of capital subsidies, and the provision of research and development and construction funds	Ding (2024)
	Education and training	Develop curriculum and teaching materials related to sustainable development, integrating environmental, social and governance (ESG) factors into existing programmes	
	Infrastructure	Construction of physical engineering facilities, such as green campus construction, to ensure the smooth implementation of energy conservation and emission reduction activities, as well as to realize carbon-neutral development	Tu and Jiao (2024)
	Information service	Through building an information platform, establish, integrate and publish relevant technical guidelines and other information to provide information services for relevant subjects to participate in the practice of shaping sustainable development values.	Ma and Liu (2024)
Environmentally oriented policy instruments	Policy development	Develop educational policies that incorporate sustainable development goals and principles and provide clear guidance and frameworks for higher education institutions	Jiang (2024)
	Creative incentives	Establishment of awards and honors, such as prizes and research grants, and innovative educational projects, such as innovation labs and makerspaces, to stimulate students' creativity and innovation	Li H. (2024)
	School-Enterprise Co-operation	Collaborate with businesses to provide internships and employment opportunities for students, while promoting corporate involvement in education and research for sustainable development	Molderez and Fonseca (2018)
	Preferential policies	Provide incentives and enabling measures, such as preferential procurement rights, to promote the adoption and practice of sustainable development values	Li M. L. (2024)
Demand-based policy instruments	Pilot construction	Implementation of specific sustainable development projects or programmes in selected higher education institutions, e.g. green campus pilots, sustainable development curriculum pilots, etc.	Sheng and Wen (2024)
	Market development	Promoting and channelling market forces to advance the practice and application of sustainable development values through various measures, such as green investment funds	Zhang (2023)
	Introduction of talent	Attracting and assembling professionals with knowledge and skills in sustainable development through various measures, such as overseas recruitment programmes and specially appointed professorships	Cynthia and Sharma (2022)

components provided in UNESCO papers, this study utilizes software to conduct a content analysis of higher education policy texts for sustainable development. Each text serves as an analytical unit to assess the influence of these policies on sustainable value formation.

3.2 Policy text options

In order to ensure the accuracy and effectiveness of the research, policy texts related to the research topic as well as texts issued by central government departments were selected. This study conducted an advanced search in the <http://PKULAW.com>. And the website of the Ministry of Education of the People's Republic of China, using the keywords “dual-carbon,” “sustainable development,” “green education,” “environmental education,” and so on. The search scope for central policies and regulations was defined from 2009 to 2024. Simultaneously, to ensure that the text is extremely consistent with the subject, manual screening was conducted according to the following criteria: first, the policy text

is related to the theme of sustainable development, for example, the document can be related to the scope of lifelong education, environmental education, dual-carbon talent development; second, the policy text must be publicly released by authoritative issuing agencies at the central level, including the Central Committee of the Communist Party of China (CPC), the State Council, the Ministry of Education, the Ministry of Environmental Protection, and the State Forestry Administration, etc.; third, policy documents include notices, opinions, announcements, outlines (excluding approvals), policy interpretations, and so on. Based on the above principles, 20 ESD policy texts were eventually sorted out and a sample data base was established, as shown in Table 3.

3.3 Coding of policy texts and statistics

In this study, the 20 ESD policy texts listed above were imported into the Nvivo12 software. The contents of the policy texts were manually coded and analyzed word by word and sentence by phrase using the policy tool categorization framework established in the

TABLE 3 Sample data base of ESD policy texts (partial).

Serial number	Name of policy text	Issuing body	Release time
1	Opinions on Doing a Good Job of Environmental Publicity and Education in the New Situation	Ministry of Environmental Protection, Central Propaganda Department, Ministry of Education	2009.06.01
2	China Education Modernization 2035	Central Committee of the Communist Party of China and State Council (CPC)	2019.11.26
3	Action Plan for Carbon Neutral Science and Technology Innovation in Higher Education	Ministry of Education	2021.07.12
	- - - - -		
18	Guidelines for the Development of New Agricultural Personnel as Guiding Specializations	General Office of the Ministry of Education	2022.08.31
19	Implementation Programme for Building a National Education System for Green and Low-Carbon Development	Ministry of Education	2022.10.26
20	Action Programme for Energy Conservation and Carbon Reduction 2024-2025	State Council (PRC)	2024.05.23

TABLE 4 Nodal list of coding dimensions of policy instruments.

Types of policy instruments	Child node	Source of the document	Reference points	Percentage (%)	Add up the total	Total share (%)
Supply-based	Capital investment	12	17	7.9	102	47.22
	Education and training	16	45	20.8		
	Infrastructure	11	25	11.6		
	information service	12	15	6.9		
Environmental	Policy development	14	30	13.9	65	30.09
	Creative incentives	11	17	7.9		
	School-Enterprise Co-operation	7	12	5.6		
	Preferential policies	3	6	2.8		
Demand-based	Pilot construction	12	21	9.7	49	22.69
	Market development	5	9	4.2		
	Introduction of talent	10	19	8.8		

preceding section, yielding 11 nodes and 216 reference points. This resulted in a coded node list of policy tool dimensions (see Table 4), which this study used to investigate the precise content of the ESD policy text.

3.4 PMC index modelling

The policy effectiveness dimension adopts the PMC index model to explore the effectiveness of the policy content issued by the Ministry of Education and other levels of the central government from 2009 to 2024, so as to propose appropriate countermeasures for the current state of development. The PMC index model is a new

type of policy evaluation method proposed by Ruiz Estrada, 2011, which evaluates the consistency and effectiveness of policies by integrating multiple dimensions and variables. It has several advantages. For starters, it may do quantitative text analysis while taking into account the diversity of affecting factors and the consistency of policy weights. Second, the objective data and PMC surface allow for single-indicator analysis and multidimensional evaluation of the effectiveness of policies. Third, the PMC index model is applicable to a wide range of fields and can easily combine many factors with policy characteristics and societal demands to create a unique and scientific quantitative model for making objective judgments on diverse policies (Yang and Hu, 2021). Its primary operational

TABLE 5 Policy effectiveness evaluation system.

serial number	Level 1 variable	Binary variable	Evaluation criteria	Sources of first-level variables
X1	Nature of the policy	X1:1 Forecast	Whether the policy reflects predictability, yes 1, no 0	Liang and Feng (2023)
		X1:2 Recommendations	Whether the policy makes recommendations, yes 1, no 0	
		X1:3 Boot	Whether the policy reflects guidance, yes 1, no 0	
X2	Policy timeliness	X2:1 Long-term	Whether the policy has been in force for more than 5 years, yes 1, no 0	Wang and Wang (2024)
		X2:2 Medium-term	Whether the policy is valid for 3-5 years, yes 1, no 0	
		X2:3 Short-term	Whether the policy is valid for less than 3 years, yes 1, no 0	
X3	Policy body	X3:1 Ministry of Education	Whether the policy is issued by the Ministry of Education, yes 1, no 0	
		X3:2 Other central departments	Whether the policy is issued by another central authority, yes 1, no 0	
X4	Policy audience	X4:1 Government	Whether the policy involves a government department, yes 1, no 0	Batchelder et al. (2023)
		X4:2 Schools	Whether the policy addresses school boundaries, yes 1, no 0	
		X4:3 Enterprises	Whether the policy is enterprise-wide, yes 1, no 0	
		X4:4 Public	Whether the policy has a public dimension, yes 1, no 0	
X5	Incentives	X5:1 Financial support	Whether the policy addresses financial support, yes 1, no 0	
		X5:2 Information enabling	Whether the policy addresses information support, yes 1, no 0	
		X5:3 Tax subsidies	Whether the policy involves tax subsidies, yes 1, no 0	
		X5:4 Base support	Whether the policy addresses base support, yes 1, no 0	
X6	Mode of action	X6:1 Mandatory	Whether the mode of action of the policy is mandatory, 1 for yes, 0 for no	Liang and Feng (2023)
		X6:2 Serviced	Whether the policy role modality is service-oriented, yes 1, no 0	
		X6:3 Incentive	Whether the mode of action of the policy is incentive-based, yes 1, no 0	
X7	Plane of action	X7:1 Countries	Whether the country is involved at the policy role level, yes 1, no 0	
		X7:2 Enterprises	Whether firms are involved at the policy role level, yes 1, no 0	
		X7:3 Schools	Whether schools are involved at the policy role level, yes 1, no 0	
		X7: 4 Persons	Whether individuals are involved at the policy role level, yes 1, no 0	
X8	Policy evaluation	X8:1 Clear objectives	Whether the policy is well targeted, yes 1, no 0	
		X8:2 Programme detail	Whether the policy is programme-detailed, yes 1, no 0	

(Continued on following page)

TABLE 5 (Continued) Policy effectiveness evaluation system.

serial number	Level 1 variable	Binary variable	Evaluation criteria	Sources of first-level variables
		X8:3 Planning science	Whether the policy is planned scientifically, yes 1, no 0	
X9	Policy disclosure	/	Whether the policy is public, yes 1, no 0	

TABLE 6 PMC index scale.

PMC index	0~3.99	3.99~5.99	5.99 to 7.99	7.99~9.00
Efficacy level	Fail	Usual	Favorable	Talented

activities are as follows: identifying variable classifications and parameters, building multi-input-output tables, calculating PMC indexes, drawing PMC surface diagrams, and evaluating and optimizing policies. Taking into account the method's requirements, the evidence of previous research results, and the characteristics of the selected policy texts, we developed the PMC evaluation system (see Table 5), which contains 9 primary variables and 27 secondary variables.

After the establishment of the policy effectiveness evaluation system, the PMC index model needs to be calculated. In Equations 1, 2: X is the first-level variable, and the association of the two equations means that all variables obey the $[0, 1]$ distribution and are assigned the value of 0 or 1; XR means rounding. In Equations 3, 4: i is the value of the first-level variable; j is the value of the second-level variable; $T(\cdot)$ is the value of the second-level variable under each first-level variable. According to Equation 4 the PMC index value can be obtained. The parameters m and n are finite and take on positive integer values. Specifically, m denotes the quantity of primary variables, and n signifies the quantity of secondary variables within the framework of the model.

$$X \sim N[0, 1] \quad (1)$$

$$X = \{XR: [0 \sim 1]\} \quad (2)$$

$$X_i \left[\sum_{j=1}^n \frac{X_{ij}}{T(X_{ij})} \right] \quad (3)$$

$$i = 1, 2, 3, 4, 5, \dots, m \quad j = 1, 2, 3, 4, 5, \dots, n$$

$$I_{PMC} = \sum_{i=1}^m \left(X_i \left[\sum_{j=1}^n \frac{X_{ij}}{T(X_{ij})} \right] \right) \quad (4)$$

$$i = 1, 2, 3, 4, 5, \dots, m \quad j = 1, 2, 3, 4, 5, \dots, n.$$

According to the results calculated by the PMC index model, these results can be classified into four grades: "Fail," "Fair," "Good" and "Excellent" (see Table 6).

$$PMC(\text{surface}) = \begin{bmatrix} X1 & X2 & X3 \\ X4 & X5 & X6 \\ X7 & X8 & X9 \end{bmatrix} \quad (5)$$

Finally, the PMC matrix was constructed based on the calculation of the scores of each variable, and the PMC surface plotting was carried out with Equation 5.

4 Findings

4.1 Analysis of the policy objective dimension

Overall, the central level policy objectives include ideology, education, research and technology, and culture. The frequency and proportion of the four policy objectives of cultivating the concept of sustainable development, promoting green and low-carbon education, strengthening the construction of ecological civilization, and promoting science and innovation are 92 (55.76%), 29 (17.58%), 28 (16.97%), and 16 (9.70%) in turn (see Table 7). It is clear that the primary goal is to instill pupils' understanding and recognition of sustainable development as a personal value. This is to ensure that students understand its significance and the roles that people and society play in achieving it through higher education legislation. The objectives of promoting green and low-carbon education and enhancing the building of an ecological civilization accounted for an equal share, reflecting that the central level still attaches importance to educating students to carry out more relevant practical actions. The objective of promoting science and innovation, which accounts for the smallest share, reflects that the central level encourages students to participate in scientific research and technological innovation to address the challenges of sustainable development, but there are still relatively few incentives to do so.

4.2 Analysis of the dimensions of policy instruments

Table 5 shows that the policy options for sustainable higher education are divided into three types: supply, environment, and demand, with frequency shares of 47.22%, 30.09%, and 22.69%, respectively. This indicates that at the initial stage of shaping sustainable development values in higher education, the policy design focuses on providing some necessary material and information support to create conditions for shaping sustainable development values in higher education (see Figure 1). Among the supply-based policy tools, the coverage of "education and training" is high, accounting for 20.8%, and the coverage of "financial input" is relatively low, accounting for only 7.9%, which shows that the central level focuses on improving teachers' competence in ESD, but there is a lack of support for the development of ESD curricula. Efforts to design ESD courses are limited. Environmental policy tools are aimed at creating an atmosphere suitable to the establishment of sustainable development values, as well as directing higher education sectors in developing and implementing educational policies and incentives related to sustainable development. However, the proportion of "preferential policies" is particularly low, accounting for only 2.8%, implying that efforts to foster the merger of industry, academia, and

TABLE 7 Nodal list of coding dimensions for policy objectives.

Type of policy objective	Source of the document	Frequency	Percentage (%)
Fostering the concept of sustainable development	20	92	55.76
Promoting green and low-carbon education	15	29	17.58
Strengthening ecological civilization	11	28	16.97
Promoting scientific innovation	7	16	9.70

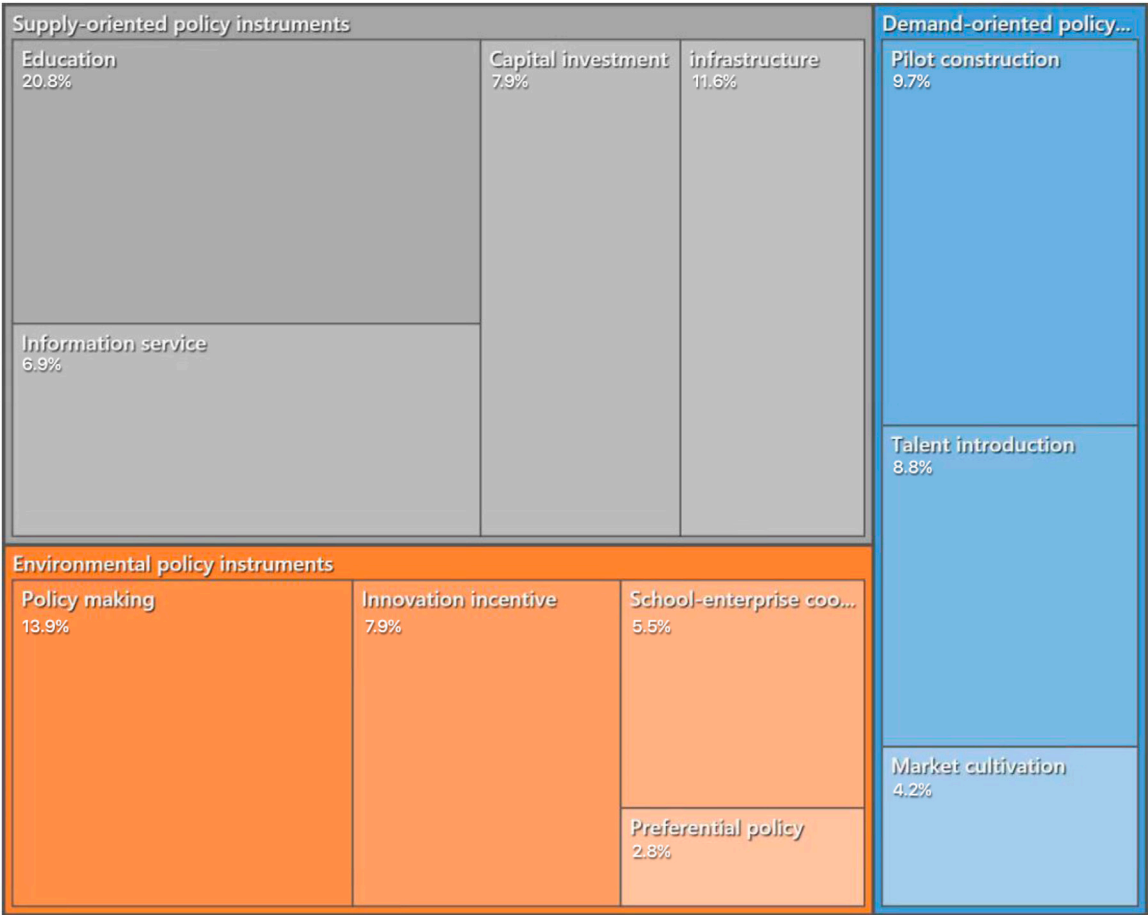


FIGURE 1
Frequency diagram of policy instruments.

research remain insufficient. Demand-driven policy instruments play an important role in creating an educational environment that supports sustainable development and stimulating related demand by stimulating and guiding demand for sustainable development values through “pilot construction” and “market cultivation.”

4.3 Analysis of policy effectiveness dimensions

In this study, 20 policy texts from the sample database were examined, with six representative higher education policy texts on sustainable development chosen for effectiveness analysis. The six

policy texts were selected using two criteria: (1) in order to ensure the authority of the policy texts, three policy texts issued by the Ministry of Education (MOE) were chosen, namely, P1, P2 and P3; (2) in order to reflect the synergy of the policy texts, three policy texts jointly signed and issued by several ministries and departments, respectively, were chosen, namely, P4, P5, and P6; the results of the screening of the policy texts are shown in Table 8.

The PMC index model can be constructed to obtain the actual perception of the effectiveness of the policy, and the larger the PMC index value, the greater the usefulness of the policy, and *vice versa*, the policy has a lot of space for development. Table 9 displays the results of this study, which assigns values to the secondary variables in the input-output tables of the six policies based on the substance

TABLE 8 Summary of 6 policy texts.

Serial number	Name of the document	Issuing body
P1	Action Plan for Carbon Neutral Science and Technology Innovation in Higher Education	Ministry of Education
P2	Guidelines for the development of new agricultural personnel as guiding specializations	Ministry of Education
P3	Implementation Programme for Building a National Education System for Green and Low-Carbon Development	Ministry of Education
P4	Opinions on Doing a Good Job of Environmental Publicity and Education in the New Situation	Ministry of Environmental Protection, Central Propaganda Department, Ministry of Education
P5	Opinions on Promoting the Construction of Learning Cities	Ministry of Education and seven other departments
P6	Circular on the Second Batch of Construction of Modern Industrial Colleges	General Office of the Ministry of Education, General Office of the National Development and Reform Commission, General Office of the Ministry of Industry and Information Technology

of the policy language. The PMC index of each of these six policies is determined separately using the PMC index formula. The grades for these six policies are then determined by combining the policy grade criteria, and the results are presented in Table 10.

This study plotted the surface diagrams of six sustainable higher education strategies to make it easier to analyze and compare their degree of concavity, as well as their strengths and drawbacks. Different colour blocks represent different index scores corresponding to the variables. In the surface, the higher the level of three-dimensional coordinates and the smaller the concavity of the surface, the more comprehensive the indexes involved in the policies are; and *vice versa*. The surface diagram allows for additional analysis of the strengths and weaknesses of each policy substance, as shown in Figures 2–7 (The numbers in the figure represent the range of values of the variable). According to the findings, Policies P1, P3, and P5 have clear objectives, an adequate foundation, thorough programmes, more scientific overall planning, cover a broader range of fields, and require less improvement, merely requiring to be altered based on the actual situation during subsequent implementation. In comparison, Policies P2, P4, and P6 require adjustments: P2 has 7 below-average first-level variables, a smaller audience, and requires increased incentives with a limited mandated measure scope, indicating greater improvement potential; P4's incentives are singly focused, narrow in scope. Policy P6 is a simplified policy programme with a smaller target audience, and the mode and level of action are only focused on the school, with no tie to the enterprise or the government.

5 Discussion

This study uses a qualitative analysis approach within the framework of “goal-tool-effect” to analyze the influence of current higher education policies on cultivating sustainable development ideals, using policy papers released by key central agencies between 2009 and 2024.

The policy objectives show remarkable effectiveness in developing students' understanding of the concept of sustainable development. This technique allows pupils to fully grasp the significance of sustainability and embrace it as a basic value.

However, there are obvious deficiencies in promoting innovation awareness. When presented with complicated environmental challenges, students may struggle to think creatively and solve problems. This deficiency may hinder their ability to propose and implement innovative solutions, with implications for the ability of society as a whole to innovate and adapt. Therefore, when formulating relevant policies, government departments should strengthen the cultivation of innovation consciousness. First, innovation education should be incorporated into the curriculum system. This can be accomplished through practical measures such as encouraging students to participate in innovative projects and contests and developing their innovative skills. Second, strengthen cooperation with enterprises and research institutions. This can provide students with internships and research opportunities that allow them to learn how to solve problems in real environments. Finally, teachers should use more stimulating teaching methods to encourage students to think independently and critically, thereby cultivating their innovative thinking.

The structure of policy instruments reveals inefficiencies and inequalities that can lead to unequal allocation of resources, which will adversely affect the quality of education and the efficiency of research. Inadequate support from supply-side policy instruments can limit curriculum diversity, undermining educational standards and research innovation. In addition, insufficient incentives in environment-based policy instruments may reduce incentives for academic-industry collaboration, thereby limiting knowledge transfer and technological progress. Moreover, inadequate market engagement in demand-based policy tools might result in the implementation of educational achievements in real-world situations, weakening social ideals and economic advantages. Therefore, when formulating relevant policies, government departments should optimize the structure of policy tools. First, increase funding for supply-oriented policy instruments to support education and research programs, and promote curriculum diversity and research innovation. Second, preferential policies to increase environmental policy tools can be utilized to encourage academic, industrial, and research community integration, as well as information transfer and technological innovation. Finally, boost market participation in demand-oriented policy tools, promote the implementation of educational and scientific research findings

TABLE 9 Inputs and outputs of six higher education policies for sustainable development.

Level 1 variable	Binary variable	P1	P2	P3	P4	P5	P6
X1	X1:1	0	0	1	0	0	0
	X1:2	1	0	1	1	1	0
	X1:3	1	1	1	0	0	1
X2	X2:1	1	1	0	1	1	1
	X2:2	1	0	1	0	0	0
	X2:3	1	0	1	0	0	0
X3	X3:1	1	1	1	1	1	1
	X3:2	0	0	0	1	1	1
X4	X4:1	1	0	1	1	1	0
	X4:2	1	1	1	1	1	1
	X4:3	0	0	0	0	1	0
	X4:4	0	0	0	0	1	0
X5	X5:1	0	0	1	0	1	0
	X5:2	1	1	1	1	1	0
	X5:3	0	0	0	0	0	0
	X5:4	1	0	0	0	1	1
X6	X6:1	1	1	1	0	1	1
	X6:2	0	0	1	1	1	0
	X6:3	1	0	1	1	1	1
X7	X7:1	1	1	1	1	1	0
	X7:2	0	0	1	0	1	0
	X7:3	1	1	1	1	1	1
	X7:4	1	1	0	1	1	0
X8	X8:1	1	1	1	1	1	1
	X8:2	1	0	1	1	1	0
	X8:3	1	1	1	0	1	1
X9	/	1	1	1	1	1	1

through market processes, and enhance social value and economic rewards.

Many policies lack predictive power, leaving them unable to adjust to future problems or changes, reducing their efficacy. Limitations in the scope and implementation mechanisms of these policies may prohibit them from covering all relevant areas or population groups, thus limiting overall effectiveness. Furthermore, over-reliance on executive power may ignore the potential contribution of non-governmental organizations, reducing prospects for public involvement and diversified collaborations while severely impacting stakeholder acceptance rates and implementation effectiveness. To combat the unpredictability of policy effects, government departments should base policy formation on in-depth data analysis and trend forecast to ensure that policies are adaptable to future challenges and changes. Second, policy measures should have a broader and more flexible scope to guarantee that their impacts reach all important sectors and groups.

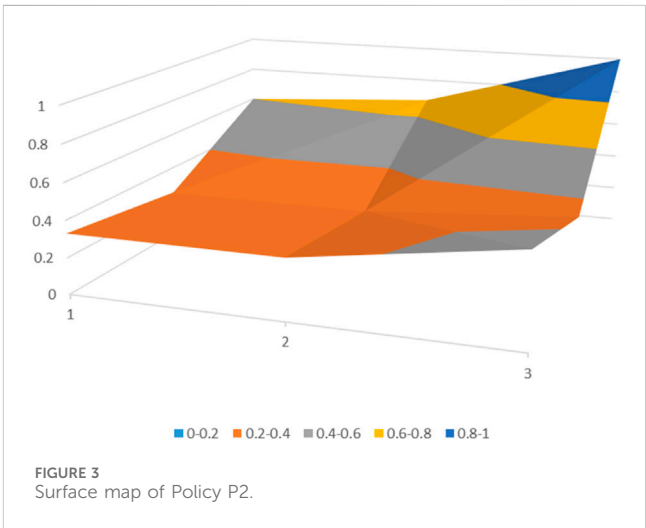
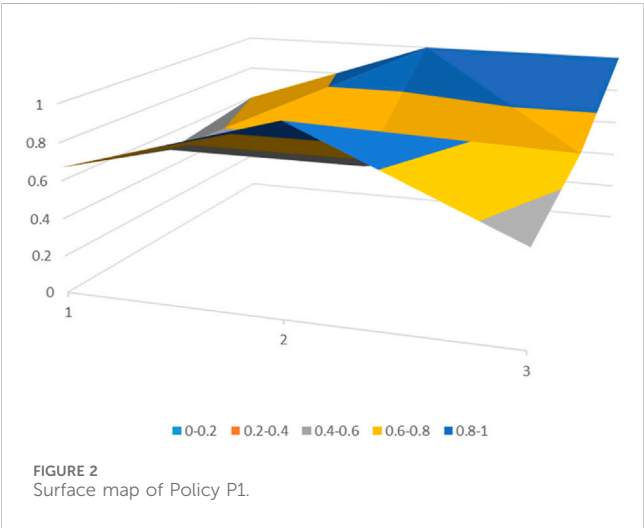
Finally, more nongovernmental stakeholders should be involved in policy creation. This will improve social engagement and pluralistic cooperation, resulting in greater policy acceptance and efficacy.

6 Conclusion

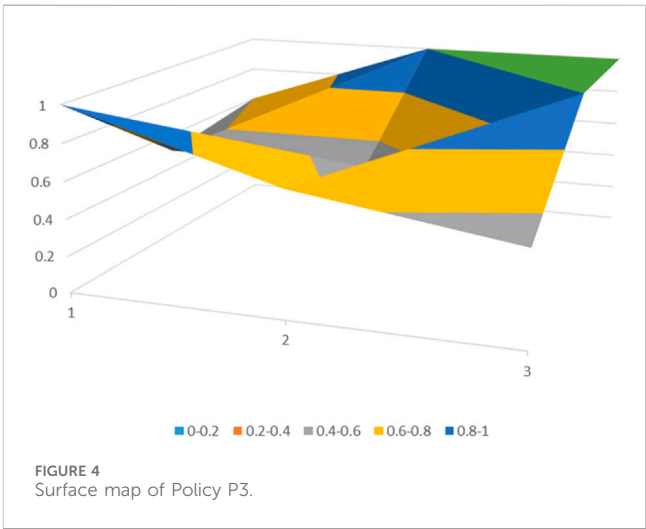
- (1) In the four components of sustainable development recommended by the United Nations, China’s higher education policy has demonstrated clear driving ideology and action direction. First, in terms of philosophy, the policy focuses on increasing students’ awareness and identification with the concept of sustainable development. Second, at the educational level, policymakers prioritize education and training. Policymakers encourage the creation of sustainability-related curricula and teaching materials in order to promote the integration of educational content with

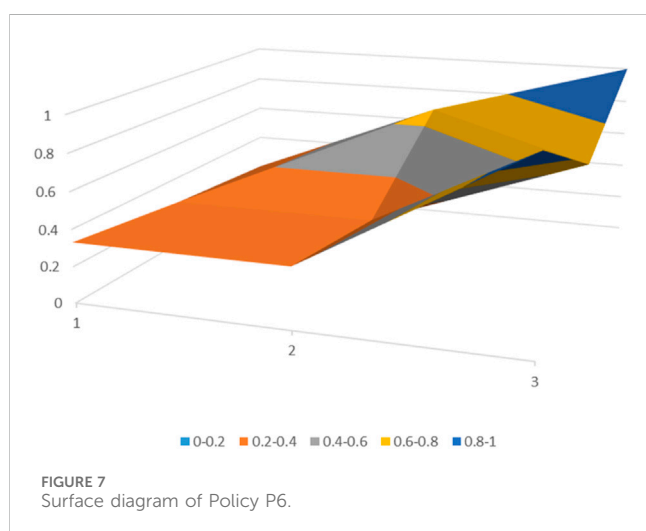
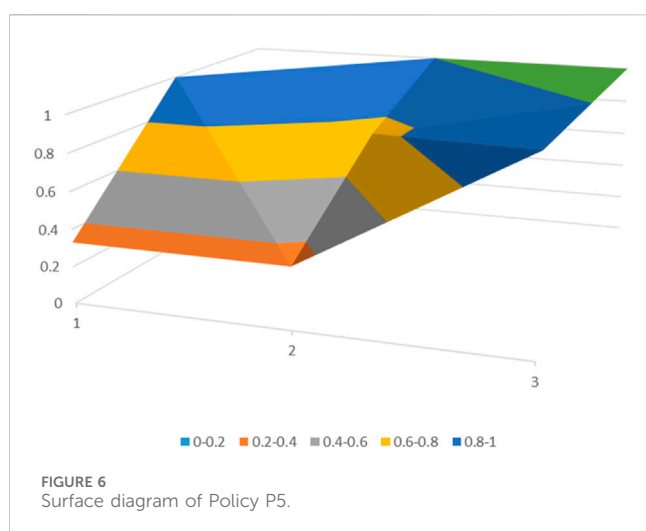
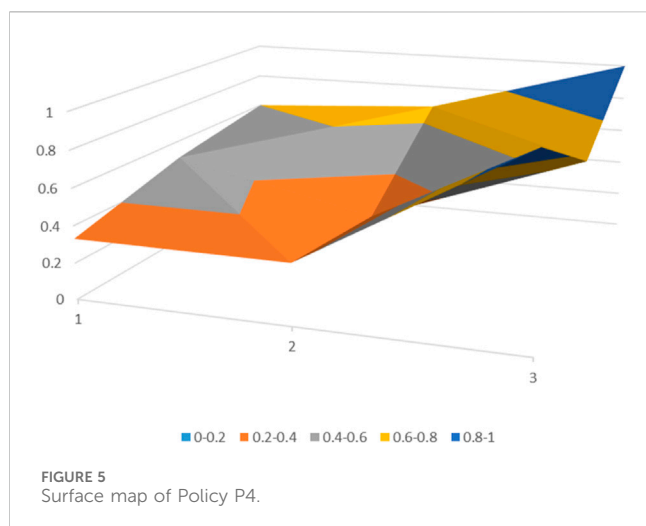
TABLE 10 PMC indices, depression indices and grades for the six policies.

Level 1 variable	P1	P2	P3	P4	P5	P6	average value
X1 Nature of policy	0.67	0.33	1.00	0.33	0.33	0.33	0.50
Policy X2 Timeliness	1.00	0.33	0.67	0.33	0.33	0.33	0.50
X3 Policy Body	0.50	0.50	0.50	1.00	1.00	1.00	0.75
X4 Policy Audience	0.50	0.25	0.50	0.50	1.00	0.25	0.50
X5 Incentives	0.50	0.25	0.50	0.25	0.75	0.25	0.42
X6 mode of action	0.67	0.33	1.00	0.67	1.00	0.67	0.72
X7 role dimensions	0.60	0.60	0.60	0.60	0.80	0.20	0.57
X8 policy evaluation	1.00	0.67	1.00	0.67	1.00	0.67	0.83
X9 Policy Disclosure	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PMC index	6.43	4.27	6.77	5.35	7.22	4.70	5.79
depression index	2.57	4.73	2.23	3.65	1.78	4.30	3.21
Efficacy level	favorable	usual	favorable	usual	favorable	usual	usual



sustainable development principles. Third, in the realm of science and technology, the policy purpose is to actively encourage scientific innovation. Policymakers encourage students to participate in scientific research and technology innovation to meet the issues of sustainable development. Fourth, in terms of culture, policy instruments focus on improving the foundation of ecological civilization, while policies encourage green and low-carbon education by preparing students to take necessary practical actions. This not only helps students develop a proper understanding of ecological environmental protection, but it also fosters the development of ecological civilization. To summarize, China's higher education policies have reflected and concentrated on four key aspects: ideology, education, science and technology, and culture. The policy formulation intends to thoroughly improve students' awareness of sustainable development and encourage its in-depth implementation through educational practice.





- (2) China's higher education programs have made significant success in three important areas when it comes to building sustainable values. First and foremost, policies encompass a wide range of critical sectors, including ideology, education, science and technology, and culture. There is a strong emphasis on encouraging sustainability, as indicated by the high percentage, demonstrating that policymakers understand that instilling sustainability ideals in pupils is critical for future social advancement. Second, in terms of policy tools, policies exhibit clear diversification features. The use of supply-oriented policy tools is especially common, accounting for 47.22%, reflecting the policy's emphasis on providing the necessary material and information support for higher education in the implementation process to foster the cultivation of sustainable development values. However, an in-depth review of the PMC index model demonstrates that policy substance is still lacking in some dimensions. Specifically, most policy parts lack foresight and predictability, which may hinder policy's ability to respond to future difficulties. At the same time, the scope and form of the policy effect reveal some restrictions, which may have an impact on the total benefit and execution of the policy. In short, China's higher education policy has made some progress toward shaping long-term values, particularly in terms of setting policy goals and diversifying policy tools. However, in terms of increasing the policy's effectiveness, broadening its scope, and improving its predictability and foresight, there is still a need for further improvement and optimization.
- (3) The following features highlight the study's value and novelty in shaping the values of sustainable development in higher education policies. First, in terms of models and methods, the study employs an innovative content analysis method and the PMC index model to construct a multidimensional analysis framework with three dimensions: policy objectives, policy tools, and policy effectiveness, as well as a comprehensive and in-depth analysis of policy texts. Second, in terms of in-depth analysis, the study employs Nvivo12 and ROSTCM6 software to conduct quantitative analyses of policy goal setting, policy tool structure, and policy implementation effectiveness in higher education policy texts, thereby improving the research's accuracy and objectivity. In terms of policy recommendations, this study not only examines the current situation, but also makes constructive suggestions to strengthen the diversification of policy objectives, particularly the promotion of scientific innovation objectives, and to balance the structure of policy tools in order to establish regular evaluation and feedback mechanisms to optimize higher education policies.

However, the study had certain drawbacks. Because the Chinese central government has only released rules on this area since 2021, there have been few comparable research in the past. The study's policy content is incomplete, as it lacks an international comparative viewpoint and addresses the issue of implementation regulations. These insights provide useful guidance and opportunities for improvement in future policy making and research.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CW: Writing–review and editing, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization. JC: Writing–original draft, Writing–review and editing, Conceptualization, Data curation, Formal Analysis, Methodology, Resources, Software.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Fostering sustainable development values among engineering students using Service-Learning

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In the majority of nations, environmental sustainability is an integral aspect of government policies, highlighting the criticality of equipping upcoming engineers with the necessary environmental awareness and skills to tackle this complex challenge. Higher education institutions assume a pivotal role in fulfilling this mission as their engineering programs aspire to generate graduates who possess the necessary competencies to effectively operate as “sustainable” engineers. Novel pedagogical methodologies, such as service learning, are currently being utilized to foster the cultivation of sustainable development values. Service-Learning represents a highly congruent approach to achieving Sustainable Development Goal (SDG) 4, insofar as it seamlessly integrates educational curricula with relevant community issues. As a result, it effectively contributes to the advancement of education for a sustainable future. This investigation sought to assess the impact of service learning projects developed in a rural school community on the boosting of social skills and environmental values among engineering students. The empirical evidence suggests that Service-Learning initiatives centered on environmental issues are efficacious in promoting the acquisition of social and environmental values among students. This, in turn, results in a positive transformation of their skill sets. Significantly, a substantial proportion of environmental engineering students who previously demonstrated a low awareness of these skills acknowledged their acquisition upon completion of the Service-Learning projects. Moreover, no less than 75% of the participants endorsed the attainment of each of the 11 competencies evaluated.

KEYWORDS

environmental sustainability, higher education institutions, Service-Learning, social and environmental values, environmental engineering, soft skills

1 Introduction

Higher education is widely recognized as a key driver in the global transition to environmental sustainability. As the world faces escalating environmental challenges such as climate change, resource depletion, and biodiversity loss, universities and other higher education institutions must prepare students to develop innovative solutions that address these issues. Engineering education is critical, as engineers are often at the forefront of designing technologies and systems that can mitigate environmental impacts.

The United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (quality education) and SDG 13 (climate action), underscore the importance of

integrating sustainability into all levels of education (Prieto-Jiménez et al., 2021). Higher education plays a pivotal role in advancing these goals by equipping students with the skills, knowledge, and values needed to lead in a sustainable future. Filho et al. (2015) argued that universities must move beyond traditional disciplinary boundaries and adopt a holistic approach to sustainability education, incorporating interdisciplinary learning, practical experience, and collaboration with communities. This is particularly important in engineering education, where students must learn to balance technical expertise with an understanding of environmental ethics and social responsibility.

The European Green Deal (European Commission, 2019) further emphasizes the role of education in achieving the EU's goal of a climate-neutral continent by 2050. As part of this ambitious agenda, the EU is calling for the transformation of educational systems to ensure that all students, particularly those in technical fields such as engineering, develop the competencies required to contribute to the transition to a sustainable Europe. This aligns with the broader global trend towards Education for Sustainable Development (ESD), which aims to empower students to make informed decisions and take responsible action for environmental integrity, economic viability, and social justice, as outlined by UNESCO (2017).

Despite the growing recognition of these imperatives, engineering programs still face significant barriers to fully integrating sustainability into their curricula. Traditionally, engineering education has focused primarily on technical problem-solving, often neglecting the social, ethical, and environmental dimensions of engineering practice. Tejedor et al. (2018) suggested that embedding sustainability into engineering curricula through innovative teaching methods, such as Service-Learning and project-based learning, can significantly enhance students' understanding of sustainability and their ability to apply it in real-world contexts.

Moreover, research highlights that environmental education can have a profound impact on students' attitudes and behaviors. Cloquell-Ballester et al. (2008) found that the more qualified individuals are about environmental issues, the greater their commitment to sustainable practices, both personally and professionally. This finding was echoed by Ali et al. (2022), who emphasized that firms benefit significantly when employees are environmentally conscious, leading to enhanced corporate social responsibility (CSR) and improved environmental outcomes. Boyle (1999) similarly argued that incorporating sustainability into higher education creates a ripple effect as graduates enter the workforce and apply their sustainability knowledge to various sectors, fostering broader societal change.

Incorporating sustainability-focused curricula into engineering education is not only crucial for preparing students to tackle environmental issues but also for ensuring their employability in a rapidly evolving job market. As industries increasingly prioritize sustainability, engineers with a deep understanding of environmental issues and sustainable practices are in high demand. According to Obrecht et al. (2022), the integration of sustainability into higher education is essential to producing graduates who can meet the environmental challenges of the 21st century. They argued that engineering programs must shift from traditional approaches to a more systemic perspective, where sustainability is embedded in every aspect of the curriculum from theory to practice.

1.1 Barriers to engineering education

Engineering university studies programs are focused on preparing competent environmental awareness professionals. However, these programs present the following two important barriers (Isaias and Issa, 2013).

1.1.1 First barrier: lack of practical experience in environmental issues

A primary challenge in engineering education is the lack of practical, real-world experience in addressing environmental concerns (Gómez Villarino et al., 2021). While theoretical case studies are commonly used, they often fall short of providing the hands-on experience necessary for students to fully develop the practical skills required in their future roles (Lehmann et al., 2008). This gap becomes particularly significant in the field of sustainability, where engineers are required not only to have technical proficiency but also the ability to implement environmental solutions in real-world contexts.

Service learning (SL) has emerged as a pedagogical approach that can effectively bridge this gap by immersing students in real-world sustainability challenges while simultaneously developing their technical and soft skills. Previous sustainability-oriented Service-Learning projects, such as rainwater harvesting systems (Salam et al., 2019), graywater treatment designs (Swargiary, 2023), and renewable energy installations (Roakes and Norris-Tirrell, 2000), have shown promise in equipping engineering students with hands-on experience. These projects reflect the students' engagement in practical environmental solutions, fostering not only technical competencies but also teamwork, leadership, and problem-solving abilities, which are often underdeveloped in traditional curricula.

However, while these projects demonstrate success in providing practical learning experiences, they also reveal challenges such as the need for sustained mentorship, alignment with community needs, and integration within the academic curriculum to ensure continuity and deeper learning outcomes (Salam et al., 2019). Despite these challenges, service learning remains an adequate solution to overcome the lack of practical experience in engineering education. Students gain the opportunity to apply theoretical knowledge to tangible environmental problems by embedding these projects within the core engineering curriculum.

1.1.2 Second barrier: development of soft skills

Another significant barrier is the lack of development of soft skills, which are crucial for engineers working on complex, multidisciplinary projects that involve both technical and interpersonal challenges (Vukomanović et al., 2016). These soft skills, often referred to as "people-focused competencies," include leadership, self-management, and self-reflection; negotiation, integrity, and reliability; conflict and crisis management; results orientation, personal communication, teamwork, engagement, and relationships; and resourcefulness (Souza et al., 2022). The lack of these skills, such as leadership, teamwork, and communication, presents a significant challenge for engineering graduates entering the workforce (Caeiro-Rodríguez et al., 2021). Future engineers will need to possess a full range of these soft skills teams to successfully tackle complex technical challenges, create a more sustainable world, and work effectively in multicultural and multidisciplinary teams (Cukierman and Palmieri, 2014). The role of a modern leader is increasingly strategic and qualitative, rather than

quantitative, emphasizing the importance of delegation, conflict management, problem solving, interpersonal relationships, and political skills (Tan, 1997). Engineering roles now require a balance of both hard and soft skills (Mateo et al., 2017). The importance of soft skills in engineering is essential to achieve success in environmentally sustainable development (Azim et al., 2010).

1.1.3 SL as a solution

SL is a pedagogical approach that integrates community service with academic learning, facilitating the development of both technical (hard) and interpersonal (soft) skills (Hart, 2021; Johnson and Notah, 1999). The method is based on the experiential learning cycle proposed by Kolb in 1984, which encompasses four stages, specifically concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 2014). Scholars have widely adopted this model as a theoretical framework for incorporating SL into course curricula (Roakes and Norris-Tirrell, 2000).

SL is frequently used as a pedagogical strategy to enhance student learning outcomes, such as critical thinking and problem-solving skills in higher skills (Astin, 2012; Castro et al., 2020). According to Bringle and Hatcher (1995), SL effectively connects classroom learning with real-world experiences, addresses community needs, and fosters relationships between college students and the community (Bringle and Hatcher, 1995, 1996).

The SL methodology typically involves three main components: preparation, action, and reflection. The preparation phase involves identifying community needs, setting learning goals, and preparing students for their service experience (Eyler and Giles, 1999; Kupietz et al., 2023). The action phase allows students to engage in community service, providing practical, hands-on experiences that enable them to apply classroom knowledge. Finally, the reflection phase requires students to critically assess their experiences and connect them to their academic learning (Brenner et al., 2023; Eyler and Giles, 1999; Jacoby, 1996).

SL can be applied across various disciplines, including education, business, engineering, social work, and health sciences (Salam et al., 2019). In these fields, SL offers students the opportunity to apply theories, concepts, and skills learned in the classroom to real-world situations (Astin, 2012). Furthermore, SL promotes the development of leadership skills, cultural competency, and a sense of civic responsibility among students (Bridgeland et al., 2006).

SL emerges as a promising solution to solve the barriers, offering students opportunities to engage with real-world environmental challenges through structured, community-based projects.

In the field of engineering, SL is particularly valuable for addressing environmental challenges such as water and air pollution, waste management, and climate change. A specific example in environmental engineering includes the design and implementation of sustainable infrastructure projects, such as rainwater harvesting systems, graywater treatment systems, and renewable energy systems (Salam et al., 2019). These projects not only provide students with hands-on experience in environmental problem solving but also directly address specific environmental needs within the community.

Integrating SL into the engineering curriculum can effectively bridge the gap between technical knowledge and the development of critical soft skills. As Keen and Hall (2009) suggested, involving students in real-world projects aimed at external clients is a powerful approach to achieving this goal.

The impact of SL is significant for both students and communities. For students, SL increases motivation and engagement, improves academic performance, and enhances critical thinking and problem-solving abilities (Lin et al., 2022). Research by Celio et al. (2011) highlighted that students involved in SL programs show notable improvements in self-esteem, perceptions of education, community involvement, interpersonal skills, and academic achievements (Celio et al., 2011). For communities, SL provides essential volunteer support, addresses unmet needs, and promotes overall community development, while also fostering stronger relationships between higher education institutions and the communities they serve.

Consequently, our primary objective in this research is to demonstrate how SL serves as an effective methodology for involving university students in real-world environmental issues, thereby enhancing their soft skills and promoting environmentally sustainable development.

2 Materials and methods

2.1 SLP case studies

The School of Engineering of Agronomy, Foods, and Biosystems trains future engineers through Bachelor of Engineering (B Eng.) degrees in Environmental Engineering, Agricultural Engineering, and Food Engineering. Specifically, students are trained in subjects such as environmental impact assessment (EIA), environmental engineering projects (EEPs), or environmental management systems (EMSs). These subjects emphasize the development of competencies linked to environmentally sustainable development. These soft skills must be developed by students during their coursework. Although theoretical environmental cases are often presented to simulate real professional experiences, they primarily serve as theoretical instruments that facilitate the practice of scientific and technical content. Consequently, it can be difficult for students to effectively develop their soft skills (Caeiro-Rodríguez et al., 2021).

Two SL projects (SLPs) were developed as the practical part of the EIA, EMS, and EEP courses. The SLP design was crucial, as they needed to offer students a compelling context for understanding environmental sciences. This included opportunities for team experience, sufficient time to learn and practice soft skills, personalized mentoring, exciting technical challenges, and robust community learning experiences (Coyle et al., 2005). These environmental experiences were carried out at the rural school named Isabel La Católica (ISCA), located in a rural region of Spain. The SLPs were agreed upon and articulated together with the external stakeholders, ISCA, and the municipality. A university professor was the coordinator of both SLPs and they were funded by the University Polytechnic of Madrid (UPM). SLPs were carried out in 2021 and 2022. Table 1 shows the link among the B Eng Grades, subjects, and SLPs that were achieved.

2.1.1 Case 1: Ecocole 2030 project: "the path to a sustainable school" (ECO2030)

ECO2030 was the first SLP among UPM, ISCA, and the municipal government. The SLP consisted of designing and implementing an EMS for the primary education services in ISCA. Fourth- and third-year students of Agro-environmental Engineering Grade and Food

TABLE 1 Links among B Eng. grades, academic subjects, and Service-Learning projects.

B Eng. grade	Semester	Subject	Year	Service-Learning Projects
Agro-environmental engineering	8th	Environmental Management Systems	2021	Ecocole 2030 Project: The path to a sustainable “school”
Food engineering	6th	Environmental impacts assessment	2021	Ecocole 2030 Project: The path to a sustainable “school”
Agro-environmental engineering	7th	Environmental Engineering Projects	2022	StormTank: Collection and use of rainwater for irrigation of educational organic gardens

Engineering Grade developed this SLP as a practical part of the EIA and EMS subjects.

The students applied the technical methodology based on school data collection, mass and energy balance analysis, current situation diagnosis, identification of environmental aspects and impacts, and proposal of correction measures for environmental improvement. Furthermore, the implementation of environmental policies and objectives and its link with the Agenda 2030 and the SDG were studied. The students designed and implemented the EMS with a scope aimed at the educational management processes of the school. For 2 months, the students performed the following seven tasks: Facilitate the implementation of the environmental policy and environmental objectives, identify and quantify the environmental aspects of the educational management processes, determine the environmental impacts linked to the identified environmental aspects, identify the applicable environmental legislation, propose corrective measures to minimize severe environmental impacts, complete an environmental training program for school staff, and create a document system for the school's environmental management system.

In addition, the documents made for this environmental service were used by the professors to evaluate the practical work of the EMS subject. Students worked in five-member teams, and they had to deliver an EMS document system as a final product of their practical work.

At the same time, the student teams carried out a dissemination program about the results and corrective measures proposed in the EMS. To this end, they prepared and developed three workshops aimed at pupils in third, fourth, and fifth grade in May 2020. The design, realization, and pedagogical adaptation of the content of the workshops aimed at primary school pupils had the lead and advice of the teachers and the school director. These environmental education workshops helped increase pupils' knowledge of environmental issues and enhanced their pro-environmental attitudes (Kurokawa et al., 2023).

2.1.2 Case 2: StormTank project: “collection and use of rainwater for irrigation of educational organic gardens” (STORM)

STORM was the second SLP and consisted of the optimized design, construction, and commissioning of a 1,000-liter (1 m³) tank to collect rainwater from the roof of the building of the kindergarten adjacent to the educational organic garden of the ISCA. The collected rainwater was used to irrigate the educational organic garden during the spring and summer seasons by connecting it to the installed drip system. This installation helped the schoolteachers in their practical natural sciences classes. Biology, ecology, and environmental

awareness are the primary school subjects that benefit from the irrigation system carried out in the ecological gardens and the cultivation programming for the gardens developed by the university students. This SLP was a practical work in the EEP subject where the students learned the methodology of environmental engineering project formulation. Specifically, the students worked on the following five items: objectives, strategic alternatives, and goals; environmental project engineering (process engineering, design engineering, engineering of edification, infrastructure, and facilities); formulation; implementation and start-up plan; and budgeting.

University students designed a project consisting of a 1,000-liter water tank connected to the roof skirt of one of the buildings of the ISCA. In addition, the students prepared a Process Engineering, Implementation, and Start-up Report that included the design of the tank and all the components to implement an alternative organic garden for the winter period and/or the summer period.

These organic garden alternatives were designed according to the monthly average rainfall to irrigate only using the water stored in the tank.

The water tank installation and its roof connection were built by the municipality operators. Finally, the students developed three workshops to divulge the project among the school pupils. These workshops generated a school extracurricular activity for the management and reuse of water and its link with Sustainable Development Goal 6 to Ensure the availability and sustainable management of water and sanitation for all of Agenda 2030 (United Nations General Assembly, 2015).

2.2 Evaluation of SLP case studies

2.2.1 Data collection

Data collection was conducted using a pre-and post-survey methodology to measure students' self-perceived development of soft skills and environmental awareness. The surveys were administered at two time points: once at the beginning of the SL projects (before the students commenced their work) and again after the projects. A total of 75 students participated, with 61 students from the EMS course surveyed during the first semester of 2021 and 14 students from the EEP course surveyed during the second semester of 2022.

The surveys were distributed through the UPM Moodle Learning Management System (Moodle 4.0. Australia: Moodle Pty Ltd.), which is a digital platform for course delivery. The pre-survey was administered to gather baseline data on students' existing soft skills and environmental awareness, while the post-survey was used to evaluate any changes in these areas after the completion of the SLPs.

Both surveys had a 100% response rate, ensuring that all participants' data were collected and analyzed.

2.2.2 Survey design and reliability testing

The survey consisted of two main sections. The first section comprised five dichotomous (yes/no) questions designed to measure students' general perceptions about SL and its influence on their environmental awareness. These questions were administered at the last time point, after the SLP was achieved, to assess students' environmental commitment and understanding of sustainability. The questions are listed in Table 2.

The second section focused on assessing students' self-perceptions of their soft skills development. A total of 11 items were adapted from established scientific studies on soft skills (Aliu and Aigbavboa, 2021; Cimatti, 2016; Crosbie, 2005; Dixon et al., 2010; Munir, 2022; Schulz, 2007; Sparrow, 2018). The questions focused on various soft skills, including adaptability, capacity for concentration, creativity and imagination, effort, and emotional control. Respect and self-confidence were also emphasized, as they are critical for engineering students engaging in sustainability-oriented projects. These questions were administered at both time points (before and after the SLP) to assess shifts in students' self-perceptions of soft skills development. Case 1 questionnaires were given in the first semester of 2021, and case 2 questionnaires were given in the second semester of 2022. The response rate was 100%.

We opted to use a single-item measure for each of the 11 soft skills assessed. While it is widely recognized that multi-item scales are often preferable for measuring complex constructs (Hair et al., 2019; Hair et al., 2010), single-item measures are not uncommon in educational research, especially when the constructs are simple and clearly defined

(Bergkvist and Rossiter, 2007). There is substantial evidence in the literature supporting the validity and reliability of single-item measures in certain contexts. For instance, Bergkvist and Rossiter (2007) demonstrated that single-item scales can achieve a level of predictive validity comparable to that of multi-item scales (Bergkvist and Rossiter, 2007), and previous studies in educational and social research have demonstrated that single-item measures can still yield valuable insights when evaluating skills or competencies (Croes and Bartels, 2021; Postmes et al., 2013; Reysen et al., 2013). The decision to use single-item measures was driven by several practical and methodological considerations:

- **Clear and Unambiguous Constructs:** The soft skills assessed in this study, such as effort, creativity and imagination, adaptability, or respect, are relatively well understood by students. These skills are commonly integrated into the curriculum and are familiar concepts in the field of engineering education. Research has shown that when constructs are unidimensional and clearly defined, a single-item measure can be as effective as a multi-item scale (Diamantopoulos et al., 2012; Sarstedt et al., 2016). The ability of students to reflect on their proficiency in these areas made single-item measures an appropriate choice.
- **Minimizing Participant Burden:** The context of the study cases study, in which students were engaged in SLPs in addition to their academic coursework, posed a unique challenge in terms of the time and effort required to complete the survey. Single-item measures reduced the cognitive load on participants, thus encouraging full participation and minimizing dropout rates. Research has shown that the use of single-item scales can lead to higher response rates in educational settings, particularly when participants are already managing multiple demands (Orben and Przybylski, 2019; Orth et al., 2018; Robins et al., 2001).
- **Balancing Brevity and Precision:** In educational assessments, there is often a trade-off between brevity and precision. While multi-item scales provide more detailed data, they can also lead to participant fatigue and increased non-response for longer surveys. Given the practical constraints of this study, we opted for brevity to maintain a high level of engagement from students, while ensuring that the core constructs were captured in a meaningful way. This approach has been validated in studies where time efficiency is paramount and the constructs are not overly complex (Diamantopoulos et al., 2012).

Responses in this section were recorded using a 4-point Likert scale ranging from "Not at all agree" (1) to "Strongly agree" (4). Although a 5-point Likert scale is typically recommended for surveys (Abascal and Grande, 2005), we opted for a 4-point Likert scale to eliminate the neutral option and force respondents to take a more definitive stance (Allen and Seaman, 2007; Wakita et al., 2012). Table 3 shows the skills and their explanations that were assessed in each of the questions. Each question is linked with a quantitative variable (VARQ_n, with n = 1 to 11) for statistical calculations.

Reliability testing was conducted on the two SLP case studies using Cronbach's alpha to measure internal consistency. A Cronbach's alpha score of 0.68 for case 1 and 0.71 for case 2 indicated an acceptable level of reliability for the items (Mallery and George, 2000). Additionally, factor analysis was used to ensure that the survey items accurately measured the intended constructs, confirming the validity

TABLE 2 Questions and results about students' opinions regarding their SL work experience and their commitment to the environment and sustainable development at the end of the SLP.

Questions	No (%)	Yes (%)
Have you previously taken a subject with a service learning experience?	88	12
Have you felt comfortable working in a genuine experience in a rural community?	15	85
Has your environmental commitment increased after this community service experience?	18	82
Has the Service-Learning project helped you to better understand environmentally sustainable development?	21	79
Do you regard the Service-Learning approach as a fundamental element in your individual development as a prospective "sustainable" engineer dedicated to the principles of sustainable development?	22	78

TABLE 3 Skills evaluated in each question.

Variable (VARQ _n) Soft professional skill	Explanation (as in questionnaire)
VARQ ₁ . Creativity and imagination	I can generate ideas, answers, and innovative and alternative proposals in relation to tasks and group work mainly related to planning and management of the environment and sustainable development.
VARQ ₂ . Self-confidence	I am confident in my own abilities to solve challenges regarding the environment and sustainable development. I discover my own capabilities, and it helps me to have confidence in myself.
VARQ ₃ . Concentration	I know how to keep my attention long enough to perform a task.
VARQ ₄ . Resilience	I know how to manage adversity and difficulties, with the ability to resist.
VARQ ₅ . Emotional control	I recognize and regulate my own emotions to properly adjust them to the needs of the moment and context, especially when I work with local communities.
VARQ ₆ . Effort	I insist on overcoming difficulties to achieve the intended achievements. This competence covers your physical, psychological, cognitive, and sociological aspects.
VARQ ₇ . Assertiveness	I know how to express my feelings, emotions, or thoughts freely and safely, without denying the rights of others and without others feeling attacked or manipulated.
VARQ ₈ . Adaptability	I adapt to any context, relationship, or situation in a positive way. Condition that allows me to accept and accommodate change, especially when I work with local communities.
VARQ ₉ . Empathy	I know how to perceive and understand the behavior, emotions, and feelings of another person group of people, group, or community.
VARQ ₁₀ . Respect	I have consideration for others according to their characteristics and personal and social situations.
VARQ ₁₁ . Self-criticism	I am willing to receive suggestions, ideas, evaluations, and criticism. I can self-analyze and recognize my own mistakes and limitations.

of the scale (Field, 2024). Responses were matched using unique student identifiers to ensure consistency and comparability between the pre-surveys and post-surveys, allowing for accurate tracking of changes in self-perception between the two time points.

2.2.3 Data analysis

The data analysis was performed using IBM SPSS Statistics (IBM Corp. 2020. IBM SPSS Statistics v 27.0. Armonk, NY, United States: IBM Corp.). (v. 27.0, IBM Corp., Armonk, NY, United States). Descriptive statistics, including frequencies, medians, and interquartile ranges (IQRs), were calculated for both the pre-survey and post-survey responses. The results were visualized using box plots to represent the distribution of scores before and after the SLPs. Non-parametric tests were used. Spearman's correlation coefficient and Kendall's Tau coefficient were calculated to assess relationships between students' soft skills and environmental values, with a significance level of $p < 0.01$ (Artusi et al., 2002) to explore correlations between variables.

The Yes/No questions from the first section of the survey were analyzed by calculating the percentage of positive and negative responses at both time points. Comparisons were made to determine any shifts in students' perceptions of SL and environmental commitment after participating in the SLPs.

2.2.4 Hypotheses

The main hypotheses evaluated in this study were hypothesis 1: "SL is an effective methodology for involving university students in real-world environmental issues," and hypothesis 2: "SL projects significantly enhance students' self-perception of their soft skills, which are critical for future work in promoting environmentally sustainable development."

3 Results

It is important to note that 88% of the students had not previously participated in a course that implemented an SL experience. This confirms the limited application of SL in the pedagogical approach of engineering studies, making it an innovative and relatively unfamiliar methodology. As such, the integration of SL has proven to be beneficial for students and should be further expanded to other subjects to promote the development of critical competencies that enhance environmental awareness. The results of the first section of the questionnaire are displayed in Table 2, which includes data collected after the SL project.

The second section of the questionnaire focused on the students' perceptions of their soft skills development. The analysis included the calculation of the median and interquartile range (IQR) for each variable (VARQ_n), representing each soft skill, in both study cases (pre- and post-SL). The Kolmogorov–Smirnov test was used to assess the normality of each variable's distribution, with the null hypothesis being that the distribution of VARQ_n is normal with the mean \bar{X}_n and standard deviation σ_n . For all variables in both study cases, the null hypothesis was rejected, indicating that the variables follow a non-parametric distribution.

The data were compared to evaluate the students' self-perception before and after the project to assess the impact of the SL project on soft skills development. The results in Table 4 provide a detailed analysis of the self-perception of soft skills in the two cases, Ecocole (case 1) and StormTank (case 2), before and after the Service-Learning project (SLP). Overall, the analysis reveals that 7 out of the 11 soft skills showed no change in their median and interquartile range (IQR) values, indicating consistent perceptions before and after the SLP.

TABLE 4 Median and IR results for cases 1 and 2 before and after environmental service.

Variables VARQ _n	Case 1. Ecocole					Case 2. StormTank				
	Median	Median	IR Q25– Q27	IR Q25– Q27	IR Q25– Q27	Median	Median	IR Q25– Q27	IR Q25– Q27	IR Q25– Q27
	Before	After	Before	After	Change	Before	After	Before	After	Change
Creativity and imagination	3	3	[2–3]	[3–4]	Yes	3	3	[2–4]	[3–4]	Yes
Self-confidence	3	3	[3]	[3–4]	Yes	3	3	[2–3]	[3–4]	Yes
Capacity of concentration	3	3	[2–3]	[2–4]	Yes	3	3	[2–3]	[3–4]	Yes
Resilience	3	3	[3]	[3–4]	Yes	3	3	[2–4]	[3–4]	Yes
Emotional control	3	4	[3–4]	[3–4]	No	3	3	[2–3]	[3–4]	Yes
Effort	3	3	[3]	[3–4]	Yes	3	4	[3]	[3–4]	Yes
Assertiveness	3	3	[3–4]	[3–4]	No	3	3	[3–4]	[3–4]	No
Adaptability	4	4	[3–4]	[3–4]	No	3	3	[3]	[3–4]	Yes
Empathy	4	4	[3–4]	[3–4]	No	4	4	[3–4]	[3–4]	No
Respect	3	4	[3–4]	[4]	Yes	4	4	[4]	[3–4]	Yes
Self-criticism	3	3	[3]	[3–4]	Yes	3	3	[3–4]	[3–4]	Yes

Three soft skills demonstrated changes in the median but maintained the same IQR, suggesting that while overall perceptions improved, the distribution of responses remained stable. One skill exhibited the same median but a shift in the IQR, pointing to increased variation in self-perception among the students.

For soft skills such as creativity and imagination, self-confidence, capacity of concentration, and resilience, both cases reported consistent medians and IQRs before and after the SLPs. The students' perceptions of these skills remained stable, as reflected by their scores on the Likert scale. In contrast, emotional control showed a notable improvement in Ecocole, where the median increased from 3 ("Agree") to 4 ("Strongly agree"), signaling a significant boost in students' self-perception of emotional control. However, in StormTank, the median remained the same, but the IQR expanded.

Respect also improved in Ecocole, with the median shifting from 3 to 4, indicating a stronger self-perception of this skill post-SLP. In StormTank, effort saw an increase in the median from 3 to 4, suggesting improvement in students' efforts after the project. Other skills such as assertiveness, empathy, and self-criticism remained constant in both cases, with no significant changes in median or IQR values, showing no major shifts in these areas.

These results highlight that, while many soft skills remained stable across both cases, certain skills such as emotional control, respect, and effort experienced notable improvements, particularly in Ecocole. The increase in IQR for some skills suggests that while the overall median perception of the group did not change, individual responses varied, indicating different personal experiences of the SLP.

The correlations between the variables related to the 11 soft skills were analyzed using Spearman's correlation coefficient (ρ) and Kendall's Tau coefficient (τ), with a significance level of $p < 0.01$ (Akoglu, 2018). Table 5 presents the results of Spearman's correlation coefficient (ρ) and Kendall's Tau coefficient (τ), which were used to examine the relationships between the soft skills measured before and

after the SLP. These coefficients assess both the strength and direction of the associations between the variables (e.g., adaptability, creativity and imagination, effort, and self-confidence), offering insight into how these skills are interrelated. The analysis was conducted at a significance level of $p < 0.01$, meaning that correlations were considered statistically significant if there was less than a 1% chance that the observed relationships occurred by random chance. Each pair of soft skills was compared to determine if improvements in one skill were associated with improvements in another. For example, if students who reported an increase in creativity and imagination also reported an increase in assertiveness, this would result in a positive correlation between these two variables.

All of the pairs of professional skills reported in the table show statistically significant correlations, meaning that there are meaningful relationships between these skills. For example, skills such as self-confidence and emotional control exhibited a high positive correlation, indicating that students who improved in one of these areas also tended to improve in the other.

4 Discussion

The SL methodology effectively engaged students in community service activities while simultaneously integrating academic learning. The data collected from the student self-report surveys indicated that hypothesis 1 was supported. Students found SL to be an engaging and effective way to apply their theoretical knowledge to real-world sustainability problems. The novelty of the approach, given that 88% of the students had no prior experience with SL, underscores its potential for enhancing engagement in engineering education. In terms of hypothesis 2, the analysis of the pre-and post-SLP data does not allow for the matching of individual student responses, so the conclusions of this study should

TABLE 5 Spearman’s correlation coefficient (ρ) and Kendall’s Tau coefficient (τ) for VARQ_n at a significance level of $p < 0.01$.

Correlated variables VARQ _n significance level $p < 0.01$	τ	ρ
Case 1 Ecocole		
Creativity and Imagination— Self-confidence	0.590	0.612
Creativity and Imagination— Effort	0.523	0.555
Creativity and Imagination— Assertiveness	0.709	0.793
Self-confidence—Resilience	0.552	0.598
Self-confidence—Emotional control	0.681	0.769
Self-confidence—Effort	0.513	0.547
Self-confidence—Assertiveness	0.593	0.619
Self-confidence—Adaptability	–	0.529
Capacity of concentration— Respect	0.519	0.550
Resilience—Emotional control	–	0.544
Emotional control—Adaptability	0.571	0.620
Assertiveness—Empathy	0.575	0.614
Adaptability—Empathy	0.588	0.617
Adaptability—Respect	0.553	0.570
Empathy—Respect	0.608	0.627
Case 2 StormTank		
Empathy—Resilience	–	0.714
Empathy—Self-criticism	–	0.852

be interpreted within the framework of a correlational rather than a causal analysis.

This means that we cannot assert that participation in the SLP directly caused the observed changes in students’ self-perceptions of soft skills. However, the results indicate a positive relationship between participation in the SLP and improvements in self-perceptions of several key competencies. A significant association was found between participation in the SLP and an increase in perceptions of skills like creativity and imagination, self-confidence, concentration, and effort.

While these findings suggest that the SLP may be linked to the development of these skills, we cannot confirm that the SL was the sole factor responsible for these changes. Specifically, students’ self-perceptions of 10 out of the 11 evaluated competencies showed significant improvement, with more than 75% of participants reporting positive development in essential skills. These results suggest that the SLP may have provided students with a practical context in which to apply their academic knowledge, which in turn appears to be associated with improvements in their perceptions of professional skills. However, due to the correlational nature of the analysis, this association should not be interpreted as evidence of causality.

Our findings show that SL was perceived as an effective method for the value of experiential learning. Kolb’s (1984) experiential

learning theory emphasized that learning is most effective when students can apply theory to practice in real-world contexts (Kolb, 1984). SL provides this opportunity by allowing students to work directly with communities to solve environmental problems.

Our focus was on students’ perceptions of their engagement and skill development. Future research could benefit from incorporating measures of environmental behavior to assess whether the increased engagement observed in SL projects translates into long-term actions. Additionally, our findings resonate with studies that highlight the value of community-based learning in enhancing students’ understanding of complex social and environmental challenges. Eyler and Giles (1999) argued that SL not only deepens students’ understanding of course content but also helps them develop a more profound connection to the community, fostering a sense of responsibility and civic engagement (Eyler and Giles, 1999). In our study, students worked with rural school communities, which likely helped them understand the real-world implications of sustainability and environmental protection.

The significant improvements in students’ self-perceived soft skills, as seen in our findings, align with previous research showing that SL projects enhance critical professional competencies. Marshall et al. (2015) found that students who participated in SL reported higher levels of confidence in applying their knowledge to practical problems, which in turn improved their leadership, teamwork, and communication skills (Marshall et al., 2015).

This is consistent with Barth et al. (2014), who highlighted the role of SL in developing not only academic skills but also soft skills, such as critical thinking, problem solving, and empathy. In sustainability education competencies (Barth et al., 2014). These skills are crucial because they enable students to collaborate effectively across varied environmental disciplines and with different stakeholders. Our study’s findings that students felt more competent in these areas after participating in SL support the thesis that SL bridges the gap between theoretical knowledge and practical application.

Moreover, Bowie and Cassim (2016) also found that SL helps students develop a more holistic understanding of their professional responsibilities and competencies. Students can see how their technical skills can be applied to solve societal problems by working on real-world projects, which enhances their sense of civic responsibility. Our findings mirror this, as students reported a stronger sense of purpose and engagement with community-focused solutions.

Our findings are in line with a growing body of literature that highlights the importance of integrating sustainability into engineering curricula. Nikolić and Vukić (2021) argued that sustainability education is essential for preparing engineers to tackle the complex environmental challenges of the future. They advocated for a curriculum that not only teaches technical knowledge, but also emphasizes the development of skills such as collaboration, leadership, and ethical responsibility. Our study supports this approach, as the SL projects gave students practical experience while fostering these critical soft skills.

Similarly, Salam et al. (2019) found that SL can lead to positive outcomes for all stakeholders involved—students, faculty, and community members (Salam et al., 2019). In our research, students gained practical experience in environmental management, while the rural school communities benefited from the implementation of

sustainable solutions. This symbiotic relationship underscores the potential for SL to generate mutually beneficial outcomes, as highlighted by Roakes and Norris-Tirrell (2000), who showed that SL projects often result in lasting improvements for both students and the communities they serve.

The findings of our research have significant implications for engineering education. First, the positive effects of SL on student engagement and skill development suggest that SL should be integrated more broadly into engineering programs. By embedding SL into the curriculum, educators can provide students with opportunities to apply their academic knowledge to real-world problems, which enhances both their technical and professional skills.

Additionally, the development of soft skills is crucial for engineers working on sustainability projects. These skills enable engineers to work effectively with diverse teams, including community members, policymakers, and other stakeholders. Given the interdisciplinary nature of sustainability challenges, the ability to collaborate across sectors is becoming increasingly important. As such, SL can help prepare future engineers for leadership roles in sustainability by providing them with the competencies they need to navigate complex, multi-stakeholder environments.

Furthermore, this study underscores the importance of community engagement in sustainability education. Students gain a deeper understanding of the social dimensions of environmental challenges as they work directly with communities. This aligns with Eyler and Giles (1999), who found that SL projects enhance students' sense of civic responsibility by connecting them with real-world problems that require practical solutions. Engineering programs should therefore seek to build partnerships with local organizations to create meaningful, community-based learning opportunities for their students.

4.1 Limitations

While our research offers valuable insights into the impact of SL on engineering students, it is important to acknowledge several limitations. First, the research relied solely on self-reported survey data, which may introduce bias, as students may overestimate or underestimate their development in certain competencies. To address this limitation, future studies could incorporate additional methods such as interviews or focus groups to provide a more in-depth understanding of students' experiences and to triangulate the findings. Second, while we observed significant improvements in students' soft skills, the study did not include direct measures of environmental awareness or behavior change. Although we suggest that the development of soft skills may contribute to future environmental protection efforts, future studies should explicitly measure these outcomes to better assess the long-term impact of SL on students' environmental values and actions. The third limitation of the study is the inability to pair individual student's pre-test and post-test responses for the same skill, which would have allowed for a more accurate assessment of changes using the Wilcoxon signed-rank test. Instead, we used Spearman's and Kendall's Tau correlations to explore the associations between soft skills variables. Future research should aim to track paired responses to better assess the changes in students' soft skills over time. Finally, the design of our study did not allow for

a direct comparison of different types of SLPs. Future research could explore whether the nature of the project (e.g., environmental vs. social) leads to different outcomes for students in terms of skill development and awareness. The relatively small sample size (75 students) limits the generalizability of the findings, and the short duration of this study limits the ability to assess the long-term impact of SL on students' competencies and sustainability practices.

5 Conclusion

The environment is becoming increasingly important in our society. Public institutions and private companies require future professionals who are committed to environmental respect and sustainable development.

It is the university's moral and social responsibility to facilitate the development of students who embody values aligned with the principles of environmental respect and sustainable development. To accomplish this objective, novel methodologies must be devised to help students cultivate these values and acquire the requisite competencies for their practical application.

SL is a valuable methodology that can be applied in higher education to enhance student learning outcomes and benefit communities. Through the integration of community service, academic instruction, and reflection, SL can provide students with opportunities to apply their knowledge, develop their skills and values, and contribute to their communities. In this context, SLPs contribute to Sustainable Development Goal 4 by promoting quality education for sustainable development. This is achieved by incorporating sustainability concepts and practices into the academic curriculum and by engaging students in community service activities that promote sustainable behaviors and values. By integrating these elements, SLPs help students to develop a deeper understanding of the interconnectedness of environmental, social, and economic systems and the importance of sustainable development in achieving global goals.

Further research endeavors can be conducted by using SLPs with local communities to address different areas of quality education. These may encompass human rights education, gender equality education, promotion of a culture of peace and non-violence, global citizenship, intercultural education, and inclusive education.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the

patients/participants or patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

JL-S: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. MF: Formal analysis, Methodology, Writing – review & editing. SZ-M: Supervision, Validation, Visualization, Writing – review & editing. LR-G: Methodology, Supervision, Validation, Writing – review & editing. MG-V: Methodology, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2024.1408896/full#supplementary-material>

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Navigating climate awareness in academia: a study of air travel attitudes among international students in Austria

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The urgent need to address climate change has prompted universities to reassess their impact on the environment, as the tension between academic internationalization and sustainability presents a complex challenge on multiple levels; including the organizations themselves, researchers or faculty, and students. The article explores the perceptions and attitudes of international students toward climate change, their personal environmental impact, and their perceptions of internationalization and mobility. To do so a qualitative case study was conducted in Austria (interview study; $n = 29$), including both bachelor's and master's program students. The study aimed to investigate the attitudes of international students toward air travel and identified five distinct types of students with varying levels of awareness and willingness to reflect on their personal impact on climate change. While some students prioritize their personal right to fly and gain experience, neglecting their contribution to climate change, others demonstrate a clear understanding of the need for change. The findings suggest that universities can play a key role in promoting environmental awareness by integrating climate change education into international study programs, providing transparent information about environmental impacts, and incentivizing sustainable mobility. Our aim is to contribute to the ongoing discussions regarding the intersection of higher education, internationalization, and climate change. We emphasize the need for significant institutional changes to address the complexities involved.

KEYWORDS

internationalization, higher education, attitude-behavior gap, travel behavior, climate change awareness, qualitative typology, case study research, Austria

1 Introduction—the complicated relationship between climate change, internationalization in academia and higher education

Do international students recognize their contributions to climate change and are they acting climate change-aware overall? The answer should be clear, as the effects of human-induced climate change have led to a wide range of increasingly catastrophic events and scientific consensus is that mankind needs to limit its emission of CO² (Gössling and Dolnicar, 2023). However, overall, the situation is much more complicated, as academics and students are expected to be *hypermobile* (Arsenault et al., 2019) and international mobility is often seen as beneficial to students, with positive effects of student mobility even being discussed at country level (Shields and Lu, 2023). And this mobility depends very often on air travel or other forms of carbon dioxide intense forms of transportation. This creates a somewhat paradox situation, both on a normative as well as behavioral level, as students now need to

navigate two competing demands; limiting the effect one has on climate change and the necessity of academic mobility.

When dealing with this paradox situation, the first more general point to discuss lies with the aspect of climate change. Here it can be argued that the UN are urging nations around the world to take substantive action to combat climate change (Pörtner et al., 2022). This call to action is based on decades of academic research, with more than 196 countries pledging themselves to honor the Paris Agreement to limit global warming (Nunez et al., 2019). Nevertheless, up until now political actual actions are limited and full of compromises (Nunez et al., 2019). As a result, it is expected that research and higher education institutions must increase their awareness and strengthen their efforts to combat the climate crisis (Borgermann et al., 2022).

This brings us closer to academia: Despite this dire global situation, the position of universities and higher education institutions is not straightforward at all (Shields, 2024). As stated before, from a normative perspective, internationalization and mobility are considered essential for academic excellence (Altbach, 2009; Arsenault et al., 2019) and is expected from faculty as well as students. Consequently, many universities and research institutions aim to attract a diverse range of international scholars, researchers and students (Uzhegova and Baik, 2022), and they actively organize events such as conferences, research stays, staff and student exchanges, and international study programs (Nurse-Bray et al., 2019). Most of these activities depend on extensive travel, often via heavily greenhouse gas-emitting planes (Arsenault et al., 2019; Shields and Lu, 2023). This tension between academic internationalization and climate change has resulted in a widespread discussion in the international higher education community, which influences several levels, that affect the organizations, the faculty as well as the students (Attari et al., 2016; Arsenault et al., 2019).

At the organizational level, research and educational institutions are reassessing their ecological impact, taking steps to reduce it, and try to act as role models when it comes to sustainability (Eskander and Istiak, 2022; Filho et al., 2022). Many universities have established guidelines to evaluate and restrict staff travel, substituting on-site events with virtual or hybrid ones, and fostering the creation of an environment that allows for more decentralized research (Filho et al., 2022; Nikula et al., 2022). However, internationalization is still a central goal of higher education institutions and part of their efforts to position themselves in a competitive landscape (Shields, 2024).

When it comes to faculty, the scientific community recognizes the impact of their intensive travels and saw the COVID-19 pandemic as an opportunity to establish a new normal, permanently cutting back on travel and greenhouse gas emissions (Kreil, 2021; Filho et al., 2022). However, individual scholars still report that they are afraid of potential competitive disadvantages if they are not mobile and perceive air travel as intricately tied to doing their work “well” (Kreil, 2021, p. 60).

For students, the situation is somewhat similar problematic, but even more pronounced. While many students are “demanding action, as evident in the agendas and activities of groups such as *Students Organising for Sustainability International* in the UK, the *Young Academy* in the Netherlands, and the Erasmus Student Network in Europe” (Nikula et al., 2022, p. 2), recent surveys indicate that international students, in particular, do not explicitly care about the environmental impact of their travel and greenhouse gas emission. For

example, only about 5.5% of Erasmus students engage in sustainable behavior during their international travels, according to a report by Green Erasmus (2022, p. 26). This supports previous research suggesting that despite the rapid pace of climate change and the potential catastrophes it may bring in the future, many international students view global travel and study abroad experiences as a right rather than a privilege (Reilly and Senders, 2009; Shahjahan and Edwards, 2022).

These findings highlight that tensions between internationalizing higher education and tackling climate change exist at both organizational as well as individual levels and at both levels there are discrepancies and paradoxes (Nikula et al., 2022, p. 6). In the academic field in particular, awareness of climate change is seen as rather high, but this does not consistently translate into a reduction in air travel. At the organizational level, there’s a conflict between the aspiration to act as a role model and develop strategies to make universities more sustainable, and the demand for internationalization, together with the socio-professional norm of academic travel in the pursuit of excellence in science. At the individual level, there are societal norms in favor of greenhouse gas emission reduction that are prevalent among highly educated individuals, but these norms conflict with competition in academia and concerns about career disadvantages. Among scientists and students, there are parallels, but there are also differences in perception. Therefore, this paper aims to add to this field of research and address the current research gap in international students’ awareness of their contributions to climate change and their corresponding behavior. It is necessary to explore international students’ views on climate change, their responsibility with respect to the climate, and how they perceive their academic and non-academic travels in this context.

To gain a deeper understanding of this complex issue, a qualitative case study was conducted in Austria during the winter semester of 2022/2023, focusing on two groups of international students—one attending a bachelor’s program at the *Johannes Kepler University of Linz* and one a master’s program at the *Paris Lodron University of Salzburg*, that will be presented in article. The second section will provide a short discussion about the state of the research in the field, before section three outlines the study design used, describes the sample in detail, and gives insight into methodology used for analysis. The fourth section will present the empirical findings and provide an in-depth analysis of the data, highlighting the different types of students that could be identified in the case study. The article will conclude by drawing relevant conclusions and offering recommendations on how international study programs may address climate change education and foster an environment that encourages students to be more aware and conscious of their actions in an international setting.

2 State of knowledge and current discussion

In response to the urgent issue of climate change, and partly as a consequence of the flight shame debate, the academic community has initiated a self-reflection process on its greenhouse gas emissions (see, e.g., Nevins, 2014; Attari et al., 2016). Numerous universities are implementing policies to reduce their environmental impact, and research shows that scientists are increasingly mindful of their

international travel (Eskander and Istiak, 2022; Filho et al., 2022). Nevertheless, contradictory routines, actions and argumentation patterns are evident at both organizational and individual levels.

Beyond their traditional role of disseminating knowledge, universities also have a social responsibility in the fight against climate change. This is particularly important as they act as multipliers, training as well as influencing future leaders and policy makers (Eskander and Istiak, 2022, p. 27). As key players, universities have the potential to influence individuals' decision making toward sustainability (Filho et al., 2022, p. 1) and should therefore generally act as role models (Nurse-Bray et al., 2019, p. 15). Many universities have already defined strategies for sustainable development. But in these sustainability guidelines, the topic of air travel is not always explicitly addressed, and concrete measures to reduce air travel are often lacking (Eskander and Istiak, 2022; Nurse-Bray et al., 2019). Moreover, the long-established socio-professional norm of internationalization and the need for personal presence at conferences, project meetings, etc., which often involve air travel, do not seem to be sufficiently questioned within the framework of the university's sustainability policy (Kreil, 2021, p. 57; Schrems and Upham, 2020, p. 9; Shields, 2024). There is still a lack of consideration of how the university encourages, rather than discourages, academic air travel. For example, by recruiting international students and faculty, requiring international experience to secure a position or advance a career, or mandating that business travel be kept as short and economical as possible (Kreil, 2021, p. 3).

When it comes to scientists and academic staff it can be stated, that on an individual level they are also broadly aware of the negative impacts of air travel and take into account the general social norm and the increasing pressure to justify air travel (Shields, 2023), particularly in terms of the purpose of the trip, for both private and business travel (Friedrich et al., 2020, p. 32). At the same time, mobility is often a professional requirement. In any case, scientists have to comply with the social norm of avoiding flight emissions as well as to the socio-professional norm of mobility and internationalization in the context of scientific activity.

According to Kreil (2021, p. 57), academics who reduce flights typically argue that it is important for the reputation of the university and that universities have a role model function, or that they have to make their contribution like everyone else, or that a reduction will be necessary sooner or later anyway. Another argument is based on the assumption that the negative effects on science are overestimated and that a restriction does not automatically lead to an impairment of academic work. Whether a reduction in air travel actually has a negative impact on careers has not been empirically proven. Wynes et al. (2019) were unable to find a significant correlation between career success and air travel in their studies. And this is despite the fact that many higher education and research institutions often boast about their historical tradition of international mobility and sometimes even outright demanding that potential candidates have spent at substantive time period abroad, if they wish to apply for and advanced position (Rivza and Teichler, 2007, p. 459).

Scientists who continue to travel by air despite their high level of climate awareness tend to experience feelings of dissonance, on the one hand they feel justified or even obligated to travel on the other hand they are confronted with the ecological impact of their behavior. According to Schrems and Upham (2020, p. 3), this highlights the barriers to behavioral change, especially when different types of

justification are used to reduce the dissonance. In this context the theoretical model of *denial of control* means that people locate the decision to travel by air not in their power but in external. The choice of air travel is justified by outside factors like limited time and money resources or accessibility or comfort (Schrems and Upham, 2020, p. 6). The necessity of the business trip in the first place is due to professional disadvantages that would otherwise exist, personal interactions (e.g., at conferences, during fieldwork) were also emphasized as a necessity for their work, which cannot be replaced by virtual techniques (Kreil, 2021, p. 54; Nikula et al., 2022, p. 4; Nurse-Bray et al., 2019, p. 15; Schrems and Upham, 2020, p. 7). *Compensation* in the form of benefits can follow a similar line, namely that the reason for the business trip is important for the career, the project or the scientific community. And that society also benefits (Schrems and Upham, 2020, p. 7). *Comparisons* also often help to reduce feelings of guilt. Comparisons with the industry, with colleagues who fly even more often, or with one's own lifestyle, which, apart from flying, is considered sustainable (Schrems and Upham, 2020, p. 8). The feeling of being entitled to these experiences could also be seen in this context (Nikula et al., 2022, p. 4; Reilly and Senders, 2009, p. 257). The *denial of responsibility* emphasizes the small contribution that an individual can make (Nikula et al., 2022, p. 4; Schrems and Upham, 2020, p. 3) and can be tied to the model of self-efficacy quite well. According to Kreil (2021, p. 57), scientists who do not want to see academic flying reduced also argue that this reduction would not make a difference—it would be a “drop in the ocean.” Furthermore, they argue that science has a special role in society and can also contribute to sustainability through research, with the freedom of science to be preserved, and with the fact that reductions have already been made and there is no more room for maneuvering without having a negative impact on scientific output. All those arguments brought forward in the last section are based on the assumption of cognitive dissonance, between one's awareness concerning climate change and the actual actions taken. However, the arguments that funnel the concept—denial of control, compensation, comparison as well as denial of responsibility—can be seen in relation to a socio-cognitive framework. Using the terminology of Bandura (1997), these four arguments are an articulation of one's lack of self-efficacy, meaning that climate change related actions may lie outside of one's own abilities.

Accordingly, one overarching argument is the call for systemic change. Reducing academic air travel requires institutional or supra-institutional structural changes, in particular changes in cultural and social norms, adaptation of funding criteria, banning domestic flights, promoting rail travel and investing in virtual communication (Kreil, 2021, p. 54). Schrems and Upham (2020, p. 8) categorizes the demands for institutional change as facilitations, incentives, restrictions, time flexibility and mindset shift. This ties the whole debate to a second central idea, the concepts of collective efficacy, which can be seen and understood as an extension of the self-efficacy model proposed before. This concept of collective efficacy is based on the idea that change needs to be demanded from academia as a whole and that a change of the current academic framework is possible and necessary (Bandura, 1997, p. 477).

Taking a look at the situation of students, there is a growing body of research that examines their contribution and attitudes toward climate change. Firstly, research in this field shows that while the estimates for the CO₂ footprint is comparatively smaller, than the ones of the faculty, it is still substantial, with an estimate of 14 megatons of

CO₂ per year associated with international student mobility at the end of the last decade – tendency rising (Shields, 2019), with most of the greenhouse gas emissions generated by students who move to high-income destinations (no matter their own origin; Shields, 2019). On an attitudinal level empirical research shows that students in general display a high level of awareness regarding climate change and CO₂ pollution. However, researchers have noted a cognitive dissonance among students in recognizing the need for action to limit the effects of climate change and committing to changes in their personal behavior, particularly with respect to travel and consumption (Green Erasmus, 2022; Kreil, 2021; Nikula et al., 2022). Gössling et al. (2019, p. 7) found that international students fly for various reasons. Particular importance was retrospectively attached to flights that took place in the context of education, flying home to family and visiting friends.

However, studies also point to factors that influence climate awareness and the extent of (academic) air travel. First among those is the attitudinal perception of flying as a privilege: Although flying is presented as a social norm, there are national and international inequalities in this regard. Most flights are taken by socially privileged people in affluent societies (Gössling et al., 2019, p. 2). International students, particularly those from developing countries or regions severely affected by climate change, tend to display a relatively high awareness of climate change (Uzhegova and Baik, 2022; Eskander and Istiak, 2022). There are differences in relation to the relative position of the individuals in the academic setting: Before the COVID-19-pandemic Wynnes et al. (2019) compared air travel behavior at different career stages. On the one hand, they showed that early-career academics were responsible for fewer emissions from air travel than senior academics; on the other hand, PhD students and postdocs, who still have more to invest in their careers, may have less scope to forgo mobility.

Additionally, there are institutional and contextual factors at play. Typically, they are tied to discipline, the international vs. national work environment or study context. Concerning these aspects there are different assumptions in literature. While Schrems and Upham (2020) find that sustainability scientists are a group that perceive particularly high levels of cognitive dissonance in relation to their air travel, Wynnes et al. (2019) find no association between disciplines or research content and the amount of air travel. Among students, awareness and concern tends to be higher among those studying science and academic subjects rather than practical or applied programs (Eskander and Istiak, 2022). Moreover, international students and those in international study programs exhibit notable differences from their peers. Students participating in international study programs, both short-term and full bachelor's and master's degrees, are more likely to engage in environmental campaigns, use public transportation, and recycle than regular students, but show little willingness to limit their travel behavior (Gössling et al., 2019; Green Erasmus, 2022). Case studies have demonstrated that the level of education on climate change is less important than engagement in climate change relevant actions and workshops (Akrofi et al., 2019).

Additionally, studies show sociodemographic differences, with gender-related one being the most pronounced: The essentialization of mobility for good science intersects with discourses of good parenting and, in the context of heteronormative discourses, mothers are more affected by childcare responsibilities (Cohen et al., 2020, p. 159). At the same time, women seem to be more pro-environmental

than men, more aware of the negative impact of flying on the climate and more willing to change their lifestyles (Chan et al., 2019; Rice et al., 2020). However, gender differences are not evident in all countries and obviously vary according to socio-cultural context (Chan et al., 2019).

In summary, there is empirical evidence that the university as an institution is reflecting on its greenhouse gas emissions and taking action to reduce its environmental impact. Despite the growing awareness, there are still institutional inconsistencies between ideals and actual practices. Studies also show that academics feel pressured to balance flight reduction with the demands of their careers, leading to cognitive dissonance and different justifications for flying. A few research findings suggest that flying habits vary depending on career level, subject area, international context and gender. Some studies have also shown contradictions between students' comparatively high climate awareness and their behavior. After examining the current state of research, a more comprehensive view of the tense relationship between higher education, internationalization and climate change from the perspective of students emerges as a research gap. In particular, there is a lack of a differentiated view of students, who prove to be a heterogeneous group, with highly differentiating demands.

This tension can be addressed particularly well with the group of international students, as they are by definition located at the intersection of higher education and internationalization. In any case, this group is also confronted with the question of how to implement their mobility requirements.

To explain these issues, we use the arguments brought forward by Schrems and Upham (2020)—denial of control, denial of responsibility, comparison and compensation (Kreil, 2021)—as well perceived self-efficacy and collective efficacy frameworks as proposed by Bandura (1997). Both theoretical frameworks lend themselves to the analysis of the issue at hand, as it allows them to explore how much students feel the possibility to assess the need to travel as well as act climate change conscious and how they position themselves in the larger collective context of academia, when it comes to climate change related actions.

Accordingly, the objectives of the study are to find out (1) what perceptions and attitudes students of international degree programs have with regard to climate change, (2) how they assess their personal environmental impact and (3) to analyze how they perceive internationalization and their own mobility, especially when it comes to flying and greenhouse gas emissions. The study strives for a differentiated view and aims to develop a typology that helps to understand how climate awareness and mobility behavior interact.

3 Study design and sample

Based on the fact that there is little consolidation about the current state of research in the field it was decided to do a qualitative interview study, that should help understanding the complex situation more and contribute toward the concept of a typology of international students and their air travel related environmental awareness. The ratio behind this was to get a chance to find more in-depth reasonings and provide participants with opportunities to explain and expand on potential mismatches or contradictions, that were highlighted during the literature discussion presented before. This is intended to provide a more sociologically inspired alternative to predominantly descriptive

discussions, such as the case study from Canda (Université de Montréal) on travel patterns by [Arsenault et al. \(2019\)](#) or to large-scale analyzes of register-based mobility data such as those by [Shields \(2019\)](#), getting insights into specific perceptions and positions.

In light of the aforementioned considerations, a qualitative study design was selected, wherein data collection is conducted through semi-structured interviews and content analysis. Semi-structured interviews were undertaken to allow participants the flexibility to share their individual perspectives and experiences, while also ensuring consistency and comparability across responses through a semi-structured thematic guide. This approach enables both in-depth insights into subjective viewpoints and targeted information relevant to the research questions, which allows to group participants *post-hoc* ([Flick, 2021](#)). A content analysis was chosen for data analysis as it provides a systematic and transparent way to identify and interpret key themes and patterns in relation to the research objectives. This allows an interpretation that takes into account both the content related issues raised by [Schrems and Upham \(2020\)](#) and [Bandura's \(1997\)](#) arguments on socio-cognitive processes of perceived self-efficacy.

The sampling strategy is defined by cluster sampling where the units of analysis are initially selected in groups rather than individually ([McClintock et al., 1979](#)). The analysis units were selected in several stages of cluster formation and stratification. In the first step, students

from international study programs in Austrian were defined as a case. In the next step, two medium-sized universities in Austria were selected, which were available to us for data collection purposes (e.g., access to courses and classes). In accordance with the logic of cluster sampling, which dictates that a case with maximum variance within the case and the lowest possible variance between the cases should be selected, a bachelor's degree program that focuses on international management and the other for a master's degree program that focuses on leadership in communication were chosen. Finally, one methods course was selected within each of the two programs and all students within each selected course were interviewed (see [Figure 1](#)). Both programs target international students, require them to spend time studying abroad after their initial stay at the host university, are taught entirely in English, and emphasize in their mission statements that their students are expected to become leaders and/or internationally active experts in their respective fields. The study involved interviewing eight students from the bachelor's program and 21 students from the master's program.

In terms of age, gender and country of origin, the data source is made up as follows: The age of the respondents ranged from 20 to 36 years. Three of the bachelor students identified as male, five as female. When it came to the master students seven were men, and fourteen were women. While most of the people in the bachelor's program came from Europe (two eastern Europe, five central Europe,



FIGURE 1
Overview of the clustering sampling strategy (own illustration).

one from Asia), the masters' program had a more diverse class. Around a quarter of them came from Latin America, another quarter from South-East Asia, and a quarter from central to northern Europe. The rest came from the Middle East. One individual was from the United States.

The interviews were conducted using a peer process, where trained student interviewers interviewed the selected group of students to minimize the effect of social desirability. In such a peer interview process, where the interviewers are both insiders, as fellow students, and outsiders, in their role as researchers, thorough theoretical and practical preparation is essential (Buys et al., 2022). It was expected that interviews by the academic staff or professional interviewers may be harmful to get more in-depth answers, however it is acknowledged that this has limited to scope of the interviews.

The selected class for the bachelor's program started their studies in October 2021, so they were in their second year of studies, while the selected class for the master's program started in October 2022, and they were in their first year of the master's program. The interviewees were given the flexibility to choose the time and place for their interviews. Those were competed in the CAPI—computer assisted personal interviews—mode and thus the talks were in person. If the interviewees agreed the interviews were recorded via either a smartphone or a laptop pc and then transcribed via a word processor. However, students could also opt out of recording and transcription and instead allowed the interviewers to take notes on the interview instead; thus, it was also allowed to create verbatim summaries of statements. This option was provided to create a setting of trust among the interviewers and interviewees and made sure that the anonymity of participants was respected. Furthermore, all interviewed students had the chance to opt out of the study at any time and decline their participation.

The average length of an interview was around 20 min, with the shortest one taking 10 min, and the longest one 40. Before conducting the study, interviewers were introduced to the interview guide, could prepare themselves for 1 week and could request coaching from the head researchers.

While only a limited number of interviewers requested coaching, all of them had some training on the method in corresponding classes.

A semi-structured interview guide was used, including a consent form that informed participants that their interviews will be used for educational and scientific purposes as well as a metadata sheet to be completed by the interviewers.

On a content level the first question dealt with the *interviewees travel behavior*, before continuing with questions about the *relevance of travel for their personal and professional life, their attitudes toward climate change and flight shaming*. The interviews were wrapped by a *summary* provided by the interviewers, that offered the interviewees a chance to amend their statements or add further information. In addition to the five main questions, which were to be asked in the pre-arranged order, the interviewers were provided with a set of follow-up questions in case the initial answers needed to be elaborated on or were not sufficient (see Table 1).

In a first step (for the process, see Figure 2 based on Kuckartz, 2016), initiating text work was carried out on the one hand by reading the interview transcripts and recording initial ideas in memos. On the other hand, the main categories and a deduction-based proto-typology were developed on the basis of the literature and the core content dimensions of the interview guide. Combining the extent of

TABLE 1 Interview questions und underlying dimensions.

Interview questions	Dimensions
Did you take an airplane trip last year? (Follow up with questions about the reason for and destination of the trip. On the use of continental flights and budget airlines)	Travel behavior/aircraft usage behavior
Have you ever considered not traveling by air for climate protection reasons?	Attitudes toward climate change
Are your travel behaviors common or uncommon in your social circle? (Possibly ask what makes the differences)	Travel behaviors/aircraft usage behaviors
How important is it to you to be able to travel far and wide easily? (Possibly ask for reasons why/why not?)	Relevance of travel for personal and professional life
How environmentally conscious would you currently rate your own travel behavior? (Follow up with questions about attitude changes in recent years and reasons for them) Are you familiar with the term "flight shame"? Do you think it is justified or not?	Attitudes toward climate change

climate awareness and the extent of airplane use results in four types that follow a four-field logic (see Figure 3). When interpreting and naming the types of the deductive typology, the dimension of the importance of travel for personal and professional life was also taken into account. The entire interview material was then coded with the main categories and the data systematically organized, taking into account the relevant aspects previously identified. Specific responses were categorized based on commonalities, coded accordingly and then compared and contrasted with each other. Subcategories were added inductively and the entire material was worked through again. In the next step, socio-demographic information was also taken into account. Finally, the types developed from the data were discussed in relation to the deductively developed proto-typology (see Figure 4).

The deductively developed typology is presented in detail below. The type with a high level of awareness of climate change and the associated (widespread) avoidance of air travel include people whose behavior corresponds to their attitude. Given the context of the study, it is assumed that this group has frequently modified its travel behavior, so the type is called *behavior change*. Corresponding to Kreil (2021), this type will argue with the role model function of universities and the general need to reduce air travel. Those who are aware of the harmful effects of air travel on the climate and still use airplanes will be confronted with dissonant feelings. Hence the name *feeling of dissonance*. This group attaches great importance to private and/or professional travel. Research (Kreil, 2021; Nikula et al., 2022; Nursey-Bray et al., 2019; Schrems and Upham, 2020) suggests that this group is likely to justify business air travel on the basis of external circumstances (no other choice, professional necessity) and comparisons with others whose contribution to climate change is greater. In the *feeling not responsible* type, behavior and attitude are not contradictory. This group uses airplanes quite naturally and does not consider the contribution of air traffic or their own flying behavior to be climate-relevant. Honnacker (2021) explains that individual actors can evade attribution of responsibility, and hence blame, because individual actions only acquire ecological relevance when aggregated.

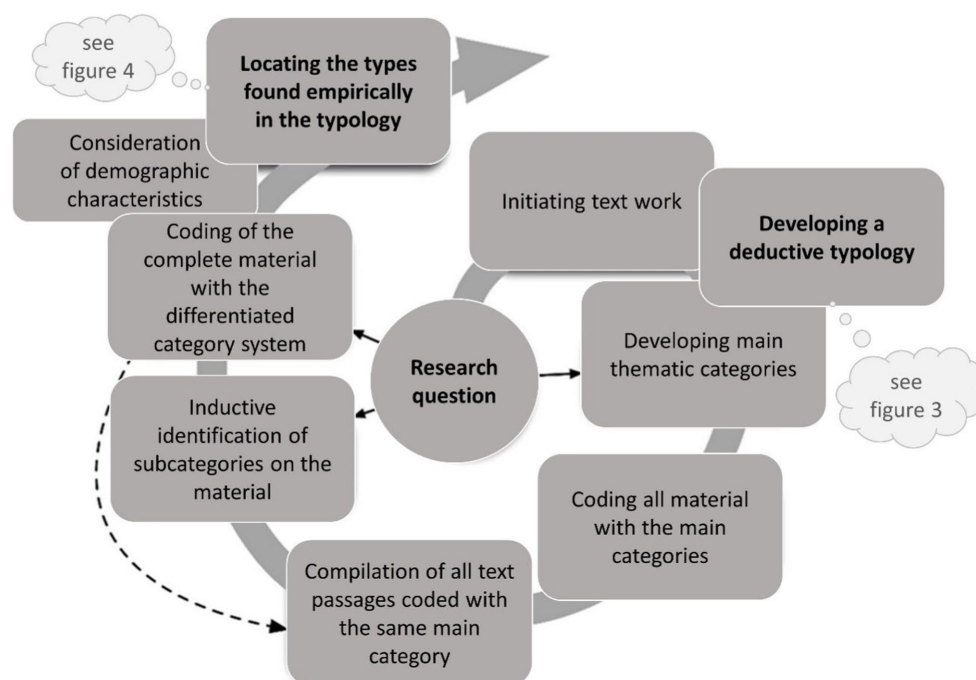


FIGURE 2
Process of data analysis. Adapted model from Kuckartz (2016) (own illustration).

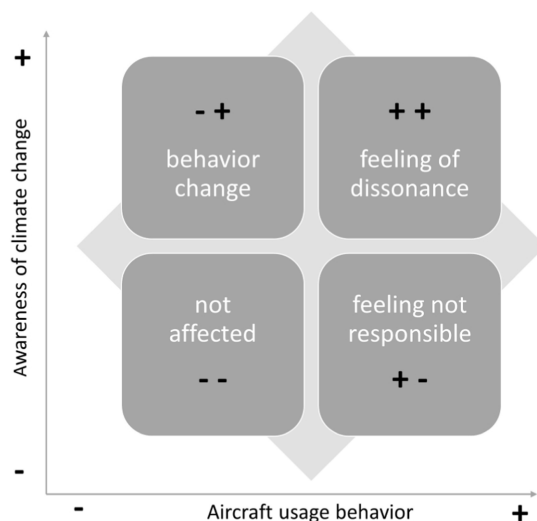


FIGURE 3
Deductive typology of air travel behavior combined with climate change awareness (own illustration).

Feelings of entitlement to these experiences will also be more common in this group (Nikula et al., 2022; Reilly and Senders, 2009). For the *not affected*, air travel plays no role because they generally have no interest in further or long-distance travel. Their travel behavior is not linked to any climate protection concerns, but these are low. It is unlikely that this group will appear frequently in connection with international students, as a certain degree of mobility is a prerequisite for studying in another country. Those in this group are likely to be from

neighboring countries that can be reached easily by train or car. However, according to the logic of the typology, the choice of transport mode would not be based on environmental awareness.

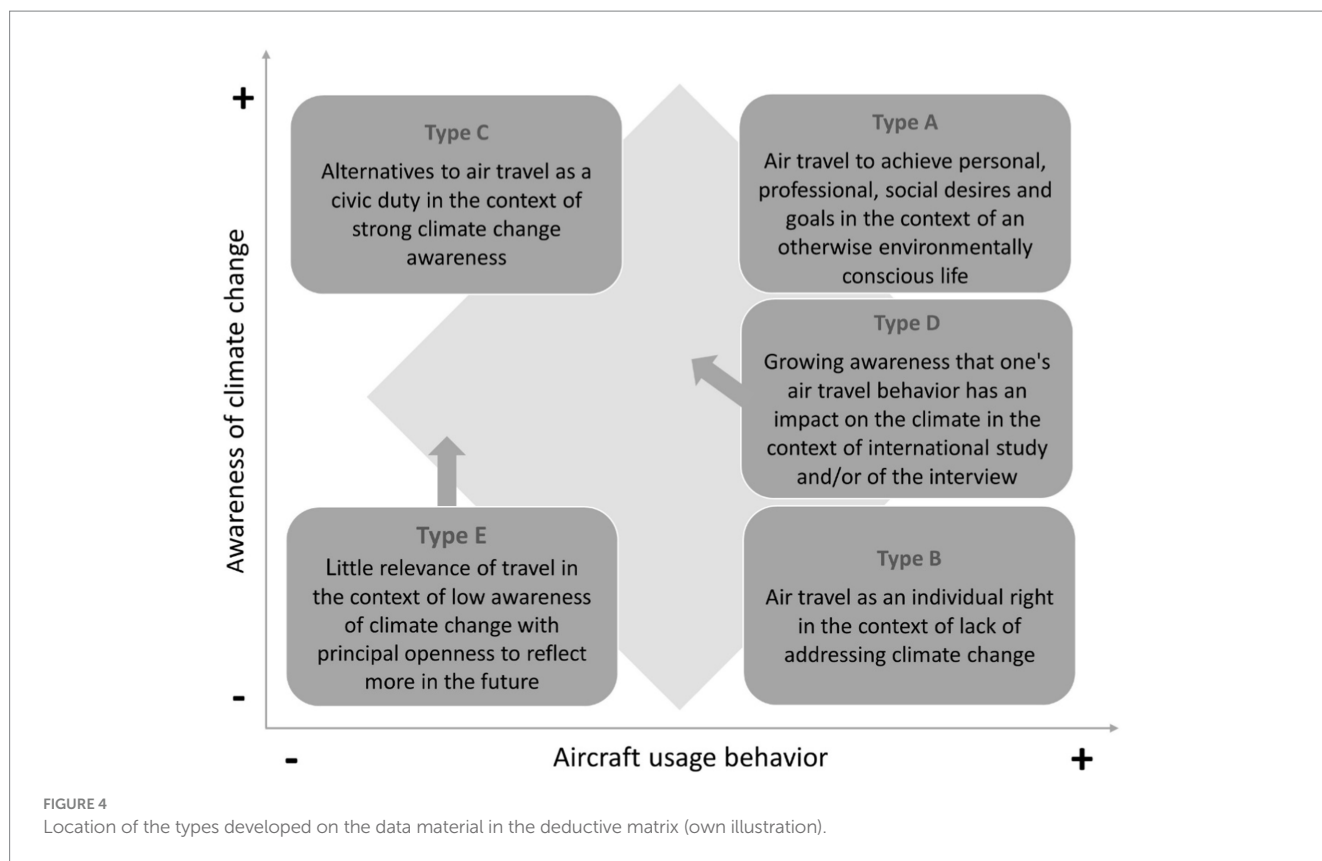
4 Results and classification

With regard to the first research question on perceptions and attitudes toward climate change, the interviews with the international students reveal a wide range: on the one hand there are those who are not concerned about climate change and on the other there are those who are. As well as nuances in between, there are also students who have been made aware through their international studies.

The second research question relates to students' perceptions of their personal contribution to climate change. Some of the students show an attempt to reduce their own carbon footprint through an environmentally conscious lifestyle and political involvement in environmental issues. However, this does not always mean giving up or reducing air travel. Some, however, refuse to take responsibility and believe they have the right to achieve their goals and dreams.

The third research question relates explicitly to personal mobility and air travel. Here, too, the whole spectrum becomes visible. On the one hand, there are those who consciously look for alternatives to air travel and do so, at least within Europe, and those who are less mobile anyway and therefore fly less. On the other hand, there are those for whom flying is very important and who feel they have a right to it, and those who do not want to or cannot give it up but are confronted with the shame of flying.

When the research questions are considered together and the attitudinal and behavioral levels are interwoven, five distinct types of students can be identified based on the interviews, that partly align



with the proto-types developed in the previous section, but provide additional insights (see Figure 4):

(A) The first type of student comes mostly from Africa or South-East Asia and either consciously or unconsciously contributes to actions against climate change, such as protesting against deforestation or promoting sustainable agriculture. This goes hand in hand with the literature from [Uzhegova and Baik \(2022\)](#) as well as [Eskander and Istiak \(2022\)](#), who argued that students from developing countries or regions severely affected by climate change, tend to display a relatively high awareness of climate change. However, this group shows little concern about their (air) travel behavior and sees it as a means to create professional and social bonds and pursue individual dreams, prestige, and stature – which meets the insights from [Shields \(2024\)](#) structural analysis, that students from low income countries who move to high income countries are often also substantially contributing to CO₂ pollution. On a content level the arguments of the students in this group are somewhat in line with the ones [Schrems and Upham \(2020, p. 6\)](#) provided for professional academics: They do not claim to be in control and there is a compensation to their behavior, at least on an individual level. There is a lack of perceived self-efficacy to act in relation to climate change, when it comes to their own travel behavior. Furthermore, these arguments are in line with [Gössling et al. \(2019\)](#) and [Green Erasmus \(2022\)](#) that there is a group of international students that is engaging with action against climate change, but not willing to change their travel behavior, creating the aforementioned feeling of dissonance:

Anchor quote: “[Air Travel] improves the quality of life where people travel to pursue dreams, connect, and gain massive achievements... I’m not seeing myself as environmentally

conscious when it comes to traveling... but I want to contribute to a safe world in terms of climate stability.”

This group is of interest when it comes to theory building: They see the need for a collective action against climate change, participate in group or societal efforts like protests, but they are not relating their own actions to the problem. There is the fact of compensation at play, individuals in this group argue that their actions lead to individual success that outweigh potential societal consequences. Because of this there is a strong dissonance that can be reported and the match the group “feeling of dissonance” proposed previously.

(B) The second type of student mostly comes from Western and Northern European countries as well as the United States. They are mostly younger, female students, with only one exception being male. They believe in individuality and, especially, their right to travel because it is highly important to them on a personal and professional level. They feel that they cannot be criticized, even if they harm the environment, as their individual enjoyment is more important. They are oblivious of environmental and societal issues at large and become highly emotional, defending their positions. Using [Schrems and Upham \(2020\)](#) terminology it can be stated that they do not feel responsible and even deny their responsibility, when confronted with facts. The attitudes of those students somewhat match the perspective from scientists that [Kreil \(2021, p. 57\)](#) described in her work, who think an individual forfeiting air travels would not make a difference. However, the arguments were mostly tied personal and not necessarily to professional reasons, like in the literature.

Anchor quotes: (1) “The plane would fly to Australia with or without me... I’m an individual, I want to live my life to the fullest,

and my choices don't matter in the grand picture." (2) "The media says flying is really bad... But everybody flies... It can't be that bad for the environment as everybody does it."

The model of self-efficacy typically targets specific areas of experience or tasks (e.g., science, education, work, politics; see [Bandura, 1997](#)). On the one hand, this group does not appear to lack self-efficacy in general, but on the other hand, self-efficacy does not play a role in relation to climate change. The participants who can be assigned to this category do not feel that they lack self-efficacy in relation to climate change or that they even need collective efficacy in academia. From a societal perspective, however, they already see a form of collective efficacy—they argue with the prominence of the issue in politics or in the media. For them, however, the issue of climate change is not linked to their own behavior. From the social-cognitive perspective of [Bandura \(1997\)](#), this shows that this group does not perceive any cognitive dissonance—their positions and actions coincide. For this reason, they neither feel the need to justify themselves excessively nor to change their behavior and are matching the proto-type that feels not responsible. What is of interest here is that the individual arguments tie to their own expectations and desires, showing a very individual centered point of view.

(C) The third type is the counterpart to the second one and consists of comparatively older students, mostly in the master's program, who are well-reflected on their environmental impact and individual behavior. They come from European countries as well as Latin American ones. They are highly aware of the issues of climate change and see hegemonic structures in place that work against substantive change. They see it as their civic duty to act against climate change and bring examples of their personal life, comparing their past actions with their present understanding of the issue. When following the arguments provided by [Kreil \(2021\)](#) in the literature review of this article, there is a clean line between these students and the academics who see behavioral change as necessary and adopt their behavior. Like the academics in the examples provided in the work done by [Kreil \(2021\)](#), this type will argue with the role model function and the general need to reduce air travel. There are particular levels of insight to be recognized in the material, e.g., students of this type are highly critical of their previous behavior.

They highlight that, at least in Europe, it is easily possible to travel without resorting to air travel.

Anchor quotes: (1) "I travel by train. I plan to move from [Country A] to [Country B] for my next study destination via sharing a pick-up [Truck] with my classmates"; (2) "I flew a lot when I was younger. I would sometimes flight-shame myself now."

They have high levels of perceived self-efficacy and acknowledge the need for collective efficacy in society—and in academia in particular—in their fight against climate change. They do not deny their role in climate change, nor do they compare themselves and their behavior to others. They try to make sure that they have as little impact on the climate as possible and match the deductive proto-type of behavioral change based on literature. Here a stronger societal orientation can be found in the arguments.

(D) The fourth group is mostly composed of students from South-East Asia and the Middle East. Before participating in international study programs, they were not too concerned about

climate change and the impact of their often-frequent air travel behavior. Their experiences in the programs or even partially during the interviews were argued to be relevant. It seems their experiences during their studies triggered a change in them, as the students in this group did not feel responsible before the interviews or at least felt only some dissonance. However, students forming this group now reflect on the fact that there are more sustainable forms of travel and they could experience the variety of public transport available in Austria or even Europe as a whole. They now recognize the dangers of climate change and believe that individuals can make a difference. There is a shift in behavior that may occur, partly because of socialization experiences ([Shields, 2024](#)). However, this result must be seen within the correct scope, as there is no evidence that their behavior changes in the long term and there is some danger of social desirability at play as well.

Anchor quote: "[...] I think my travel behavior is not environmentally conscious. Especially after this interview, I'm a bit ashamed of my answers. I've realized that some people consider other modes of transportation because of the environment, and I didn't even know that."

This shows that the perceived and communicated collective efficacy in the field of academia is very important. Students develop a position concerning climate change and a perceived efficacy, when it comes to dealing with climate change. Here Bandura's model provides a strong insight into the dynamics between institutional goals and the development of individual predispositions.

(E) The final group is not particularly aware of the environmental impact of their travels or of climate change in general. They also do not place much emphasis on travel, either because they have traveled in the past or because they have never considered it as important and see it as more of a necessity. They are open to learning about climate change and there is no clear pattern in terms of their socio-demographics or background. The main point is, that this group neither feels responsible or in control when it comes climate change, but they do compare themselves with others on an attitudinal level. This provides an important indicator insofar, that the issue is not of relevance to all students involved in international study programs and there are still some not affected like proposed in the proto-types derived from literature.

Anchor quote: "I don't think that traveling is that important to me. It's not because of climate change that I don't fly at the moment. I don't really care either way."

They neither show signs of cognitive dissonance, nor do they argue that they have or do not have a responsibility when it comes to climate change. They argue that they are in control of their actions and do not position themselves from a normative position, relying on a pragmatic argument. They stated that they do not act in a climate change inducing way, but also state that this is not tied to ideological, but rather practical aspects. Overall, it seems possible that this group may be open to develop an efficacy-based position on climate change and climate change related behavior, as they are participating in academic field as students, who are expected to understand scientific literature and arguments. However, as they do not favor air travel their impact may be low in general.

5 Conclusion and recommendations

This paper aimed to conduct a qualitative investigation concerning the attitudes of international students toward climate change, their personal environmental impact, and internationalization and mobility. The results of the qualitative case study revealed worrying attitudes toward air travel and its prioritization among most interviewees. While the results cannot be quantified, they align with previous quantitative studies while providing a more nuanced starting point for future studies, which may aim at generalization or quantification.

On a general level, this study highlights a concerning trend: international students, who are being trained as future decision-makers, often lack awareness of the severity of the climate crisis and their own contributions to it. This is in line with other recent findings and arguments found in the corresponding literature like Nikula et al. (2022). Furthermore, many of the findings are in line with the contradicting attitudes found in academia overall and may be tied to the strong idealization of international mobility in academic socialization (Kreil, 2021; Shields, 2024). Nevertheless, it has to be highlighted that it was a qualitative study in a western European country, generalizations should therefore be avoided. However, this point definitely shows the limits of the qualitative research conducted in this work and would warrant a quantitative follow up.

Secondly, using the qualitative methodology inspired by the work of Kuckartz (2016) we were able to identify five distinct groups of students, all of them with different attitudes. Of those, only one group (B), consisting of young, Western, mostly female students, who placed high value on personal enjoyment, showed no reflection concerning their behavior and were dismissive of their impact in climate change. This group is at least somewhat in line with what Kreil (2021, p. 57) described in her study as scientists, who do not want to see academic flying reduced and argue that a reduction would not make a difference, as it would be a “drop in the ocean.” This group is mostly defined by their *denial of responsibility*, as they emphasize the small contribution that an individual can make and see their individual needs as more important (Nikula et al., 2022, p. 4; Schrems and Upham, 2020, p. 3). This group could be clearly placed in the inductively created analytical matrix (see Figure 4). There is no cognitive dissonance in their actions, but they neither see an individual responsibility to act in the face of the climate crisis, nor do they acknowledge expert knowledge—as illustrated in the quote in the previous section. They come from a more privileged group that is typically responsible for most CO₂ emissions among international students (Shields, 2024). They follow in some ways previously established patterns about mobility from an academic point of view. They are a prime example of why institutional change and institutional guidelines are necessary and collective efficacy is important, as on an individual level the concept does not target or include them.

Three other groups had varying levels of awareness and willingness to reflect on their impact, either before or after the interviews. Interestingly, some students developed clear positions through reflection, while others only partially engaged with the necessity of action. Here very often the argument is not tied to enjoyment, but more on the necessity and the perceived levels of efficacy are highly divergent—while some groups like C are showing initiative others like those group A do see the need for collective action but are somewhat caught in a cognitive dissonance concerning their own individual action, in other words their own travel behavior. D was originally not

engaged in the topic on an individual level, but because of institutional and circumstantial development may become self-efficacious. This also supports the claims from Kreil (2021, p. 54) that academia overall is in need of institutional or supra-institutional structural changes, in particular changes in cultural and social norms, when it comes to environmental consciousness overall and air travel in particular. The results show however that students need to be included in this discussion and seen as central for any potential change (Shields, 2024), as they get socialized in this context. And this can further both collective efficacy and self-efficacy.

And the final group (E) did not have strong opinions on climate change or travel but was willing to learn more. They provide insight into the fact that there is still a group of students who are not involved in one of the central challenges humanity faces during the 21st century, where also institutions can provide a chance to develop both a problem centric view on the issue, that may result in both collective efficacy and self-efficacy.

Overall, those five different groups of international students with varying levels of awareness and willingness to reflect on their impact on climate change also suggest that universities and higher education institutions can play a crucial role in promoting environmental awareness and sustainability among international students. Accordingly, it can be expected that international study programs, which transparently address the environmental impact of individual mobility and incorporate mandatory courses on climate change into their curriculum may shape students’ understanding of their actions in relation to climate change. Also grants and incentives for sustainable mobility could be helpful to create experiences with climate friendly ways of travel, instigating an opportunity for behavioral change. In this context the idea of collective efficacy becomes central as well: Academia as a whole is currently experiencing a paradigm shift on what internationalization can and potentially even should contribute to the field of science. On the one hand it is clear that international mobility is both a gratification and expectation for those active in the field, and our study as well as previous literature highlight this. On the other hand, we can see that there is uncertainty and a gap in understanding how global academia may function when limiting those aspects, no matter if one looks at the organizational level, the level of faculty or students—like we did in our study. Thus, just like Schrems and Upham (2020, p. 8) put it, any changes to academia at all—and this includes international students as well—need to be understood in relation to a deep institutional change, as “*facilitations, incentives, restrictions, time flexibility and mindset shift are necessary.*”

Data availability statement

The datasets presented in this article are not readily available because the dataset consists of qualitative interviews (dialog between two human participants, based on structured questions). Participants did not consent to the sharing of their data in raw form; the consent agreement only included the information that aggregated information and selected, non-identifiable passages may be shared in the context of academic publications. We can NOT share full interview transcripts. Requests to access the datasets should be directed to Dimitri Prandner, dimitri.prandner@jku.at.

Ethics statement

Ethical approval was not required for the studies involving humans in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required as all participants received an information form and were informed about their rights regarding the European GDPR and the Austrian research law (FOG - Forschungsorganisationsgesetz). Participants were assured of their right to withdraw from an interview, refuse to provide information, or even ask for their statements to be deleted/ignored.

Author contributions

DP: Formal analysis, Methodology, Supervision, Validation, Writing – review & editing, Conceptualization, Data curation, Investigation, Project administration, Writing – original draft. KH: Formal analysis, Methodology, Supervision, Validation, Writing – review & editing, Visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Transforming document management for environmental sustainability: the mediating effect of pro-environmental culture and service satisfaction in higher education institutions

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This research investigates the factors influencing environmental sustainability in a Peruvian higher education institution (HEI), using Structural Equation Modeling (SEM) with SmartPLS. The methodology included data collection through questionnaires administered to students, alumni, and professors, followed by SEM analysis to assess the relationships between technological support (TS), document management (DM), open government (OG), pro-environmental organizational culture (POC), service satisfaction (SS), and environmental sustainability (ES). The findings emphasize that technological infrastructure significantly enhances document management, which in turn boosts service satisfaction and promotes a pro-environmental organizational culture. The pro-environmental organizational culture emerges as the most powerful mediator, significantly impacting environmental sustainability. Although service satisfaction also contributes positively, its effect is less pronounced. Furthermore, transparency and open access to information improve document management, albeit with a lesser impact. Sociodemographic variables such as gender and academic program within the institution influence the relationship between the examined variables, suggesting that these characteristics can affect the perception and effectiveness of sustainability practices. This study provides a robust foundation for designing effective strategies to promote environmental sustainability in higher education institutions and would contribute to the fulfillment of the SDGs.

KEYWORDS

document management, environmental sustainability, pro-environmental organizational culture, higher education institution, service satisfaction, SEM

1 Introduction

Documents are the most crucial assets of any organization; therefore, understanding how to properly maintain a paper trail can significantly impact the efficiency of its management (Reyes et al., 2023), conversely, document management represents a major issue for higher education institutions. According to Regla and Marquez (2020) extensive storage spaces, filing cabinets, and necessary security measures are required, Sheela Rani et al. (2023) indicate that

records, time, and energy are lost, and resources are squandered, with the main challenge being the upkeep of records and the failure to meet deadlines for obtaining information. In most higher education institutions (HEIs), there are no academic document management systems (DMS) nor are the necessary technologies for their development identified (Hüller et al., 2022). Added to this, other issues of document management (DM) include the quality of managerial staff, the significance of the work, the funding, and the information, which directly affect the administration of archives and documents overall (Sun, 2022).

Moreover, the continuous enhancement of education with various approaches and reforms has led to a substantial number of educational policies, programs, and research reports, which also increases the processing and information load for HEIs, also, traditional methods of classification and manual filing are ineffective and vulnerable to the loss of documentation and inefficiency in DM processes (Zhang et al., 2024). Additionally, many offices use a hierarchy of folders on computers to organize documents and the use of labels to sort them, which is currently not an efficient process due to the vast amount of documentation generated (Watanabe et al., 2024). Similarly, when it comes to collecting information managed traditionally, it becomes an isolated process due to the lack of communication between different types of stored data and even incomplete documentation (Korro et al., 2024). HEIs also face the maintenance of their documents and records, where records, time, and resources are lost, not meeting the search for documents (Sheela Rani et al., 2023).

Industrial advancement has led to economic progress and societal well-being, but the impact of industrial complexes has altered the environment, causing environmental effects and climate changes (Barragán-Ocaña et al., 2024). The growing awareness of environmental challenges, resource scarcity, and the urgent need to address climate change necessitate paradigm shifts in product and service design (Lyu et al., 2024). Increasingly, companies are seeking to enhance their operational performance and paying more attention to sustainability issues, leading to practices that improve sustainability performance and, specifically, environmental impacts (Fiorello et al., 2023). Companies are even beginning to discuss a “green paradigm,” seeking the integration of Industry 4.0 technologies and management model principles that enhance precision, customization, competitiveness, and environmental sustainability (Costa et al., 2024). This fosters green product innovation as a key strategic issue in companies.

In universities, energy usage is a critical issue, as the aim is to balance growing operational demands with ES (Laporte et al., 2024). Additionally, it must be considered that HEIs have a significant impact on the society and environment in which they operate, influencing various fields of development, including ES, and contributing with their social role in the education of future generations (Usta et al., 2024). However, many HEIs place significant emphasis on integrating ES at a strategic level, but generally lack policies that incorporate it into operational aspects (Christou et al., 2024).

Nevertheless, the environmental implications remain relatively unknown, and there is no substantial literature addressing the elements of this research. Therefore, this article offers an analysis of DM in HEIs, evaluating the level of organizational culture and service satisfaction present as a mediating effect on environmental sustainability. This will identify the needs for “paperless” management, the use of digital environments, and enhancing operational efficiency

by adopting new digital practices framed in Digital Transformation (DT), understood as the process by which HEIs integrate digital technology to all its areas, which will allow cultural and operational changes that are better adapted to the changing needs of users, thus improving the perception of its benefits by users.

The aim of this research is to use Structural Equation Modeling (SEM) to assess the mediation of organizational culture and service satisfaction between document management and environmental sustainability, whose findings will define environmental strategies and policies in HEIs.

The significance of this study lies in its potential to generate valuable knowledge that enables HEIs to foster a cultural change that promotes the commitment and active involvement of various stakeholders, raising awareness of ES, developing pro-environmental policies, and incorporating them into curricular experiences. This is supported by efficient DM based on effective strategies that reduce the environmental footprint, aligned with sustainability principles, under a “paperless” approach, using digital environments and optimizing operational processes. This will lead to tangible benefits such as reduced paper usage, savings in natural resources, and contributing to the education of professionals and citizens aware of the importance of environmental preservation.

2 Theoretical framework

2.1 Document management in organizations

DM and archiving are critical responsibilities in any organization, as they must ensure the access, upkeep, preservation, and oversight of pertinent information. The ISO 30300 standard offers a framework that sets forth guidelines for the enhancement of DMS in organizations (Manzanelli, 2023). Similarly, in DM, best practices need to be established for the creation and maintenance of information and documentation, which enables decision-making, activities, and operations within the organization, easing its use in business procedures and at every level of the organization (Alonso, 2020).

In the context of HEIs, Hüller et al. (2022) observe that these institutions retain vital academic and administrative data that must be safeguarded. However, many of them still lack the required technology to implement effective DM. According to Mulchan and Wang (2024) digital transformation is progressing rapidly, with the widespread presence of digital technologies and technology-driven innovations transforming organizational processes, where one of the principal initiatives is to enhance record and document management to boost productivity.

In a study by Simwaka et al. (2023) at universities in Malawi, a survey uncovered the presence of document records such as minutes, grades, theses, political documents, and reports, but there was an absence of management of such documentation due to, among other factors, a lack of management policies, limited financing, and information technology infrastructure. On the other hand, Henriksen (2023) examined the impact of user-focused digitalization on record management in the public sector in Norway. Through interviews, it was discovered that municipalities lack resources and technologies and do not engage their users, despite their professionals attempts to assist them. Likewise, according to Mosweu and Bwalya (2023),

government entities frequently implement automated record management systems without a clear governance structure to support automation.

2.2 The role of technological support in document management efficiency

Over the past decades, the role of technological support (TS) has been a significant concern in research. The acceptance and application of innovations in information systems (IS) and information technology (IT) have been evaluated through theoretical frameworks examining their acceptance (Dwivedi et al., 2019). Among these frameworks, the Unified Theory of Acceptance and Use of Technology (UTAUT) stands out, proposing that actual technology utilization is driven by behavioral intention. This theory suggests that technology adoption hinges on performance expectations, effort expectations, social influence, and facilitating conditions, with individual perceptions of technology being crucial for enhancing job performance (Marikyan and Papagiannidis, 2023).

Recent advancements in technologies are affecting document and record management worldwide. Key elements of the Fourth Industrial Revolution, such as blockchain technology and artificial intelligence (AI), are shaping how digital records are administered within organizations (Ngoepe et al., 2024). In Tsabedze (2024) study, viewpoints and readiness of professionals for records and archives management were assessed through a survey, revealing insufficient experience and budget constraints for acquiring technology. Therefore, improved funding and AI integration into DM are suggested.

In the context of HEIs, this swift technological progress has introduced innovative methods for safeguarding crucial student data (Dongre et al., 2024). Similarly, Reyes et al. (2023) identify documents as the most valuable assets in a university, so maintaining paper trails greatly impacts DM efficiency. Consequently, technological platforms and IT systems have been developed to organize and centralize their files.

Various studies, such as those by Ayaz and Yanartaş (2020), have examined UTAUT, concluding that technological support is essential for the acceptance and effective use of systems, positively affecting document management. Additionally, Alghobiri et al. (2022) demonstrated that advanced technologies in HEIs, such as optimization with graph-based document clustering algorithms and distance functions, enhance document retrieval. Sidhimantra et al. (2024) indicate that repository system development improves academic document management and supports accreditation processes in HEIs. Karpenko et al. (2020) note that these systems also contribute to the effectiveness of academic workload distribution, and (Chen et al., 2022) assert that the adoption of technologies like blockchain enhances the security and efficiency of the entire DM process.

The reviewed studies provide consistent evidence of the positive effect of technological support on DM. Although various approaches and technologies are utilized, all studies conclude that technological support is fundamental for the automation, security, and accessibility of DM, directly impacting efficiency in HEIs.

Finally, the role of technological support represents an opportunity to boost the efficiency of DM processes. Therefore, the following hypothesis is proposed:

Hypothesis 1: Technological support has a significant impact on effective document management in HEIs.

2.3 Impact of efficient document management on user satisfaction in HEIs

As Alonso (2020) highlights, DM establishes best practices for the generation and maintenance of information and records, facilitating appropriate decision-making. According to Gamido et al. (2023), the procedure of an electronic DMS starts with the transformation of paper documents into digital files with standardized formats, enabling effective document organization and encouraging the reduction of paper waste in document reproduction. It also enhances user access to essential documents distributed in real-time, with simple searches and retrieval of necessary records.

According to Alade (2023), one sector that has seen rapid expansion in recent years is document management, regarded as essential in the organizational work environment. For this reason, a web-based electronic DMS was developed, which, when utilized, achieved a 96.60% satisfaction rate among participants, concluding that it enhances user satisfaction, boosts productivity, and ensures data efficiency in a timely manner.

In Peru, according to Ramirez et al. (2023), public institutions have a substandard service in DM. To tackle this, robotic process automation (RPA) technology was implemented, reducing the processing time of procedures, preventing citizen dissatisfaction, and improving their experience.

DT is acknowledged as a phenomenon that has drastically changed how organizations function. The emergence of digital technologies in the public sector presents multiple possibilities, where user satisfaction is deemed one of the most critical conditions for effective DT implementation (Kitsios and Ioannou, 2024). DMS are a necessity in the organizational work environment and specifically in HEIs because they facilitate access to documents in shortened times (Alade, 2023) and must have secure and interoperable management of crucial and legal documents (Siva Rama Rao et al., 2023), both for university faculty with documentation related to their academic duties (educational, methodological, scientific, and organizational) (Pleskach et al., 2023), and for general document procedures. Therefore, this service satisfaction regarding digital document management could generate positive user attitudes toward sustainable practices, facilitating their adoption and maintenance.

Based on the reviewed literature, the following hypothesis is proposed:

Hypothesis 2: Efficient document management positively influences service satisfaction in HEIs.

2.4 User satisfaction as a driving factor for environmental sustainability in HEIs

User satisfaction as a driving force for environmental sustainability in HEIs is based on the notion that when the services provided meet user expectations, users develop affirmative behaviors and attitudes toward the institution, which results in greater commitments to sustainable practices.

In the study by [Mansoor and Hussain \(2024\)](#) on the impact of knowledge-based leadership on service quality in HEIs, it was shown that effective and user-centered management can significantly influence service quality, which in turn promotes a more sustainable environment conducive to pro-environmental practices. Similarly, [Rolo et al. \(2024\)](#), concerning service quality in HEIs in Portugal and Angola, emphasize the importance of adjusting service quality strategies to local needs and expectations. In the context of environmental sustainability, this suggests that HEIs should consider user specifics to implement sustainable practices perceived positively. Likewise, [Kidido et al. \(2024\)](#), on the management and sustainability of event facilities in HEIs in Ghana, also discovered that user perception of facility management can affect their satisfaction and, consequently, their support for sustainable resource practices.

The research by [Bao et al. \(2024\)](#) on the assessment of sustainable service quality in HEIs emphasizes the importance of considering the varied opinions and expectations of users in the decision-making process. HEIs can design and adjust their services to better meet user needs, incorporating sustainable practices that are valued by the educational community. On the other hand, [Alshamsi et al. \(2024\)](#) examine the factors driving the sustainability of blockchain technology in higher education, underscoring that its implementation largely depends on user acceptance and satisfaction, concluding that well-received technology can contribute to more sustainable practices in HEIs.

As stated by [Ozdemir et al. \(2020\)](#), measuring sustainable service quality on university campuses includes dimensions such as waste management, energy efficiency, and community participation, highlighting a holistic approach to campus sustainability. [Santos et al. \(2020\)](#) explore the influence of social responsibility on service quality and student satisfaction in higher education, concluding that when universities implement socially responsible practices, such as volunteer programs and environmental sustainability, they tend to have more satisfied and committed students.

These studies underscore that service satisfaction in HEIs is closely linked to environmental sustainability. By focusing on user satisfaction, positive cycles are created where satisfaction and sustainability reinforce each other. Therefore, the following hypothesis is proposed:

Hypothesis 3: Service satisfaction has a positive impact on environmental sustainability in HEIs.

2.5 Promoting a pro-environmental organizational culture through efficient document management

According to [Nanayakkara and Wilkinson \(2021\)](#), organizational culture (OC) theory is one of the most influential in the workplace because if an organization does not maintain a suitable culture to support its activities, it could adversely impact its procedures and overall performance. Additionally, [Sindakis et al. \(2024\)](#), the adoption and transfer of culture are achieved through the sharing of knowledge within and between areas, departments, and units of large organizations. Additionally, as [Schlegel et al. \(2023\)](#) emphasize in the context of DT, having a data-based OC is a crucial factor in data analysis capabilities, innovation, and competitive advantages for companies.

Based on the study by [Souza and Aganette \(2022\)](#), digital preservation and efficient DM are closely associated with POC, arguing that implementing efficient document management practices can positively impact organizational culture, promoting sustainable and pro-environmental practices. Similarly, [Netshakhuma \(2022\)](#) demonstrated that using the SharePoint platform as a DMS in a university not only enhances administrative efficiency but also supports the development of a sustainability-oriented OC.

The reviewed studies provide evidence that efficient DM can be a key driver in fostering an organizational culture dedicated to environmental sustainability in HEIs, therefore proposing the following hypothesis:

Hypothesis 4: Efficient document management promotes a pro-environmental organizational culture in HEIs.

2.6 Influence of pro-environmental organizational culture on achieving sustainability in HEIs

Various studies have indicated that an organizational culture that fosters pro-environmental values and behaviors can significantly affect the environmental sustainability of HEIs. [Kalsoom and Hasan \(2022\)](#) stress that a POC can transform educational and administrative practices in HEIs. Additionally, [Diegues \(2023\)](#) underscores the importance of leadership as part of the organizational culture in the sustainability of higher education, promoting educational transformation and enhancing the entrepreneurial and innovative spirit necessary to implement sustainable practices in HEIs.

As proposed by [Khan and Terason \(2022\)](#) fostering pro-environmental behaviors through a green organizational culture can encourage sustainable attitudes among the employees of an institution. [Barros et al. \(2020\)](#) illustrate in a Brazilian university that an organizational culture centered on sustainability leads to the development of sustainable practices and greater environmental awareness. Moreover, [Žalėnienė and Pereira \(2021\)](#) suggest that global integration allows universities with this pro-environmental culture to serve as global models that incorporate sustainability into all facets of university life.

According to [Fuchs et al. \(2023\)](#), an organizational culture dedicated to sustainability is crucial for the success of Sustainable Development Goals (SDG) initiatives in Latin American universities. [Marques et al. \(2023\)](#) contend that an organizational culture that values sustainability can facilitate cooperation between universities and businesses, promoting a positive impact on environmental sustainability.

These theories and studies provide insights into organizational culture and its role in advancing environmental sustainability in HEIs; therefore, the following hypothesis is proposed:

Hypothesis 5: A pro-environmental organizational culture positively influences environmental sustainability in HEIs.

2.7 Open government and transparency as enablers of effective document management

Digital technologies have a recognized potential to create more efficient, trustworthy, and innovative public institutions ([Aguerre](#)

and Bonina, 2024). Government open data are crucial drivers of DT in the public sector, as they allow for insight into how strategies are formulated, executed, and assessed for their ongoing success, aiming to encourage users to engage with and make use of these essential resources (Begany and Gil-Garcia, 2024). However, it is necessary to have governance structures that support the integration of technologies across various platforms and adapt to an increasingly digital society (Zwitter, 2024). This facilitates the development and interpretation of data visualizations that simplify information access, enhance comprehension, and bolster information literacy (Barcellos et al., 2024), this term has gained significant relevance in the digital era, marked by the abundance of information and the rapid evolution of information and communication technologies.

A study in Spain, one of the most decentralized nations globally (Curto-Rodríguez et al., 2024), discovered that open government has a favorable outlook and a promising future despite challenges such as resistance to change. Pasillas-Banda et al. (2024) in Mexico observed that there are advancements in governance through open government with the application of technologies in diverse media, emphasizing citizen engagement. Similarly, in Chilean municipalities (Hernández-Bonivento and Moller, 2024) state transparency is being promoted by involving citizens in public affairs and encouraging public accountability, which leads to insights on social and political participation, poverty levels, and information dissemination.

According to Saptarini et al. (2024), a result of the pandemic, particularly in online education, was the necessity for paperless document management, which offers benefits such as cost reduction, time efficiency, decreased physical storage needs, and access to documents anytime and anywhere. However, resistance to change, lack of technical expertise, and investment costs could hinder its implementation.

As part of the DT, Gelashvili and Pappel (2021) argue that a key component of e-governance is paperless management, which streamlines data exchange and digitized workflows, allowing for secure document recording, traceability, and immutable archiving for future access. Additionally, it is essential to complement these practices with DM policies based on technologies, tailored to each HEI's conditions, regulatory framework, and the readiness of its experts (Jiménez et al., 2022). Payment for services in DMS processes should also be considered (Glavev, 2023). However, as Ioannou et al. (2022) point out, the effectiveness of these e-government initiatives faces hurdles due to insufficient specialized knowledge, limited funding, and weak political initiatives and decisions, often resulting in flawed designs that merely transfer existing bureaucracy into the digital sphere. In Peru, the Digital Government law regulation (Decreto Supremo No 029-2021-PCM, 2021) seeks to promote the integration of digital technologies in public services, encompassing digital identity, interoperability, security, and digital architecture. Nevertheless, in practice, its application is very limited, considering that many HEIs do not even use digital signatures or have proposed automation of the processes involved in DM.

These findings underscore the significance of open government and transparency as fundamental contributions to document management, leading to the following proposal:

Hypothesis 6: Open government and transparency have a substantial impact on effective document management in HEIs.

2.8 Document management as a catalyst for environmental sustainability in higher education institutions

Environmental sustainability (ES) is presently a crucial element for both economic progress and human well-being. Environmental deterioration is alarming, leading nations and global organizations to conduct conferences and agreements (Luo and Sun, 2024). It should be acknowledged that the environmental crisis is the outcome of industrial, economic, and social development, which has adversely affected the planet's ecosystem (Córdor-Salvatierra et al., 2022). Similarly, the evolution and utilization of information and communication technologies (ICT) have brought growing prosperity and accessible information globally. Nevertheless, this advancement has not been devoid of notable environmental costs that jeopardize environmental sustainability, such as electronic waste that contaminates soil and water, releasing hazardous substances that endanger human health and biodiversity. As Tkachenko and Denisova (2022) propose, the intricate connection between digitalization, sustainability, and profitability has not garnered much focus from the academic community; however, it represents significant research domains on its own.

HEIs not only prepare professionals and future leaders but also need to heighten awareness about environmental preservation and directly influence communities to adopt sustainable practices (Karalam and Mathew, 2023). Furthermore, there is increasing concern about involving HEIs in an international effort to assume a more fitting role as champions of sustainable development (Pereira de Moraes et al., 2024). This necessitates beginning with curricular incorporation of environmental sustainability viewpoints, as many countries' educational systems are limited by rigid disciplinary frameworks and do not encourage transdisciplinary perspectives, which could address environmental concerns and the need for their protection. This is supported by Vidrevich and Pervukhina (2023), who highlight the significance of embedding environmental sustainability into HEI curricula and the necessity for educators to adopt teaching methods aligned with these integrative principles. Moreover, the United Nations Sustainable Development Goals (SDGs) have prompted substantial shifts in environmental education, making it vital to reform educational research and classroom methodologies (Guevara-Herrero et al., 2023), to cultivate critical individuals and professionals with initiatives aimed at fostering a more sustainable, inclusive, and resilient world.

As Dongre et al. (2024) suggest, universities manage vital student data that must be safeguarded and protected. Consequently, they should adopt innovative strategies as a crucial step toward a sustainable future, where digitalization will play an essential role in necessary technological transformations. From the viewpoint of Alnafrh and Mouselli (2021) HEIs in low-income nations tend to be delicate and responsive to the political and economic climates in which they operate, influencing the costs of obtaining and certifying credentials for students. Hence, a hybrid national platform based on blockchain was proposed to consolidate academic record management, advancing sustainable development.

Therefore, based on the examined documentary approaches, the following hypothesis is proposed:

Hypothesis 7: Effective document management contributes to environmental sustainability in HEIs.

The following mediator hypotheses are also defined:

Hypothesis 8: Service satisfaction will mediate the connection between effective document management and environmental sustainability in HEIs, acting as a catalyst that amplifies the positive effect of document management on environmental sustainability.

Hypothesis 9: Pro-environmental organizational culture will mediate the link between effective document management and environmental sustainability in HEIs, facilitating and enhancing the beneficial impact of document management on environmental sustainability.

Next, in [Figure 1](#), a conceptual framework is presented as a graphic design, which offers a visual understanding of the variables and their theoretical basis, as well as the hypothesis proposal where the variables involved are related. This conceptual framework allows an easy interpretation of the SEM model that will be applied, allowing an understanding of each variable in the structure of the study, without the need to have a technical background in this type of analysis.

3 Materials and methods

The investigation used a quantitative method and applied a non-experimental design. This method involved creating survey tools

through an exhaustive review of existing literature, including scholarly articles and regulations.

Considering this, a questionnaire was created and administered to users of document management, such as students, alumni, and faculty members. The questionnaire aimed to assess the effectiveness of document management toward environmental sustainability within the context of a pro-environmental organizational culture and service satisfaction.

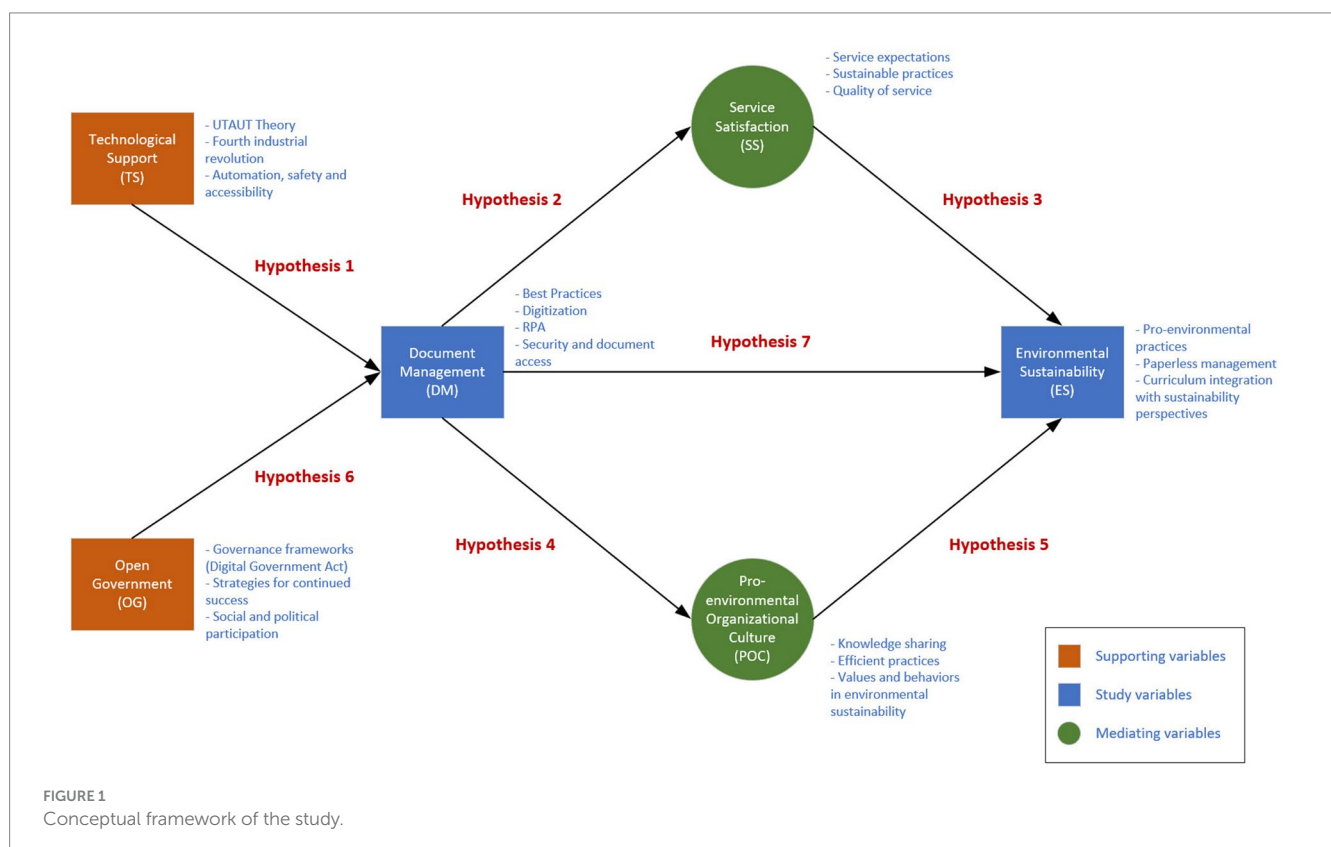
3.1 Participants

The study was applied to a population of 2,000 individuals, considering a sample of 247 participants, distributed among students, graduates and teachers of a Peruvian HEI. The inclusion criteria were higher education students, appointed teachers and graduates of the last 3 years.

A non-probabilistic convenience sampling was applied, considering only one faculty in the study, with participation being voluntary through informed consent.

The justification for the sampling method lies exclusively in the constraints of resources and time. By applying this type of sampling, our sample is diverse within the area of study, thus ensuring reliable outcomes. The applied method provided us with an initial approach to generate valuable insights on the effectiveness of document management among the different actors of the institution.

The participants come from five professional schools at a public university, offering a rich and varied depiction of the educational community. More than half belong to the Computer Engineering and Informatics program, highlighting a strong interest in how



technologies can support environmental sustainability. Although fewer in number, students from Statistics, Electronic Engineering, Mathematics, and Physics also contribute valuable perspectives and are directly related to the population in each school.

Regarding roles, 51.4% are students, 34.8% are alumni, and 13.8% are faculty members. This indicates that most participants are still in their educational process or have recently completed their studies, thus providing current opinions on DM and sustainability. The age range of the participants shows that almost half (46.2%) are between 23 and 30 years old, something expected in a university setting. However, there is also a notable representation of people of different ages, which enriches the intergenerational perspective of the study. In terms of gender, the majority of participants are men (78.1%) compared to 21.9% women. This difference suggests possible trends in enrollment in certain programs or specific roles within the institution, which is important to consider when interpreting the results.

The way participants obtain information about the status of their administrative procedures reflects a preference for multiple communication channels. Most prefer email (28.7%) and face-to-face interaction (20.6%), although some combine both methods (15.4%) or use information systems and applications like WhatsApp to a lesser extent. This variety emphasizes the need to offer flexible communication tailored to individual preferences. Table 1 presents the sociodemographic data of the surveyed sample.

Finally, it is indicated that all participants in the study possess experience and expertise in the document management process within the institution.

3.2 Instruments

Based on the identification of theoretical constructs and literature review, the instrument was created, comprising 27 items using a 5-option Likert scale, where 1 means not satisfied or not fulfilled, and 5 means completely satisfied or its fulfillment is total and adequate.

For the instrument, six variables were established: **service satisfaction** with four items where the service and attention are rated, as well as the average response time and the level of staff training are assessed; **document management** with five items focused on dissemination mechanisms, clarity of procedures, support, and advice (Jiménez et al., 2022; Zambrano Plúa et al., 2021); **technological support** with three items covering the level of automation and the tracking of procedures (Kholiya et al., 2021; Monarcha-Matlak, 2021); **open government and transparency** with three items oriented to the awareness of the transparency portal and the data published on it (Vidrevich and Pervukhina, 2023); **pro-environmental organizational culture** with eight items oriented toward training, policies, initiatives, programs, and participation in activities (Ioannou et al., 2022) and finally, **environmental sustainability** with five items addressing environmental aspects and their sustainability (Gestión Documental y Sostenibilidad: Reduciendo el Impacto Ambiental, 2023).

The survey was consolidated into an online form for its application, adding sociodemographic questions such as age range, gender, academic program, role, and how they know the status of their procedure. Additionally, three open-ended questions were added for subsequent analysis.

3.3 Validation of instruments

A pilot test was conducted with a small group of 10 participants to ensure the clarity and validity of the questions. Based on the feedback received, minor adjustments were made to the questionnaires.

Cronbach's alpha coefficient and composite reliability with values above 0.7 were used (Table 2). Additionally, the square root of the average variance extracted (AVE) was applied for each of the variables, ensuring that their values are not higher than the correlations among all variables with values above 0.5.

3.4 Reliability and validity analysis of the evaluated variables

In this study, variables such as service satisfaction, document management, technological support, open government and transparency, as well as pro-environmental organizational culture and environmental sustainability were evaluated. Below is an analysis of the reliability and validity of these factors, aiming to provide a clear and accessible overview. To begin, service satisfaction (SS) was assessed through questions about the overall service rating, the attention received, response time, and the level of staff training. The results indicate that the questions used were very consistent with each other, reflecting a high Cronbach's alpha value (0.939). Furthermore, it is observed that perceptions of these facets are strongly interrelated, suggesting that SS is being effectively measured. Regarding document management (DM), aspects such as the effectiveness of procedure dissemination, clarity of instructions, staff support, information accessibility, and data privacy were analyzed. A high internal consistency was also found (Cronbach's alpha of 0.915), meaning the questions align well to measure DM. However, a question on data privacy had a slightly lower correlation with the rest, suggesting that this question could be refined to ensure it measures the same as the others. Technological support (TS) focused on process automation, information security, and procedure tracking. The results show that the questions were consistent and reliable (Cronbach's alpha of 0.879), indicating that participants view these elements as interconnected aspects of TS. This underscores the importance of technology in the efficient management of procedures. The open government and transparency (OG) variable was evaluated through questions about awareness and updates of the transparency portal, as well as deadline compliance. Again, the responses showed high consistency (Cronbach's alpha of 0.886), indicating that these questions well capture the perception of transparency in the university. Regarding pro-environmental organizational culture (POC), the questions covered topics from sustainability training to the perception of organizational values and participation in environmental activities. This variable showed excellent consistency (Cronbach's alpha of 0.937), although a question about sustainability as a core value had a lower correlation. This suggests that while most questions are well-aligned, some could be adjusted to improve the set's cohesion. Finally, environmental sustainability (ES) was evaluated through questions about investment in sustainable technologies, the use of renewable inputs, the promotion of sustainability in curricula, and sustainable printing practices. The responses also showed high consistency (Cronbach's alpha of 0.923), reinforcing the validity of the questions to measure ES in the university. The variables evaluated in this study

TABLE 1 Sociodemographic profile of the sample (n = 247).

Sociodemographic	Category	Frequency	%
Academic program	Statistics	47	19.00%
	Physical	8	3.20%
	Electronic Engineering	37	15.00%
	Computer and Informatics Engineering	127	51.40%
	Math	28	11.30%
Role	teacher	34	13.80%
	Graduate	86	34.80%
	Student	127	51.40%
Age range to which they belong	Up to 19	28	11.30%
	20–22	37	15.00%
	23–30	114	46.20%
	31–40	26	10.50%
	41–55	12	4.90%
	46–50	7	2.80%
	Over 50	23	9.30%
Gender	Female	54	21.90%
	Male	193	78.10%
How do you know about the status of your procedures? (You can select more than one option)	By mail	71	28.70%
	In person	51	20.60%
	By mail, in person	38	15.40%
	Computer system	14	5.70%
	By mail, By WhatsApp	12	4.90%
	By mail, Computer System	11	4.50%
	By WhatsApp	11	4.50%
	By mail, in person, computer system	10	4.00%
	Statistics	29	11.70%

present high reliability and validity. This means that the questions used are consistent and well capture the perceptions and attitudes of the participants.

3.5 Data collection and analysis method

Information was gathered through an online survey administered to various participants. The study was conducted between April and May 2024, spanning 5 weeks. An online questionnaire was distributed containing nine sections: the first included information about the survey and informed consent; the second section contained general user details; sections 3 to 8 corresponded to the six variables analyzed; and finally, section 9 included open-ended questions. A total of 247 responses were collected from participants.

3.6 Quantitative analysis

Descriptive statistics were used to summarize the survey results. Structural Equation Modeling (SEM) (Ávila and Moreno, 2018; Escobedo et al., 2016) was utilized to examine the relationships among

pro-environmental organizational culture, service satisfaction, the effectiveness of document management, and environmental sustainability. SEM allowed for the concurrent evaluation of multiple dependent and independent relationships, measuring both observable and latent variables (Romero-Sánchez and Barrios, 2023).

The SEM approach overcomes the limitations of traditional methods such as those of Baron & Kenny and Andrew Hayes by integrating mediation and moderation analyses into a unified model, which facilitates the evaluation of direct, indirect and conditional effects in a robust manner. This approach was key to our study to capture the complex interactions between the dimensions analyzed and provide more generalizable results.

The software SmartPLS-v4 educational version (Ávila and Moreno, 2018) was used to assess the theoretical model based on partial least squares (PLS) methods using structural equation models.

3.7 Structural equation modeling (SEM)

SEM is suitable for this research due to its ability to model intricate relationships between latent and observable variables, providing a more detailed and precise understanding of the interactions between

TABLE 2 Results of the instrument quality tests evaluated by each of the model variables.

Variables	Item code	Average	DE	Factor loading	Cronbach's alpha	Composite reliability	Average Variance Extracted (AVE)
Service satisfaction	SATSER1	3.00	1.17	0.933	0.939	0.939	0.845
	SATSER2	3.10	1.20	0.921			
	SATSER3	2.55	1.29	0.909			
	SATSER4	2.99	1.14	0.913			
Document management	GESTDOC1	2.89	1.16	0.903	0.915	0.923	0.749
	GESTDOC2	3.06	1.12	0.891			
	GESTDOC3	3.01	1.11	0.898			
	GESTDOC4	2.83	1.19	0.880			
	GESTDOC5	3.59	1.19	0.746			
Technological support	SOPTEC1	2.87	1.10	0.917	0.879	0.881	0.806
	SOPTEC2	3.23	1.07	0.869			
	SOPTEC3	2.86	1.18	0.907			
Open government and transparency	GOBTRANS1	3.09	1.15	0.897	0.886	0.888	0.814
	GOBTRANS2	3.04	1.08	0.918			
	GOBTRANS3	2.72	1.22	0.891			
Pro-environmental organizational culture	COPROA1	2.79	1.19	0.912	0.937	0.96	0.755
	COPROA2	2.92	1.12	0.919			
	COPROA3	2.75	1.23	0.917			
	COPROA4	2.88	1.20	0.927			
	COPROA5	2.82	1.15	0.931			
	COPROA6	2.83	1.12	0.935			
	COPROA7	3.74	1.19	0.409			
Environmental sustainability	SOSTAMB1	3.07	1.16	0.834	0.923	0.936	0.767
	SOSTAMB2	2.88	1.11	0.917			
	SOSTAMB3	2.75	1.16	0.930			
	SOSTAMB4	2.79	1.14	0.925			
	SOSTAMB5	3.13	1.15	0.761			

pro-environmental organizational culture, service satisfaction, document management, and environmental sustainability. Relevant observable indicators were included based on the survey responses.

4 Results

The assessment of the variables examined in this study offers an in-depth perspective on how participants perceive various aspects of their experience at the institution, as illustrated in Table 3. The results concerning service satisfaction indicate that 38.06% of the participants evaluate the service as high, 35.22% as moderate, and 26.72% as low. While the majority hold a positive view of the service, it is evident that a quarter of the respondents believe there are areas that require improvement. This may highlight problems at certain times or in specific areas of attention.

Regarding DM, 50.61% of the participants view it as high-quality, indicating that most perceive the document processes as effective.

However, the average and low evaluations (31.98 and 17.41%, respectively) suggest that some individuals encounter difficulties, potentially due to issues with accessibility or insufficient clarity in procedures. TS also reveals notable outcomes. 39.27% of respondents assess it positively, while 38.06% rate it as average, and 22.67% consider it poor. This implies that, although many find the technological support satisfactory, a substantial number of users experience technical issues impacting their experience. For the OG variable, 36.84% of participants rate it as high, 40.08% as average and 23.08% as low. This shows that, while transparency initiatives are recognized, there is a need to enhance accessibility and update information to build greater trust among users. The POC gets a high rating of 42.51%, average of 37.25%, and low of 20.24%. This indicates that the majority of participants acknowledge the institution's dedication to environmental sustainability. Nevertheless, one-fifth of the respondents believe that the pro-environmental policies could be more effective or better communicated. Lastly, regarding ES, 38.06% of participants rate it as high, 39.68% as average, and 22.27%

TABLE 3 Scale of the evaluated variables.

Variables		High	Average	Low
Service satisfaction (SS)	<i>n</i>	94	87	66
	%	38.06%	35.22%	26.72%
Document management (DM)	<i>n</i>	125	79	43
	%	50.61%	31.98%	17.41%
Technological Support (TS)	<i>n</i>	97	94	56
	%	39.27%	38.06%	22.67%
Open government and transparency (OG)	<i>n</i>	91	99	57
	%	36.84%	40.08%	23.08%
Pro-Environmental Organizational Culture (POC)	<i>n</i>	15	92	5
	%	42.51%	37.25%	20.24%
Environmental Sustainability (ES)	<i>n</i>	94	98	55
	%	38.06%	39.68%	22.27%

as low. The closeness of high and average ratings suggests a generally positive perception but also highlights areas where the execution of sustainable practices and their communication to the university community could be improved. Overall, these findings offer a thorough view of the current state of participant experience and perception at the institution. The variables of DM and POC stand out as strengths, which is promising for sustainability and administrative efficiency initiatives. However, the variables of SS and TS present clear opportunities for enhancement, suggesting that addressing these areas could significantly improve the overall perception of the institution. The interaction between these variables provides crucial insights into the study, emphasizing how advancements in one area can positively affect others. For example, enhancing technological support and clarity in document management can boost service satisfaction. Conversely, greater transparency and a solid organizational culture can reinforce participants' trust and commitment to sustainable practices. Thus, the study not only identifies specific areas for enhancement but also underscores the importance of a comprehensive strategy that considers how these factors interconnect to create a more positive and effective educational and administrative experience.

4.1 Proposed research model

In the current landscape of HEIs, ES has emerged as a domain of growing interest and importance. Incorporating sustainable practices not only demonstrates a commitment to environmental conservation but can also improve operational efficiency and institutional standing. This study suggests a framework to assess the factors affecting environmental sustainability within a HEIs, utilizing SEM. It will explore how various factors, such as technological support, document management, open government and transparency, as well as pro-environmental organizational culture, influence environmental sustainability. Furthermore, two crucial mediators are incorporated in this model: service satisfaction and pro-environmental organizational culture. It is posited that effective document management, supported by solid technological support and open government and transparency, can greatly improve service satisfaction, which in turn might enhance efforts toward increased environmental sustainability.

Moreover, a POC is viewed as a pivotal driver in this process, fostering values and practices that advance environmental sustainability. The framework will also include sociodemographic factors such as gender, academic program, age, and role within the institution as moderators, to better understand individual variations in the perception and impact of these practices. These moderators will help reveal how personal traits and specific roles within the institution can affect the connections between the examined variables.

The diagram of the conceptual model shown in [Figure 2](#) illustrates these associations and offers a visual basis for the analysis. This comprehensive approach aims not only to identify the direct connections between the mentioned variables but also to investigate how demographic traits and specific roles might moderate these connections. Through this study, it is anticipated to contribute to the development of more effective and adaptive strategies that reinforce HEIs' dedication to environmental sustainability and offer a more holistic and detailed understanding of the factors driving environmental sustainability in the academic context.

4.2 Summary of direct hypotheses

The examination of the proposed model unveils significant insights into how different variables impact ES in a HEI. Several direct hypotheses were tested, with their relationships and significance providing a thorough view of these factors, as presented in [Table 4](#).

Firstly, TS demonstrates having a crucial impact on DM. With a path value of 0.699 and a *p*-value of 0.000, this correlation is clearly positive and significant. This suggests that enhancing technological infrastructure not only facilitates document management but also boosts operational efficiency. This finding highlights the importance of investing in technology to improve administrative procedures. Document management, in turn, has a notable effect on service satisfaction, as indicated by a path value of 0.857 and a *p*-value of 0.000. This positive and significant link underscores that effective document management is crucial to ensure users are content with administrative services. Clearly, efficient document handling not only results in smoother operations but also in greater user satisfaction. When examining the link between service satisfaction and

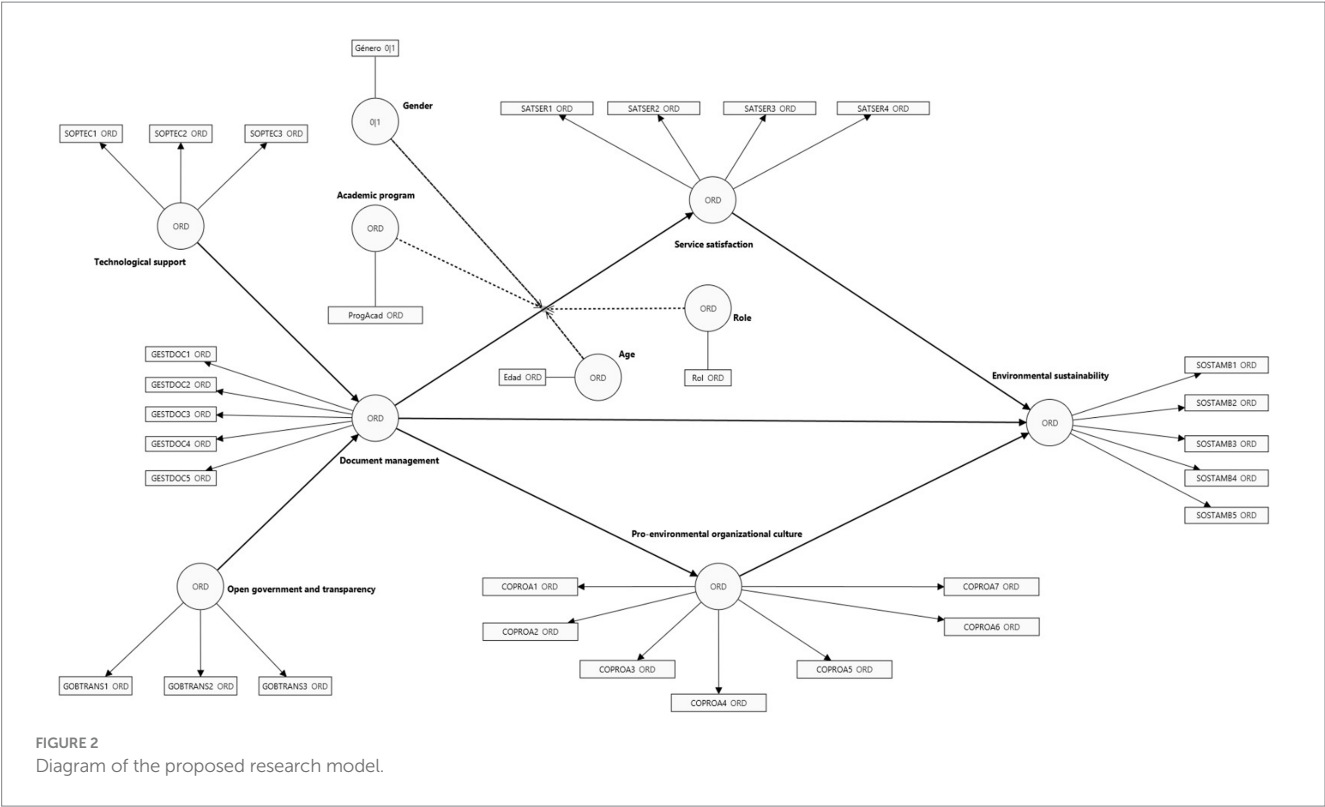


TABLE 4 Hypotheses proposed.

Hypothesis statement	<i>p</i> -value	Path value	Condition	Interpretation
Technological Support → Document Management	0.000	0.699	Accepted	The relationship is positive and significant
Document Management → Service Satisfaction	0.000	0.857	Accepted	The relationship is positive and significant
Service Satisfaction → Environmental Sustainability	0.030	0.185	Accepted	The relationship is positive and significant but weak
Document Management → Pro-Environmental Organizational Culture	0.000	0.701	Accepted	The relationship is positive and significant
Pro-Environmental Organizational Culture → Environmental Sustainability	0.000	0.726	Accepted	The relationship is positive and significant
Open Government and Transparency → Document Management	0.000	0.219	Accepted	The relationship is positive and significant but weak
Document Management → Environmental Sustainability	0.217	0.103	Rejected	The relationship is not significant

environmental sustainability, a positive and significant, albeit relatively weak, connection is observed with a path value of 0.185 and a *p*-value of 0.030. This indicates that, although service satisfaction contributes to environmental sustainability, its impact is not as strong as other factors. Nevertheless, this result suggests that improving user satisfaction may have beneficial effects on sustainability practices, though indirectly. On the other hand, DM also shows a significant association with POC, with a path value of 0.701 and a *p*-value of 0.000. This positive correlation underscores how well-organized document management can cultivate an organizational culture that values and promotes environmental sustainability. It is evident that

clear and accessible document processes not only facilitate daily tasks but also reinforce pro-environmental principles within the organization. Additionally, POC has a strong effect on SS, with a path value of 0.726 and a *p*-value of 0.000. This result emphasizes the importance of an organizational culture dedicated to sustainability for achieving positive environmental outcomes. Promoting sustainable values and practices within the institution is crucial for the success of environmental initiatives. The association between open government and document management is also positive and significant, though weaker, with a path value of 0.219 and a *p*-value of 0.000. This suggests that transparency and open access to information contribute to

TABLE 5 Moderation analysis.

Hypothesis Statement	<i>p</i> -value	Path value	Condition	Interpretation
Gender moderates the relationship between Document Management and Service Satisfaction	0.012	0.172	Accepted	The relationship is significant
The academic program moderates the relationship between Document Management and Service Satisfaction	0.019	0.059	Accepted	The relationship is significant
Age moderates the relationship between Document Management and Service Satisfaction	0.427	−0.025	Rejected	The relationship is not significant
The role moderates the relationship between Document Management and Service Satisfaction	0.207	0.040	Rejected	The relationship is not significant

TABLE 6 Mediation analysis.

Hypothesis statement	Type	<i>p</i> -value	Path value	Condition	Interpretation
Document Management → Pro-Environmental Organizational Culture → Environmental Sustainability	Mediator	0.000	0.509	Accepted	Mediation is positive and significant
Document Management → Service Satisfaction → Environmental Sustainability	Mediator	0.030	0.159	Accepted	Mediation is positive and significant but weak

enhanced document management, although its effect is not as strong as other factors. Nonetheless, fostering transparent practices remains essential for improving administrative efficiency. Finally, the hypothesis linking DM directly to ES was not supported, with a path value of 0.103 and a *p*-value of 0.217. This indicates that document management, on its own, does not have a significant direct impact on environmental sustainability. Its influence is likely mediated through other variables, such as service satisfaction and pro-environmental organizational culture. In summary, the results from the direct hypothesis analysis underscore the importance of technological support, document management, and a pro-environmental organizational culture as key factors in driving environmental sustainability. Although service satisfaction also plays a relevant role, its effect is more subtle.

4.3 Moderation analysis

This study examines the influence of various demographic and academic factors on the relationship between DM and SS in higher education environments providing new insights to enhance ES through customized document management practices, detailed in Table 5.

The results indicate that gender has a notable impact on the mentioned relationship ($p = 0.012$, Path = 0.172), suggesting differences in service satisfaction perceptions between men and women. This finding highlights the need to develop inclusive DM strategies that foster both environmental sustainability and fairness in service satisfaction. Additionally, the academic program was identified as a significant moderator ($p = 0.019$, Path = 0.059), emphasizing the importance of tailoring DM practices to the specific context of each program to enhance service satisfaction. This outcome underscores

the need for a customized approach in DM initiatives for various academic settings. In contrast, neither age ($p = 0.427$, Path = −0.025) nor role ($p = 0.207$, Path = 0.040) demonstrated significant moderation in the studied relationship. This indicates that DM practices can be uniformly implemented in these areas without compromising their effectiveness.

Finally, this study provides empirical evidence on the importance of considering gender and academic program when designing DM strategies in universities, with the goal of advancing environmental sustainability and service satisfaction. The absence of significant moderation by age and role offers a practical perspective for the consistent application of these practices in certain domains. These results establish a solid foundation for future research and practices in sustainable DM, tailored to the specific needs of diverse groups within the university environment.

4.4 Mediation analysis

The mediation analysis in the model, as detailed in Table 6, assists in understanding how certain variables affect environmental sustainability through key mediators in the HEI under examination.

Below are the findings of the mediation hypotheses, explaining how document management, pro-environmental organizational culture, and service satisfaction interact to affect environmental sustainability. Initially, it was found that DM influences environmental sustainability through pro-environmental organizational culture. With a Path value of 0.509 and a *p*-value of 0.000, this mediation is positive and significant. This means that effective DM can enhance pro-environmental organizational culture, which in turn greatly increases environmental sustainability. In this case, the mediation is complete, highlighting the importance of pro-environmental

organizational culture as a key channel for achieving sustainability through efficient DM. This finding underscores that cultivating a culture that values sustainability is crucial for maximizing improvements in DM. The practical implication is that universities should not only focus on enhancing DM but also on developing an organizational culture that supports and fosters sustainability.

Conversely, it was found that service satisfaction also mediates the relationship between document management and environmental sustainability. With a path value of 0.159 and a *p*-value of 0.030, this mediation is positive and significant, albeit weaker. This indicates that effective DM can increase service satisfaction, which in turn contributes to environmental sustainability. Although this mediation is also complete, the impact is less pronounced, suggesting that service satisfaction plays a role in sustainability but not as strongly as pro-environmental organizational culture. This finding highlights that while service satisfaction is important, additional complementary efforts are required to achieve a notable change in sustainability. Practically, this means that HEIs should work to enhance service satisfaction as it can positively impact their sustainability initiatives, but they should complement these efforts with other more direct actions toward sustainability.

These findings are essential for understanding how intermediate variables can amplify the effects of DM practices on environmental sustainability. POC emerges as a very important mediator, suggesting that initiatives to improve sustainability should focus on building and strengthening a culture that values and promotes environmental sustainability. On the other hand, service satisfaction, while less influential, also contributes positively, indicating that improving the service experience can have beneficial effects on sustainability practices. The mediation analysis shows that both POC and service satisfaction are key mediators in the relationship between document management and environmental sustainability. However, pro-environmental organizational culture has a much stronger and more significant impact. This provides a solid basis for designing effective strategies in HEIs, highlighting the importance of the complete mediations identified in this study.

4.5 R² analysis

The R² analysis offers a clear understanding of how much of the variability in certain critical areas can be explained by the studied factors, detailed in Table 7. At the research location, four main variables were investigated: pro-environmental organizational culture, document management, service satisfaction, and environmental sustainability.

For the POC, the outcomes show that 49.2% of the variability in this domain can be accounted for by the model, with an adjusted R² of 0.490. This implies that nearly half of the changes in pro-environmental organizational culture within the institution are due to factors such as DM, technological support, and transparency. These insights underscore the significance of these components in fostering a culture that values and endorses environmental sustainability. In the case of DM, it was found that 77.7% of the variability can be explained by the elements of the model, with an adjusted R² of 0.775. This indicates that enhancing technological support and transparency has a substantial impact on the efficacy of document management. These findings highlight the importance of

TABLE 7 R² analysis.

Variables	R squared	R-squared-adjusted
Pro-environmental organizational culture	0.492	0.490
Document management	0.777	0.775
Service satisfaction	0.734	0.733
Environmental sustainability	0.781	0.771

TABLE 8 Summary of fit indices.

	Saturated model	Estimated model
SRMR	0.053	0.063
d_ULS	1.381	1.401
d_G	0.897	0.945
Chi-square	1,009.338	1,017.348
NFI	0.948	0.929

these areas for efficient administrative operations and suggest that investments in technology and transparent practices are essential. SS was also examined, revealing that 73.4% of the variability can be explained by the model, with an adjusted R² of 0.733. This implies that document management and pro-environmental organizational culture have a significant impact on how users perceive the quality of the service. Enhancing these aspects is crucial to increasing user satisfaction with the services provided by the institution. Lastly, for ES, it was found that 78.1% of the variability can be explained by the model, with an adjusted R² of 0.771. These results emphasize the necessity for integrated approaches that consider multiple factors to promote sustainable practices. In summary, the R² and adjusted R² values illustrate that the studied factors adequately explain the key areas of interest. The results suggest that improving document management, fostering a pro-environmental culture, and increasing service satisfaction are vital to driving environmental sustainability.

4.6 Model fit: summary of fit indices

The evaluation of the fit indices offers an assessment of how well the proposed model aligns with the observed data at the study site, with the outcomes displayed in Table 8.

The following are the findings and interpretations of the main fit indices for the saturated model and the estimated model. The value of SRMR (Standardized Root Mean Square Residual) is an indicator that measures the discrepancy between the observed and predicted correlations by the model. In the saturated model, the SRMR is 0.053, while in the estimated model it is 0.063. These values indicate a good fit, as they are below the commonly accepted threshold of 0.08. This suggests that the discrepancies between the observed and predicted correlations are small, implying that the estimated model adequately represents the data. The d_ULS (Unweighted Least Squares Discrepancy) index in the saturated model is 1.381 and in the estimated model is 1.401. These values are quite close to each other, indicating that the fit of the estimated model is similar to that of the saturated model. Although there is no specific threshold for d_ULS,

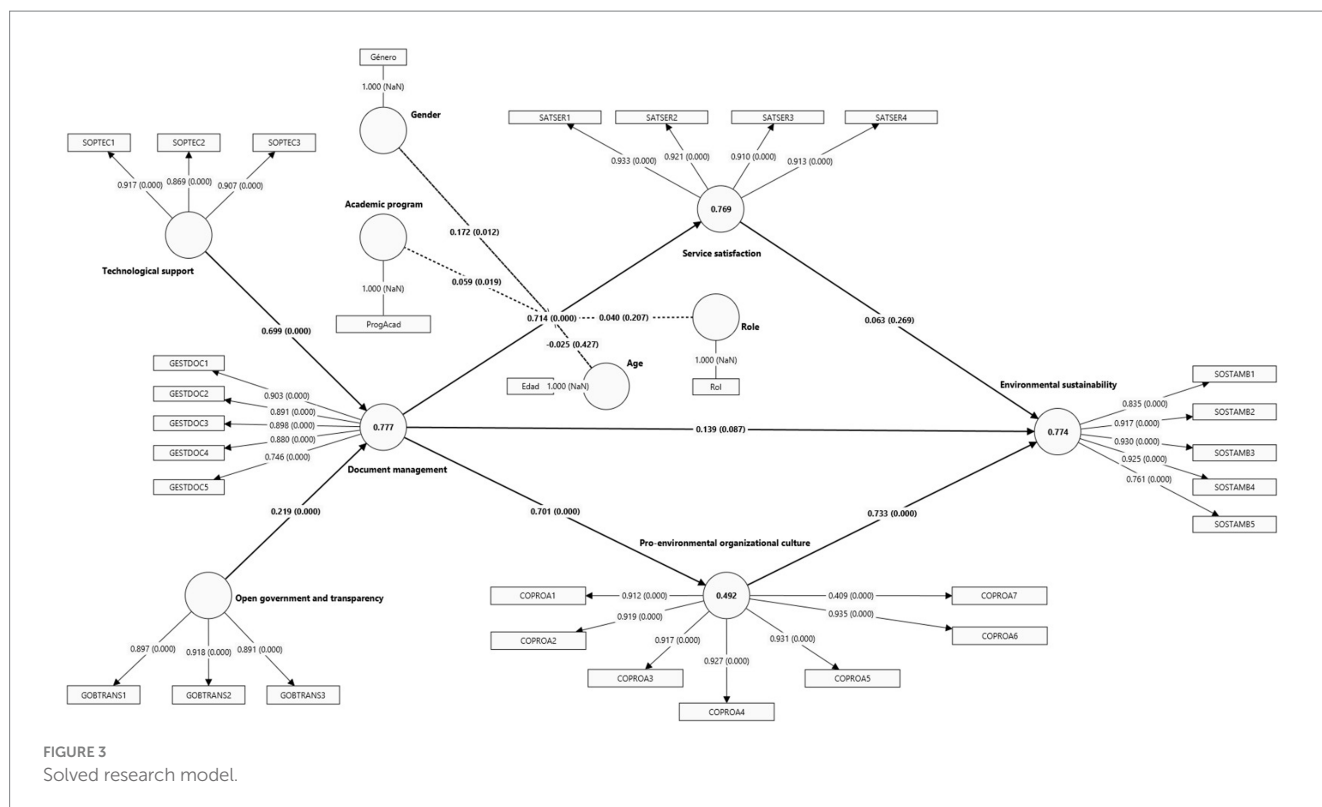


FIGURE 3
Solved research model.

lower values are preferable and these results suggest that the model has a good fit. The value of d_G (Geodesic Discrepancy) shows values of 0.897 for the saturated model and 0.945 for the estimated model. These close values also suggest a good fit of the estimated model compared to the saturated model. As with d_{ULS} , lower values indicate a better fit. The Chi-square value is 1,009.338 for the saturated model and 1,017.348 for the estimated model. The Chi-square measures the discrepancy between the observed data and the expected data by the model; lower values indicate a better fit. Although both values are relatively high, the small difference between them suggests that the estimated model does not differ much from the saturated model in terms of fit. The value of NFI (Normed Fit Index) is 0.948 for the saturated model and 0.929 for the estimated model. NFI values close to 1 indicate a good fit. Both values are high, suggesting that the estimated model has a reasonably good fit, although slightly inferior to the saturated model. Finally, the analyzed fit indices show that the estimated model has a good fit with the observed data. The values of SRMR, d_{ULS} , and d_G indicate that the discrepancies between the observed data and the predicted data by the model are small. Although the Chi-square values are high, the small difference between the saturated and estimated models suggests that the fit is adequate. Finally, the NFI value close to 0.93 supports the quality of the fit of the estimated model. These results suggest that the estimated model is a reasonably accurate representation of the relationships between the variables in the studied context.

4.7 Solved research model

The research model (see Figure 3) generated with the values: p -value, path coefficients and factor loadings between the constructs (direct, mediators and moderators) is presented below.

5 Discussion

The primary aim of the study was to evaluate the mediation of pro-environmental organizational culture and service satisfaction between document management and environmental sustainability. The SEM showed very satisfactory fit indices. Moreover, the R^2 values demonstrated that 49.2% of the variability in this area can be explained by the model, with an adjusted R^2 of 0.490. For document management, 77.7% of the variability can be explained by the model factors, with an adjusted R^2 of 0.775. Concerning service satisfaction, the analysis indicated that 73.4% of the variability can be explained by the model, with an adjusted R^2 of 0.733. Finally, for environmental sustainability, it was found that 78.1% of the variability can be explained by the model, with an adjusted R^2 of 0.771.

Regarding hypothesis 1, TS shows having a pivotal influence on document management. With a path value of 0.699 and a p -value of 0.000, this relationship is evidently positive and significant. In another context, Dwivedi et al. (2019) indicate that the role of technological support is a significant concern in research, where the acceptance and use of innovations in information systems (IS) and information technology (IT) were examined using theoretical models that investigate their acceptance; the Unified Theory of Acceptance and Use of Technology (UTAUT) stands out and suggests that the actual use of technology is determined by behavioral intention. It points out that technology adoption depends on performance and effort expectancy, social influence, and facilitating conditions, and individuals' perceptions of technology are crucial for enhancing job performance (Marikyan and Papagiannidis, 2023). Therefore, this hypothesis is validated, and although our research does not examine the acceptance theory, the findings suggest that technology use influences document management.

Concerning the second hypothesis, the outcomes of the relationship between open government and document management are also positive and significant, although weaker, with a path value of 0.219 and a p -value of 0.000. This suggests that transparency and open access to information contribute to better document management. As [Aguerre and Bonina \(2024\)](#), mention, digital technologies have recognized potential to build more efficient, credible, and innovative public institutions. Additionally, [Aguerre and Bonina \(2024\)](#), indicate that open government data are important agents of the DT of the public sector, allowing us to understand how strategies are designed, implemented, and evaluated for their continuous success, with the goal of engaging users and utilizing these vital resources ([Begany and Gil-Garcia, 2024](#)). It is necessary to have governance frameworks that allow the integration of technologies into different platforms and the adaptation to an increasingly digital society ([Zwitter, 2024](#)), constructing and interpreting data visualizations that simplify access to information, enhancing interpretation and strengthening information literacy ([Barcellos et al., 2024](#)). Therefore, these aspects suggest and confirm the importance of the relationship between OG as a catalyst for providing data for adequate document management.

Concerning the third research hypothesis, the outcomes show that DM has a notable impact on service satisfaction, with a path value of 0.857 and a p -value of 0.000. This evidences a positive and significant relationship, confirming that efficient document management is essential to ensure users are satisfied with administrative services. On the other hand, [Alade \(2023\)](#), indicates that an area that has experienced rapid growth in recent years is document management, a necessity in the work environment of an organization, concluding that it improves user satisfaction, increases productivity, and ensures data efficiency in a timely manner. Therefore, the results obtained in our hypothesis closely relate to what was indicated. In Peru, according to [Ramirez et al. \(2023\)](#), public institutions have a deficient document management service, so they implemented the automation technology to reduce the time for processing procedures and avoid citizen dissatisfaction, improving their experience. Thus, our hypothesis is significant to avoid such problems in organizations.

In the fourth hypothesis, the outcomes demonstrated that POC has a strong influence on environmental sustainability, with a path value of 0.726 and a p -value of 0.000. According to [Nanayakkara and Wilkinson \(2021\)](#), the theory of organizational culture is one of the most powerful in the workplace and could impact its processes and overall company performance. [Sindakis et al. \(2024\)](#) mention that the adoption and transfer of culture is achieved through knowledge exchange within and between areas. As [Schlegel et al. \(2023\)](#) point out in the context of DT, having an organizational culture based on data is an important factor in data analysis capabilities, innovation, and competitive advantages of companies. This allows us to infer that innovation and competitive advantage in companies are factors that contribute to environmental sustainability. According to the study by [Souza and Aganette \(2022\)](#), digital preservation and efficient document management are closely related to pro-environmental organizational culture. Consequently, this would generate digital use of documents, avoiding physical archives, which reaffirms the results obtained in our research. Similarly, [Netshakhuma \(2022\)](#) demonstrated that using the SharePoint platform as a document management system supports the development of a sustainability-oriented organizational culture. The reviewed studies provide evidence that efficient document

management can be the key driver for fostering a culture committed to environmental sustainability in HEIs. Therefore, based on the results, our hypothesis is accepted, as confronting it with various authors confirms this strong relationship between the two constructs.

The fifth hypothesis, examining the direct relationship between document management and environmental sustainability, was not accepted, as it yielded a path value of 0.103 and a p -value of 0.217. This indicates that document management alone does not have a significant direct impact on environmental sustainability, suggesting that its influence may be indirect and mediated by other variables, such as service satisfaction and pro-environmental organizational culture.

The sixth hypothesis shows a positive and significant connection, although relatively weak, with a path value of 0.185 and a p -value of 0.030. The impact of service satisfaction on environmental sustainability is not very strong. [Mansoor and Hussain \(2024\)](#) demonstrated that effective and user-centered management can significantly influence service quality, which in turn fosters a more sustainable environment inclined toward pro-environmental practices. Consequently, this indirect fostering is represented by the weak result in the relationship between these variables. Likewise, [Rolo et al. \(2024\)](#), regarding service quality in HEIs in Portugal and Angola, highlight the importance of adapting service quality strategies to local needs and expectations. In the context of environmental sustainability, this implies that HEIs should consider user particularities to implement sustainable practices that are positively perceived. Nonetheless, this finding suggests that improving user satisfaction can have beneficial effects on sustainability practices, albeit indirectly.

The seventh hypothesis, relating document management directly to environmental sustainability, was not accepted, with a path value of 0.103 and a p -value of 0.217. This evidences that document management alone does not have a significant direct impact on environmental sustainability. In conclusion, the outcomes of the direct hypothesis analysis highlight the importance of technological support, document management, and pro-environmental organizational culture as key factors for driving environmental sustainability.

5.1 Theoretical and practical implications

In terms of theoretical implications, this study contributes to the field of environmental sustainability in HEIs by exploring how document management, mediated by pro-environmental organizational culture and service satisfaction, contributes to sustainable practices. By incorporating these factors as mediators, the study provides a conceptual framework that evidences the influence of cultural and internal satisfaction dimensions on the effectiveness of environmental initiatives. Thus, the findings suggest that sustainability in HEIs depends not only on operational actions, but also on a committed institutional culture and the satisfaction of the organization's members. These results can serve as a reference for future research seeking to understand the relationship between organizational culture, service satisfaction and sustainability in different contexts and sectors. Furthermore, the application of the SEM model proves effective in analyzing these interrelationships, which reinforces the potential of this analytical tool in sustainability and management studies in educational settings.

And in reference to the practical implications, the findings highlight the need to implement sustainable strategies in document management within HEIs, promoting the digitization of documents, a greater reduction in the use of paper and the adoption of standards and practices that favor sustainability. The digitization and proper management of digital files not only improves the efficiency of document processes, but also significantly reduces the environmental impact of the institution. Additionally, the results indicate the importance of fostering a pro-environmental culture at all levels of the organization. To this end, it is essential to implement awareness and training programs, suggesting that courses should have content on environmental care and the implications of the carbon footprint, to strengthen the collective commitment to sustainability, ensuring that the university community actively participates in environmental initiatives and that these values are part of the institutional mission. Finally, the SEM analysis suggests that HEIs could develop environmental policies based on the principles of sustainability and document management, integrating a long-term environmental strategy that consolidates them as models of sustainability within the community, thus inspiring other organizations and promoting a significant transformation toward sustainability.

Aligned with the SDGs, the TD of document management in HEIs not only optimizes internal processes, but also contributes directly to quality and accessible education, in line with SDG 4, where the digitization of documents and institutional resources reduces physical barriers and facilitates more inclusive learning, allowing teachers, students and graduates to access relevant information regardless of their location. In the area of sustainable communities, established in SDG 11, HEIs can lead the change by adopting pro-environmental practices, strengthening the role of institutions as models of sustainability in society, inspiring both students and local organizations to adopt a culture of responsible consumption and practices aimed at greater community resilience and sustainable development.

On the other hand, the shift toward digitized document management allows IES to significantly reduce its consumption of paper and other resources, complying with the SDG 12 principles on responsible production and consumption. At the same time, these proactive digitization practices help to reduce the institutional carbon footprint, in line with SDG 13 on climate action, where, by reducing the physical storage and waste derived from printed documents, it contributes to mitigate climate change, reinforcing the role of higher education not only as a knowledge educator, but also as an actor committed to climate action and environmental preservation.

5.2 Limitations and future studies

Nevertheless, the study presents certain constraints. Firstly, the specific geographical and cultural context of a single university restricts the generalization of the findings to other institutions or regions with different cultural and geographical backgrounds. Moreover, although the model encompasses several key factors, there are other potentially significant variables that were not considered in this study, such as the availability of financial resources and the commitment of top management.

For future research, it is recommended to expand the scope of the study to other faculties within the same university or to other HEIs,

both nationally and internationally, to validate the generalization of the findings obtained. Additionally, it would be advantageous to include other pertinent variables that might impact environmental sustainability, such as financial resources, senior management commitment, and specific institutional policies on sustainability, which would enrich understanding in this field. Complementing quantitative analyses with qualitative studies would deepen the comprehension of the perceptions and experiences of university community members regarding sustainability practices.

6 Conclusion

In the context of HEIs, environmental sustainability has become a crucial pillar for institutional growth. This research has offered a more profound understanding of the factors affecting ES within a Peruvian HEI, using the Structural Equation Modeling (SEM) methodology through SmartPLS.

The analysis disclosed that technological infrastructure has a notable and favorable impact on document management, emphasizing the importance of investing in technology to streamline administrative operations and enable effective document management, as stated by Alade (2023), the web-based electronic DMS, obtained a 96.60% satisfaction of respondents. Consequently, efficiency in document management translates into higher service satisfaction and promotes a pro-environmental organizational culture, key elements for enhancing user experience and supporting sustainable practices within the institution. The pro-environmental organizational culture emerged as the strongest mediator, significantly influencing environmental sustainability, Barros et al. (2020) shows that in a Brazilian university introduced an electronic information system with the aim of virtualizing administrative processes (until then paper-based), resulting in savings of 57.5% in printed paper. Advancing an organizational culture dedicated to sustainability is vital to achieving favorable environmental results (valor path 0.726). Although service satisfaction also has a positive effect on environmental sustainability, its influence is less substantial (valor path 0.185) compared to other elements. Nonetheless, improving user experience is advantageous for sustainable practices. Transparency and open access to information, open government factors, aid in better document management, although their effect is not as marked (valor path 0.219) as other influences.

Additionally, sociodemographic factors such as gender and academic program within the institution moderate the relationship between the examined variables, indicating that these attributes can affect the perception and efficacy of sustainability practices.

Finally, designing and evaluating specific interventions based on the findings of the study, aimed at improving document management, technological support and pro-environmental organizational culture, would promote greater environmental sustainability in HEIs and contribute to the fulfillment of the SDGs. These interventions would not only improve the efficiency and accessibility of educational processes in line with SDG 4, but would also strengthen the role of universities as agents of change in their communities, aligning with SDG 11. Furthermore, by reducing paper consumption and promoting sustainable practices, these initiatives would be in line with SDG 12 and 13, reducing the institutional carbon footprint and contributing to global efforts against climate change.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee 2024-IIICyT-ITCA. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JB: Conceptualization, Funding acquisition, Investigation, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. CV: Conceptualization, Formal analysis, Investigation, Resources, Validation, Writing – original draft, Writing – review & editing. RA: Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. NG: Conceptualization, Data curation, Validation, Visualization, Writing – original draft, Writing – review & editing. OS: Data curation, Formal analysis, Investigation, Resources, Software, Writing – original draft, Writing – review & editing. JA: Formal analysis, Investigation, Resources, Visualization, Writing – original draft, Writing – review & editing. MA: Conceptualization,

Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. LG: Data curation, Formal analysis, Resources, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Understanding the drivers of a pro-environmental attitude in higher education institutions: the interplay between knowledge, consciousness, and social influence

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Academicians with a pro-environmental attitude can play a pivotal role in developing curricula and new programs aimed at education for sustainable development. Therefore, it is of utmost importance to identify the factors that influence academicians' positive attitude toward the environment. This study attempts to investigate the effects of environmental consciousness, environmental knowledge, and biospheric values, as well as the moderating effects of social influence, on the attitude toward the environment among the faculty members of higher education institutions (HIEs) in Southern Pakistan. The data were collected from six universities in the district of Vehari, Punjab, Pakistan. After checking for reliability and validity, the study used the structural equation modeling technique to examine the aforementioned association. The results reveal that environmental consciousness and biospheric values significantly influence the attitude of faculty members toward the environment. Furthermore, social influence positively moderates the relationship only between biospheric values and attitudes toward the environment. Overall, this study contributes original insights into the factors influencing pro-environmental attitudes among faculty in a specific cultural and educational context. Its findings can inform targeted strategies to enhance environmental education and engagement in higher education, making it a valuable addition to the literature on education for sustainable development. The findings could guide policymakers of higher education institutions in promoting a pro-environmental attitude among faculty members by implementing awareness programs that increase environmental consciousness and integrate biospheric values into their core mission. Furthermore, HEIs should also establish "green teams" to induce a positive environmental attitude through social influence.

KEYWORDS

higher education institutions, environmental consciousness, environmental knowledge, biospheric values, attitude toward the environment, social influence, sustainable development

1 Introduction

The concept of Education for Sustainable Development (ESD) emerged between 1990 and 2000 (Acosta-Castellanos et al., 2024), and it was founded on the sustainable development model presented by the United Nations (UN) on 4 August 1987. ESD is defined as “the process of equipping students with the knowledge, understanding, skills, and necessary attributes to work and live in a way that safeguards environmental, social, and economic well-being” (Longhurst et al., 2014). The basic aim of ESD is to address the environmental challenges caused by human activities and promote a sustainable future for coming generations through education (Marouli and Duroy, 2019; Rendón López et al., 2018). Furthermore, in 2014, 17 Sustainable Development Goals (SDGs) were announced by the UN (Biasi et al., 2019). The fourth goal of quality education states that “all students acquire knowledge and skills necessary to promote sustainable development” (Elmassah et al., 2022). In this sense, it has become the core responsibility of higher education institution (HEI) teachers to develop curricula and new programs in line with the concept of SDGs. Environmental education is deemed essential for enhancing pro-environmental behavior and effectively preserving the natural environment (Fortner and Teates, 1980; Michelsen and Fischer, 2017). Comprehending Pakistan’s complex environment, a nation confronting numerous environmental challenges, aids in delineating the arduous path that lies ahead. The notion of environmental sustainability is at its nascent stage of comprehension in Pakistan, with most individuals failing to adopt practices for environmental protection and preservation.

Pakistan, an emerging economy, is among the top 10 countries that are prone to environmental catastrophes as a result of global warming (Siddiqui, 2022). Out of 118 economies, it has also been classified as the second-most polluted country in the world (Rasool et al., 2021). Furthermore, 10,000 recorded deaths have been attributed to environmental disasters, and 173 extreme weather occurrences have cost the nation more than USD 4 billion in lost revenue (Siddiqui, 2022). The amount of solid trash that Pakistan produces each year is estimated to be 20 million tons, and it is increasing by 2.4% annually. In the absence of sufficient trash collection and disposal, the majority of this waste is burned or is allowed to decay in dumps, which are typically located in cities. According to the data, more than 90% of polluted industrial and city waste is discarded into the ocean. Recycling and ecologically friendly solid waste management are rarely taken into consideration, even though rubbish collection is occasionally given priority on the national agenda as a result of poor governance. The climate difficulties facing Pakistan have been identified by the US Institute of Peace as a threat to national security that calls for immediate action from the government, businesses, and consumers, indicating that the situation appears dire. Furthermore, economic and industrial development provides many benefits to human life, but it also creates difficulties such as air pollution, water pollution, and climate change. These difficulties affect the environment, society, and economic growth, yet research indicates that over the past two decades, affluent economies have made significant progress toward addressing environmental change (Nozari et al., 2021). However, an important gap between environmental issues and environmental adaptability has been observed in growing

economies (Hameed et al., 2019). This gap is frequently attributed to the limited understanding of the population regarding environmental changes (Ikeme, 2003), and the lack of commitment by the HEIs to emphasize mounting environmental degradation issues in the curricula (Habib et al., 2021).

Therefore, the present research concentrates on the academicians of HEIs since they are seen to be influential in encouraging students to adopt green practices by imparting knowledge about environment-friendly items that both normalize and protect the environment. These students can play a pivotal role in establishing eco-friendly mechanisms and practices in the industries where they will find employment after graduation. However, prior research has overly focused on the collaboration of consumers and marketers to reduce pollution and environmental destruction (Nozari et al., 2021). Others have analyzed the impact of environmental knowledge, consciousness, and values mainly on green purchase intentions (Chanda et al., 2024; Li et al., 2021; Sherwani et al., 2021; Zaremohzzabieh et al., 2021). Zsóka et al. (2013) investigated the association between environmental education, environmental knowledge, attitudes, and self-reported behaviors among university and high school students. The study by García-Salirrosas et al. (2024) demonstrates that environmental awareness positively influences attitudes and perceived behavioral control. However, there is a serious lack of research on how these factors influence the positive attitude of the academicians of HEIs toward the environment in an environmentally prone country. Pakistan is confronted with significant environmental challenges, including severe air and water pollution, deforestation, and heightened vulnerability to the impacts of climate change. Understanding how academics perceive and engage with these environmental issues is essential for fostering a culture of sustainability within higher education, which, in turn, can influence future generations. Academics play a critical role in shaping public opinion and policy through their research, teaching, and community engagement. By systematically examining faculty attitudes toward the environment (ATE), this study aims to elucidate how faculty members can effectively serve as advocates for environmental stewardship, thereby exerting a positive influence on their students and the broader community. This exploration is vital for developing strategies that promote sustainability and enhance the role of higher education in addressing pressing environmental concerns. The present study attempts to fill this gap in the literature in the context of Pakistan, where awareness about climate change is still in its infancy. More precisely, the purpose of this study is to analyze the impacts of EK, EC, and BV, as well as the moderating effects of SI, on the attitude toward the environment among the faculty members of higher education institutions in Pakistan using the value-belief-norm theory and the theory of the planned behavior model. This is the first study that uses social influence as a moderator between environmental knowledge, environmental consciousness, biospheric values, and ATE. Bertossi and Marangon (2022) contributes to the scientific literature by highlighting the pivotal function of higher education institutions (HEIs) in promoting sustainable development through the encouragement of pro-environmental behaviors among students, but this research contributes to the literature by focusing on the academicians of HEIs toward the environment.

This study will contribute to the existing body of literature in several ways. First, it adds to the growing debate on sustainability transformation in higher education institutions in emerging economies. This will help developing economies to align their educational policy with ESD. Second, our paper enriches the growing literature on the determinants of positive attitude toward the environment. This attitude will not only help us build a responsible society but also save trillions of dollars through conserving natural landscapes and water resources. Third, students tend to apply the standards and values imparted by their teachers, which will help them make eco-friendly decisions in their practical lives. We also extended the horizon of research on ESD by examining the role of different individual and social indicators in shaping the pro-environmental attitudes of the key players (i.e., academicians) of HEIs. Finally, this research provides theoretical guidance on how HEI policymakers can develop an eco-friendly attitude among their employees.

2 Theory, literature review, and hypothesis development

2.1 Theoretical underpinning

Stern et al. (1999) developed the value-belief-norm (VBN) theory to explain how human values impact behavior in an environmental setting. This theory proposes a causal chain of linkages between values, beliefs, norms, and behaviors (Choi et al., 2015; Stern, 2000b; Stern et al., 1999). By serving as a trigger for the activation of personal norms toward pro-environmental behavior, environmental knowledge can reinforce ideas about environmental issues. Environmental consciousness fosters good attitudes and, eventually, pro-environmental behavior by reinforcing beliefs about the effects on the environment and one's own duty. Importantly, people with strong biospheric values are likely to sense a moral need to preserve the environment. Stern et al. (1999) mentioned how beliefs about environmental risks are shaped by values, especially biospheric values. These ideas then trigger individual norms that result in actions to benefit the environment.

The theory of planned behavior (TPB) is the addition of the theory of reasoned action (TRA) (Schiffman et al., 2010). According to the theory of planned behavior (TPB), individuals' behavioral intentions are influenced by three key factors, namely, their attitudes toward the behavior, subjective norms, and perceived behavioral control (Ajzen and Fishbein, 2001). TPB is an attitude mold used to check links between individuals' beliefs and societal standards of their ecological procurement (Khare, 2015). In many studies on green intentions, TPB is utilized as an interpreter (Ko and Jin, 2017; Paul et al., 2016; Yadav and Pathak, 2017). Scalco et al. (2017) showed that TPB is a strong representation to describe personal behavior toward eco-friendly products. TRA was developed to anticipate the intentions in the sectors of green marketing, for instance, reusing behaviors (Davies et al., 2002) and environmentally friendly products (Ha and Janda, 2012; Sparks and Shepherd, 1992; Wahid et al., 2011). Han et al. (2010) mentioned that TPB is authorized to study the impact of individual factors, non-volitional factors, and the public

environment on attitude and intentions. Many studies utilized TPB to explore environmental knowledge and concerns (Maichum et al., 2016). Furthermore, TPB also includes subjective norms, which represent the influence of others (e.g., social influence) on an individual's actions. Therefore, TPB serves as the basis for studying teacher's attitudes regarding the environment.

2.2 Environmental knowledge and attitude toward the environment

Blackwell et al. (2006) highlighted that an individual's attitude is a negative or positive belief, action, or behavior, which, in turn, influences their actions or behaviors. If people know the reason and effect of their actions on the environment, their knowledge intensity will enhance and will encourage a positive attitude toward the environment (Cox, 2008; D'Souza et al., 2006). Teachers are considered the most influential in educating youth—the leaders of tomorrow—to protect the environment. Higher education institutions are social entities responsible for educating future leaders who possess the necessary abilities and skills to tackle societal issues (Menon and Suresh, 2022). HEIs can significantly contribute to achieving sustainable development as they can function as “change agents” and “co-creators for sustainability” (Peer and Stoegelehner, 2013; Stephens et al., 2008; Trencher et al., 2014). Thus, they should also have good knowledge about the environment and demonstrate pro-environmental behavior and attitude to integrate the concept of ESD into their teaching methodology (Esa, 2010). Many studies used environmental knowledge as an interpreter of eco-friendly attitudes and intentions. Environmental knowledge and attitude toward environmental products are interlinked (Yadav and Pathak, 2016). EK and attitude toward the environment mutually reinforce each other (Bamberg et al., 2003). Barber et al. (2009) emphasized that attitudes toward the environment tend to shift favorably as environmental knowledge develops. Consumers' attitudes toward eco-friendly products can also change as they acquire new information about these items (Polonsky et al., 2012). Additionally, students and teachers who have taken courses on sustainable development exhibit significantly more positive attitudes toward sustainability (Nousheen et al., 2020). Environmental knowledge, motivation (Vicente-Molina et al., 2013), intellectual information, and values play a crucial role in shaping green attitudes and promoting the adoption of environmentally responsible behaviors (Schneiderhan-Opel and Bogner, 2020). Yadav and Pathak (2016a) examined the positive impact of environmental knowledge on attitudes toward green products. Consistent with this study, previous studies, such as Kaiser and Gutscher (2003), have concluded that environmental knowledge positively influences environmental attitudes. According to Rios et al., (2006), Lee (2008a), Kaiser and Gutscher (2003), Huang et al. (2014), individuals with greater knowledge and concern for the environment tend to have a positive attitude toward eco-friendly products. Therefore, based on these findings, we hypothesize the following:

H1: Teachers' EK has a positive impact on their attitude toward the environment.

2.3 Environmental consciousness and attitude toward the environment

Environmental consciousness is an important part that is related to knowledge and ideas about emotional values, behaviors, and beliefs about environmental protection (Shagun et al., 1994). Environmental consciousness explains that people are aware of their environmental troubles and their willingness to resolve and deal with these troubles (Alibeli and Johnson, 2009). The issue of environmental consciousness is rarely studied in the context of teachers and HEIs in Pakistan. Habib et al. (2021) showed that sustainability in Pakistan's higher education institutions is in its infancy. According to Kalsoom et al. (2017), pre-service teachers in Pakistan demonstrated lower levels of sustainability consciousness than those in Swedish upper secondary pupils. However, a bunch of studies are available from the perspective of consumer green purchase intentions (Alsmadi, 2007; Kim and Seock, 2009). Environmentally conscious individuals are more likely to utilize green items (Hu et al., 2010; DiPietro and Gregory, 2012).

Numerous researchers have established a positive relationship between environmental consciousness and the intention to take pro-environmental actions (Chen and Peng, 2012; Schwepker Jr and Cornwell, 1991; Walker, 2013; Wang et al., 2014). Jamanti (2014) suggests that environmental consciousness is associated with changes in beliefs, attitudes, and intentions, which contribute to environmental improvement. Previous studies have also found a positive relationship between environmental consciousness (EC) and individuals' attitudes toward ecological products (Mishal et al., 2017). Individuals with a strong sense of environmental consciousness are more likely to have higher intentions to preserve the natural world (Dhandra, 2019). Law et al. (2017) and Verplanken (2018) demonstrated that environmental consciousness fosters positive environmental attitudes and strengthens the intention to use eco-friendly products. Moreover, environmental consciousness has been shown to positively influence both attitudes and intentions (Salam et al., 2021). Based on these findings, we hypothesize the following:

H2: Teachers' environmental consciousness has a positive impact on their attitude toward the environment.

2.4 Biospheric values and attitude toward the environment

According to Bhattacharyya and Rahman (2020), values are considered key determinants in forecasting and explaining various variables, such as attitudes and behavioral intentions. Biospheric values, in particular, offer a more nuanced perspective on individuals' views toward the natural environment (Lee et al., 2013). These values emphasize environmental superiority, contributing to individual wellbeing (Nguyen et al., 2016). Individuals with higher biospheric values are more concerned about the benefits of the environment and natural resources (Ateş, 2020; Kim and Koo, 2020), and they often identify as pro-environmental (Hughner et al., 2007). Those with a biospheric value orientation tend to prioritize the intrinsic value of nature and the environment (Gkargkavouzi et al., 2019). Moreover, biospheric values are positively correlated with green attitudes (Steg et al., 2014). Stern et al. (1993) suggested that the

value orientation model emphasizes the influence of environmental values, particularly biospheric values, on attitudes toward the environment. Lee and Jan (2015) mentioned that biospheric values can significantly shape responsible environmental behavior. Additionally, biospheric values directly influence the development of individuals' pro-environmental attitudes (Stern et al., 1998). Rahman and Reynolds (2019) found that biospheric values, along with attitudes toward the environment, can predict individuals' patronage intentions. Several studies have identified biospheric values as a primary predictor of attitudes toward the environment (Dietz et al., 1998). Hansla et al. (2008) asserted that biospheric values, as part of environmental concerns, directly influence decision-making through attitudes. Individuals who hold values emphasizing human unity, especially those with a biospheric value orientation, are more likely to adopt positive attitudes toward environmental safety efforts (Kempton et al., 1996). Biospheric values also mediate the relationship between attitudes and eco-friendly behavior (Martin and Czellar, 2017). According to Steg and De Groot (2012), biospheric values may serve as a predictor for eco-friendly product preferences, sustainable behavior, intentions, and environment-related norms. Based on these insights, we hypothesize the following:

H3: Teachers' BV has a positive impact on their attitude toward the environment.

2.5 Moderating role of social influence

Social influence (SI) refers to the changes in an individual's attitudes and behaviors as a result of the influence of others around them (Delamater and Myers, 2010). SI occurs when individuals modify their opinions, thought processes, or actions in response to social pressures or their environment (Turner, 1991). It alters perspectives and behaviors to align with those of a broader social group (Chen-Yu and Seock, 2002). SI has been identified as a significant factor in shaping green behavior among university students (Irawan and Darmayanti, 2012) and is considered a substitute for subjective norms (Wahid et al., 2011). Studies by Salazar et al. (2013) and Costa et al. (2014) in advanced countries, with their distinct cultural contexts, highlighted the significant role of SI in influencing green behavior. Lee (2008b) argued that SI is a key factor in shaping green purchase intentions. It is expected that if educators are knowledgeable about the environment, their attitudes toward it will be positive, and this relationship will be further strengthened if individuals in their social circle also encourage environmentally friendly behaviors. People tend to adjust their environmental attitudes based on societal opinions. Therefore, we hypothesize the following:

H4: Social influence will positively moderate the relationship between teachers' EK and ATE.

Hoyer and MacInnis (2004) established that the behavior of people is affected by their feelings and thoughts. In Western countries, different researchers have studied the relationship between environmental consciousness and attitude toward the environment (Roberts and Bacon, 1997; Van Liere and Dunlap, 1981). Teachers as role models have a positive influence on the pro-environmental behavior of students (Liang et al., 2022). Society often expects teachers to be role models in promoting environmental awareness. Furthermore, environmentally conscious parents also exert pressure on educators to equip their children with environmental knowledge. Therefore, it is expected that, if

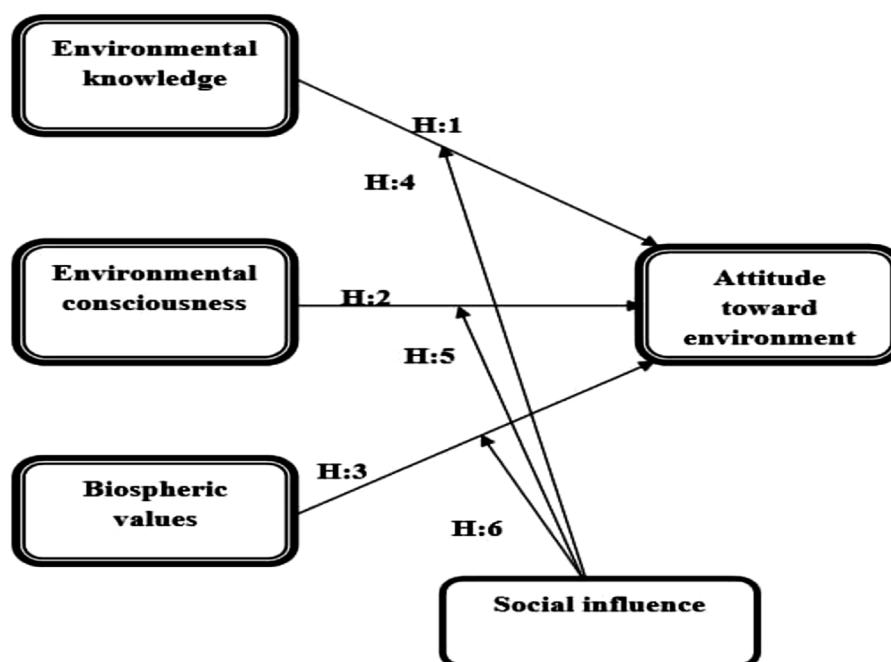


FIGURE 1
Conceptual framework.

teachers are conscious of the environment, they will be more alert regarding the effects of their doings on the environment, and the opinion of other parents/society will strengthen this relationship. Thus, we built the following hypothesis:

H5: Social influence will strengthen the relationship between teachers' EC and ATE.

Biospheric values are essential in motivating eco-friendly beliefs, norms, and behaviors. BV highlights the inherent value of the natural world and the environment. Values, beliefs, attitudes, or norms change with time (Feather, 1995). These values, beliefs, and norms affect the attitudes and behavior of individuals (Nordlund and Garvill, 2003). Many studies have found that values influence behavior, attitude, and motivation (Howell and Allen, 2019), and it also affects attitudes and actions toward the environment (Stern, 2000a). Human attitude toward the environment is strongly affected by values (Liu and Chen, 2020). Therefore, it is expected that people having higher BV will have a positive attitude toward the environment, and this relationship will be strengthened by social influence if the opinion of other people and society also encourages green behavior. The following hypothesis has been developed:

H6: Social influence will positively moderate the relationship between teachers' BV and ATE.

3 Methodology

3.1 Research design

The data for this study were collected through questionnaires. A causal research design was employed to test the hypotheses involving independent, moderator, and dependent variables.

Questionnaires were distributed to the target respondents both in person and online. The conceptual framework of the study is presented in Figure 1.

3.2 Procedures

The target population of this study was university teachers of the Vehari district, Pakistan. Respondents are teachers of COMSATS University Islamabad, Vehari campus (CUI, Vehari campus), University of Education Vehari Campus (UE, Vehari campus), Bahaudin Zakariya University, Vehari Campus (BZU, Vehari campus), Virtual University Vehari campus (VU, Vehari campus), University of Agriculture Faisalabad, Burewala Campus (UAF, Burewala campus), and PMAS Arid Agriculture University Burewala Campus (PMAS, Burewala campus). Stratified random sampling—employed in current research—is competent in cost and time (Guthrie, 2010). According to Huysamen (1994), stratified random sampling is a valuable instrument in research. In this study, six strata are formed. Samples are drawn from each stratum according to the whole strength of teachers in each university. The study used the sample size formula by Hair et al. (2014) (28×10). According to Hair et al. (2014), the sample size of this study is 280. However, 420 respondents were selected for the study, which is adequate for data analysis.

3.3 Measures

The first independent variable, environmental knowledge, is measured through a questionnaire with five items adopted from

TABLE 1 Respondent demographics (N = 350).

Measure	Category	Frequency	Percentage
Gender	Male	198	56.6
	Female	152	43.4
Age	25–30	59	16.9
	31–40	197	56.3
	41–50	75	21.4
	51 or above	19	5.4
Qualification	MS/M.Phil	205	58.6
	PhD	145	41.4
Job scale	Research associates	123	35.1
	Lecturer	212	60.6
	Assistant professor	15	4.3
Institution	CUI, Vehari campus	130	37.1
	UE, Vehari campus	59	16.9
	BZU, Vehari campus	25	7.1
	VU, Vehari campus	64	18.3
	UAF, Burewala campus	34	9.7
	PMAS, Burewala campus	38	10.9

Fryxell and Lo (2003). The second independent variable, environmental consciousness, measured using a questionnaire with ten items, is adopted from Alsmadi (2007), and the third independent variable, biospheric values, is measured with four items

taken from Steg et al. (2014). The dependent variable, an attitude toward the environment questionnaire with three items, is opted from Lee (2011). The social influence is measured with three items adopted from Armitage and Conner (1999). The participants’ answer to each item is measured on a 5-point Likert scale. According to Zikmund et al. (2003), “1” is equal to strongly disagree and “5” is equal to strongly agree.

3.4 Data analysis

The quantitative technique for data analysis is used in this study. SPSS software is used for the descriptive statistics, whereas SmartPLS-3 is used for the structural equation model and analysis of the measurement model. The structural model has two sub-models, namely, the inner model, which describes the association between independent and dependent variables, while the outer model describes the association among variables and their items. SmartPLS in functional research is used for structural models when respondents are finite and the distribution of data is slanted (Wong, 2011). SmartPLS also represents an algorithm to calculate regression models and bootstrapping to calculate the statistical significance of data. All these features make SmartPLS the best fit for the current study.

4 Empirical results

4.1 Respondents’ demographics

We contacted almost 420 respondents, out of which 378 answers were returned. After excluding missing and

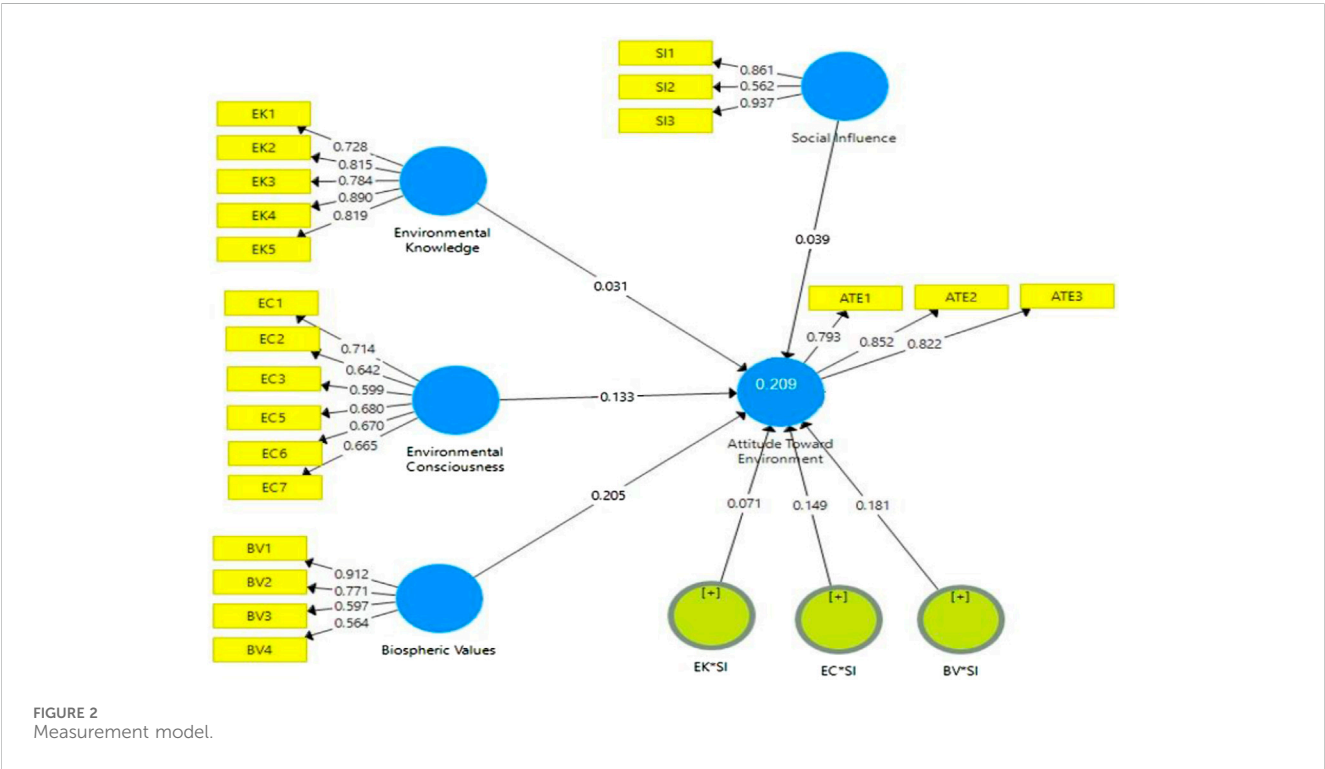


TABLE 2 Outer loadings, reliability analysis, and AVE.

Construct	Item	Loading	CR	Cronbach's alpha	AVE
Environmental knowledge	EK1	0.726	0.904	0.870	0.655
	EK2	0.816			
	EK3	0.784			
	EK4	0.889			
	EK5	0.821			
Environmental consciousness	EC1	0.715	0.824	0.784	0.523
	EC2	0.640			
	EC3	0.594			
	EC4	0.681			
	EC5	0.670			
	EC6	0.666			
Biospheric values	BV1	0.915	0.808	0.776	0.522
	BV2	0.768			
	BV3	0.590			
	BV4	0.560			
Attitude toward environment	ATE1	0.810	0.863	0.761	0.677
	ATE2	0.843			
	ATE3	0.815			
	GPI2	0.871			
	GPI3	0.802			
Social influence	SI1	0.860	0.840	0.766	0.646
	SI2	0.566			
	SI3	0.937			

TABLE 3 Fornell–larcker criterion.

	Attitude toward environment	Biospheric value	Environmental consciousness	Environmental knowledge	Social influence
Attitude toward environment	0.823				
Biospheric values	0.251	0.723			
Environmental consciousness	0.201	0.178	0.662		
Environmental knowledge	0.114	0.150	0.368	0.809	
Social influence	0.093	0.137	0.056	0.065	0.804

Note: The bold values represent the square root of average variance extracted.

outliers, the current study considered 350 valid responses. Demographic information provided in Table 1 shows that 198 respondents are male and 152 are female respondents. The ages of respondents were from 25 to 30 years for 59 respondents, which is (16.9%), 31–40 years for 197 respondents, which is (56.3%), 41–50 years for 75 respondents, which is (21.4%), and 50 or above years for 19 respondents, which is (5.4%). Approximately 58% of the respondents were qualified MS/M. Phil, 41% of the respondents were qualified for Ph.D., 60% of the respondents

TABLE 4 Multicollinearity (inner VIF) results.

	ATE
EK	1.169
EC	1.178
BV	1.058
ATE	1.000
SI	1.022

were lecturers, 35% of the respondents were assistant professors, and 4% were research associates. In total, 37% of the respondents were from CUI Vehari, 16% of the respondents were from the University of Education, Vehari, 7% of the respondents were from BZU Vehari, 18% of the respondents were from VU Vehari, 9% of the respondents were from UAF Burewala, and 10% of the respondents were from PMAS AAU Burewala.

4.2 Measurement model

As shown in Figure 2, the measurement model determines reflective and formative measurement. The reflective measurement evaluates construct reliability and validity. A validity test is used to check the correctness of items through SmartPLS. Convergent and discriminant validity are used to evaluate validity. Furthermore, unlike traditional regression techniques, the structural equation modeling (SEM) technique can examine direct, indirect, and mediating effects, making it ideal for testing intricate causal relationships. It is particularly useful when dealing with latent variables, such as attitudes or motivations, as it estimates their relationships with observed variables. Additionally, SEM provides a comprehensive approach by assessing both measurement and structural models together, ensuring robust results. Therefore, the current study employed SEM as its core statistical methodology to examine the proposed association.

4.2.1 Reliability analysis

The SmartPLS algorithm is used to evaluate the composite reliability (Holland & Light) of the construct. Cronbach's alpha value must be larger than 0.7 (Litwin, 1995), as must the CR of all constructs (Hair et al., 2011), so the result value of six variables shows

high internal consistency and reliability. According to Nitzl (2010) and Fuchs (2011), Cronbach's alpha must be 0.7 or higher. According to Götz et al. (2010), the reliability of all indicators is checked through the factor loading of each item in the construct. The indicator reliability of individual items is represented via outer loading.

Table 2 represents that the outer loading value of all items is higher than 0.5, except for four items of environmental consciousness, because outer loading values are less than 0.5. Researchers concluded that items with a loading value of 0.5 are acceptable, while those less than 0.5 are not acceptable and should be removed (Chin, 1998; Hair et al., 2010b). SmartPLS is used to check the factor loading values of all indicators of the model. The factor loading value of 0.4 is acceptable (Holland and Light, 1999), and loading values between 0.4 and 0.7 of items must be assessed before removing (Ringle and Sinkovics, 2009).

4.2.2 Convergent validity

Convergent validity highlighted how intimately scale is related to other variables and measures of equivalent construct. The outer loading values of items and average variance extracted (Zafar et al., 2019) technique were used to assess the similarity of the construct. High outer loading values of declared indicators have high reliability. The outer loading values of all items are higher than 0.5, with the exception of four items of environmental consciousness, which have outer loading values less than 0.5. Convergent validity is represented by the AVE of variables (Fornell and Larcker, 1981). The average variance extracted value of the construct must be higher than 0.5. Table 2 presents all AVE values that are higher than 0.5.

4.2.3 Discriminant validity

Fornell and Larcker (1981) measured discriminant validity via associating the square root of AVE of construct correlation. The AVE square root of the construct should be high in construct correlation (Fornell and Larcker, 1981). Table 3 represents square root values in a diagonal way of construct that meets the requirement.

4.3 Structural equation model

The structural models illustrate the relationship between the independent and dependent variables. According to Urban and Mayerl (2013), it provides an opportunity to test the hypotheses and also illustrates fundamental apparatus if the model does not completely fail. It helps make a decision regarding the acceptance or

TABLE 5 Hypothesis testing.

Hypotheses of the study	Path coefficient	T-statistics (O/STDEV)	P-value	Decision
EK → ATE	0.031	0.677	0.490	Not supported
EC → ATE	0.133	2.322	0.014	Supported
BV → ATE	0.205	4.615	0.000	Supported
EK*SI → ATE	0.071	0.959	0.312	Not supported
EC*SI → ATE	0.149	0.928	0.356	Not supported
BV*SI → ATE	0.181	3.056	0.002	Supported

rejection of the hypotheses. The multicollinearity, *t*-value, *p*-values, and path coefficients were completed, and these results are presented in Tables 4, 5, respectively.

4.3.1 Multicollinearity

Multicollinearity is recognized through the assessment of VIF (Hair et al., 2010a). Multicollinearity occurs when independent variables are associated with the model. According to Hair et al. (2011), the value of VIF must be less than 5.0. Table 4 shows that the VIF values are less than 5.0, indicating that there is no evidence of multicollinearity among independent variables.

4.3.2 PLS measurement results for the inner model

Table 5 provides the results of all the hypotheses of the study. Path coefficient values were tested through the SmartPLS algorithm function, whereas *t*-values were tested through the SmartPLS bootstrapping function. The table signifies the assessment of SmartPLS results. Path coefficient has values between +1 and −1, with +1 indicating a strong positive relationship, −1 indicating a strong negative relationship, and 0 indicating a weaker relationship. *p*-values and *t*-statistics were evaluated for significant levels.

4.3.3 Hypothesis testing and results

The SmartPLS bootstrapping technique is used to estimate the *t*-values that conclude the significance of the relationship between the variables. Table 5 shows that environmental knowledge (*t*-value = 0.677, *p*-value = 0.490, and *r* = 0.031) does not have a significant impact on the attitude toward the environment. Environmental consciousness (*t*-value = 2.322, *p*-value = 0.014, and *r* = 0.133) has a positive and significant impact on the attitude toward the environment. Biospheric values (*p* < 0.01) have a positive and significant impact on the attitude toward the environment. Social influence (*t*-value = 0.959, *p*-value = 0.312, and *r* = 0.071) does not significantly moderate the association between EK and ATE. Social influence (*t*-value = 0.928, *p*-value = 0.356, and *r* = 0.149) also does not moderate the relationship between environmental consciousness and attitude toward the environment. However, SI (*p* < 0.05) positively and significantly moderates the relationship between BV and ATE. As a result, H2, H3, and H6 are supported at the 0.05 significant levels.

5 Conclusion

The current study aimed to investigate the factors influencing pro-environmental attitudes among faculty members in the higher education institutions (HEIs) of Pakistan, with a focus on environmental consciousness, environmental knowledge, biospheric values, and the moderating role of social influence. The findings indicate that environmental consciousness and biospheric values significantly shape faculty attitudes toward the environment, supporting H2 and H3. Additionally, the moderating effect of social influence was observed, specifically enhancing the relationship between biospheric values and attitudes toward the environment, supporting H6. These insights contribute to the literature on ESD, offering valuable recommendations for enhancing environmental education within HEIs. By highlighting

the importance of raising environmental consciousness and integrating biospheric values into institutional practices, the study provides actionable guidance for policymakers and educational leaders to foster a pro-environmental culture among faculty members. Finally, the study achieved its objectives by identifying key factors influencing the pro-environmental attitude among faculty members in higher education institutions (HEIs) in Southern Pakistan.

6 Discussion

Education for Sustainable Development is mentioned in United Nation's Sustainable Development Goal (SDG) # 4, and Pakistan is among those nations that have adopted SDGs as their national agenda (Nousheen et al., 2020). However, the essential role of education in boosting productivity and creating job opportunities cannot be overlooked (Akbar et al., 2023). It is a well-established fact that teachers pass on their norms and beliefs to their students, who then apply these norms in their practical lives after graduation. Therefore, the present study explored the antecedents of HEI teachers' attitude toward the environment, with the moderating role of social influence. First, we analyzed the impact of environmental knowledge on ATE. Results show that the impact of EK on ATE is very weak and insignificant. In Pakistan, a significant portion of the population lacks sufficient environmental awareness. As noted by Levine and Strube (2012) and Fielding and Head (2012), meaningful efforts toward environmental protection are contingent on individuals possessing accurate and adequate knowledge; otherwise, such efforts remain ineffective. In the context of Pakistani higher education institutions (HEIs), sustainability is not deeply integrated into curricula or faculty development initiatives (Habib et al., 2021). Consequently, many individuals remain unaware of whether the products they use are environmentally friendly or recyclable. Additionally, faculty members in Pakistani HEIs exhibit limited knowledge of education for sustainable development (ESD), with minimal exposure to holistic or alternative learning approaches (Saqib et al., 2020). These factors may collectively explain why H1 is not supported in this study. Findings illustrate that the impact of environmental consciousness on the attitude toward the environment is significant. It implies that H2, which states that environmental consciousness has a positive impact on the attitude toward the environment, is supported. Previous studies suggest that environmental consciousness emerges from changes in beliefs, attitudes, and intentions, which collectively drive actions that contribute to environmental improvement (Jamanti, 2014). Mishal et al. (2017) found a positive connection between environmental consciousness and people's attitudes. Furthermore, the theory of planned behavior (TPB) posits that attitudes toward a behavior are shaped by beliefs about the outcomes of that behavior. Accordingly, higher levels of environmental consciousness are expected to foster positive beliefs about the benefits of pro-environmental actions, thereby promoting a more favorable attitude toward the environment. Empirical findings also demonstrate that biospheric values significantly influence attitudes toward the environment. TPB further emphasizes that attitudes are shaped by underlying beliefs and values; thus, individuals with strong biospheric values are more likely to hold positive beliefs about the benefits of environmental protection,

ultimately cultivating a positive attitude toward the environment (ATE). Notably, the younger generation, which upholds biospheric values, tends to be more inclined toward supporting a clean and sustainable society (Schuitema and De Groot (2015) and is better informed about environmental issues (Ansar, 2013).

Here is an improved version of the paragraph:

The results indicate that social influence does not moderate the relationship between environmental knowledge and attitudes toward the environment. In Pakistan, where a substantial portion of the population has limited awareness of environmental issues, it is unlikely that individuals can effectively impart environmental knowledge to others or influence their decisions and attitudes toward the environment. Moreover, research suggests that even when people observe the impacts of climate change, their ability to adapt remains constrained if they lack access to critical resources such as land, financial means, or accurate information (Bryan et al., 2009; Bryan et al., 2013). Furthermore, households tend to adjust their lifestyles in response to a combination of economic, social, and environmental stressors rather than focusing solely on climate-related factors. As a result, perceptions of climate change may have a limited influence on their adaptation strategies (Burnham and Ma, 2018; Erwin et al., 2021; Galappaththi et al., 2020; Hoque et al., 2018; Lenaiyasa et al., 2020). The results reveal that social influence (SI) positively moderates the relationship between biospheric values (BV) and attitudes toward the environment (ATE). This moderation occurs because societal norms and interactions significantly shape individuals' beliefs and behaviors regarding environmental protection, reducing pollution, respecting nature, and recognizing the benefits of preserving the environment and natural resources. Furthermore, it is essential to highlight that curricula play a critical role in addressing sustainability challenges in the emerging world, fostering awareness and equipping individuals with the knowledge needed to tackle these issues effectively (Abbas et al., 2019). Academicians play a pivotal role in developing curricula for HEIs. Therefore, any goal to achieve a sustainable environment without considering teachers will remain a dream.

6.1 Practical implications

The current study has important implications for incorporating the ESD framework in developing countries like Pakistan. The government, regulators, and educators can get a deeper insight into how to positively influence the attitude of the teachers toward the environment, which will have transformational effects on the pro-environmental behavior of the students (Liang et al., 2022). To boost teachers' eco-friendly attitude, policymakers should formulate policies that support environmental consciousness and biospheric values in educational institutions. Higher environmental consciousness and biospheric values among HEI faculty can lead to increased adoption of sustainable practices, reduced resource consumption, and potentially lower operational costs. This could also foster a culture of research and innovation in green technologies, which could attract funding and partnerships, boosting economic competitiveness in the education sector.

Moreover, to encourage students toward environmental protection, teachers can incorporate increasing amounts of

content related to environmental issues into their course outlines. Meanwhile, the government's initiatives supporting ESD will help protect natural resources, leading to the creation of a green society that serves as a symbol of sustainable growth. These initiatives will raise a high level consciousness in the society at large, and as people's extent of social awareness increases, more and more people will become conscious of the value of living environmentally. From a business perspective, the first step in convincing customers to express their intention to buy green products is education. As part of their corporate social responsibility (CSR) strategy, managers can create marketing campaigns and educate the community about the benefits of being green. This may promote companies by increasing consumer demand for eco-friendly goods and benefit society at large by encouraging greater consciousness and environmentally friendly behavior.

6.2 Limitations and future recommendation

Despite its important implications, the study has certain limitations, which will be discussed below to suggest guidelines for future study. The present study focuses only on the antecedents of the ATE of teachers; future studies could explore the impact of socioeconomic, cultural, and psychological factors on the attitude and intentions of the students of HEIs. Results are limited due to the time and resource constraints, as the survey was conducted only in the district Vehari of South Punjab, Pakistan. Future studies can be executed at the country or regional level. This study sample was limited to university staff members of district Vehari. Future studies should use different samples to verify the validity of the results.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for this study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants OR patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

AS: conceptualization, data curation, formal analysis, investigation, methodology, and Writing—original draft. Oranzab: conceptualization, formal analysis, methodology, supervision, and writing—original draft. MA: project administration, validation, writing—original draft, and writing—review and editing. PP: funding acquisition, validation, visualization, and writing—review and editing. AV: funding acquisition, project administration, validation,

visualization, and writing–review and editing. TH: funding acquisition, project administration, resources, visualization, and writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Integrating biodiverse edible school practices: enriching undergraduate liberal education for elevated learning outcomes

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This study investigated the implementation of biodiverse edible school concepts in undergraduate liberal education courses across universities. It aims to evaluate the impact of integrating these concepts on students' learning outcomes related to biodiversity, agriculture, and sustainability. Teaching practices incorporating biodiverse edible school elements were developed and applied in six classes at National Taiwan University and one class at Universiti Malaya, covering various disciplines including agriculture, language, and green chemistry. Data were collected using classroom observations, assignments, and questionnaire surveys. The results showed that the interventions generally enhanced students' understanding of biodiversity and agriculture, increased their willingness to consume local and seasonal foods, and supported the achievement of course learning objectives. Outdoor educational activities were especially effective in improving students' knowledge of edible plants on campus. The findings contribute to experiential learning in agricultural and environmental education, offering practical examples for implementation in diverse educational contexts. Moreover, this study revealed that these practices aligned well with several Sustainable Development Goals, particularly Goal 2 (zero hunger), Goals 12 (responsible consumption and production), Goal 15 (life on land), and Goal 3 (good health and wellbeing). This study demonstrates that biodiverse edible school concepts can be successfully adapted for higher education, providing new ways to integrate these topics into university curricula.

KEYWORDS

biodiverse edible schools, biodiversity, environmental education, food and agricultural education, higher education, liberal arts, sustainability, urban agriculture

1 Introduction

The sustainability field has received considerable attention for its importance across social, economic, and environmental dimensions (Purvis et al., 2019). The 17 Sustainable Development Goals (SDGs) are included in the 2030 Agenda for Sustainable Development, adopted by the United Nations (Sachs et al., 2019; Mensah, 2019). Among these goals, quality education is seen as a crucial transformation step for achieving the SDGs, and there has been a notable increase in higher education sustainability programs aimed at meeting these goals (Sachs et al., 2019; Brundiers et al., 2021). Various innovations, collaborations,

and investments have been initiated to meet the inclusive, equitable, quality, and lifelong education targets (Owens, 2017; Ferguson and Rooft, 2020). Agriculture, which supports food security, provides ecosystem services, and serves educational purposes, is essential for achieving many of the SDGs (DeClerck et al., 2016; Viana et al., 2022). Focusing on urban and peri-urban agriculture has become a popular topic in SDG studies worldwide (Viana et al., 2022).

Urban and peri-urban agriculture involves the production of food, other outputs, and related processes occurring on land and in various spaces within cities and surrounding regions, aiming to address local population needs and achieve multiple goals and functions (FAO et al., 2022). It has the potential to mitigate urbanization challenges and offers advantages such as improved wellbeing, social cohesion, and food security (Kingsley et al., 2021; Wadumestrigi Dona et al., 2021; Ayoni et al., 2022). Various forms of garden city and community supported agriculture help facilitate the integration of sustainability and agriculture into educational frameworks (Brown and Miller, 2008; LaCharite, 2016). Examples of garden cities, urban farms, and different edible landscapes have been implemented in metropolitan areas such as Taipei city (Hsiao, 2021; Mabon et al., 2023; Zhou et al., 2023; Zheng and Chou, 2023b). These movements are in good agreement with the recently announced Food and Agricultural Education Act in Taiwan and offer important opportunities for ecological and nutritional education (FAO et al., 2022; Mabon et al., 2023; Huang et al., 2023).

Education that incorporates agriculture can provide interdisciplinary experiences for younger generations, particularly those from urban areas (Orr, 1994). Schools serve not only as centers for environmental education but also as valuable reservoirs of urban biodiversity (Rickinson, 2001; Liu et al., 2021). Recently, the concept of “Biodiverse Edible Schools,” demonstrated in a secondary school in Berlin, connects healthy food, school gardens, and local biodiversity. This approach has the potential to strengthen students’ connections with nature, deepen their understanding of food production, and promote healthier diets (Fischer et al., 2019).

1.1 Biodiverse edible schools and the potential in higher education

The idea of biodiverse edible schools has been influenced by previous research on the benefits of school gardens for children and young students. Blair (2009) underscored the positive impact of school gardening on academic performance, nutrition knowledge, and environmental attitudes. Ohly et al. (2016) conducted a systematic review that linked school gardening programs to improved health and wellbeing. Similarly, school gardening not only enhances students’ academic, health, and environmental outcomes but also increases their willingness to try new vegetables and their ability to identify them (Ozer, 2007; Ratcliffe et al., 2011).

The biodiverse edible schools described in Fischer et al. (2019) represent a special approach to integrate food production, environmental education, and biodiversity conservation within educational settings. A biodiverse edible school encompasses four key components: (1) a school kitchen supplied with food from

local producers; (2) a garden on the school grounds for producing food; (3) a neighboring wild site that serves as a habitat for edible wild plants; and (4) collaborative activities in planning, managing, and using these spaces. The school kitchen emphasizes the use of local produce to prepare nutritious meals, encouraging students to understand where their food comes from and to adopt healthier eating habits. The school garden serves as a practical learning environment where students grow a variety of vegetables, fruits, and herbs. The nearby wild site provides opportunities for students to explore urban natural habitats, learn about edible wild plants and expand their understanding of local ecosystems. Collaborative activities involve various stakeholders, including school staff, students, local government representatives, environmental organizations, and researchers, who work together to develop biodiverse edible school programs. These activities include workshops, garden maintenance, foraging, and lessons that integrate topics such as biology, nutrition, and environmental science.

While biodiverse edible schools have demonstrated to be well-suited for secondary education, their potential for adaptation to university settings remains unexplored. Can these concepts be effectively implemented in university education? Its applicability in higher education could be supported by integrating agriculture into sustainability education (LaCharite, 2016) and incorporating experiential learning in food studies at universities (Lehrer, 2024). Our discussions among university educators through the platform of Presidents’ Forum of Southeast Asia and Taiwan Universities have further explored this idea. The framework of biodiverse edible schools is chosen for implementation in university courses because of its unique approach, which expands beyond traditional school gardens by incorporating wild urban spaces and edible plants. Building on these concepts, we have attempted to integrate the principles of biodiverse edible schools into four liberal education courses in Taiwan and Malaysia. These works include brainstorming biodiverse edible school options suitable for campuses and conducting outdoor vegetation survey activities to engage students with local biodiversity and sustainability practices.

1.2 The liberal education courses and sustainability education in this study

At National Taiwan University (NTU), the integration of SDGs into liberal education courses follows the Ministry of Education’s policies and the “Learn SDGs for Taiwan Schools” handbook (Liu and Kan, 2024). This reflects an increasing awareness of the importance of the SDGs and the actions needed to achieve them (Ho et al., 2022). To contribute to these goals, the first author previously implemented experiential learning activities in an agricultural course, encouraging students to explore campus biodiversity (Shen et al., 2023). To explore the relevance of some existing teaching practices with biodiverse edible school elements, new activities and assignments were developed and expanded to three other courses in this study: Introduction to Agriculture in Taiwan (IAT), Organic Agriculture (OA), and Taiwanese Conversations in the Rural Life (TCRL), with the aim of examining the current state of biodiverse edible cases from university students’

perspectives in Taiwan. These efforts aim to explore university students' perspectives on biodiverse edible practices and assess their linkages to the SDGs.

From the perspective of the Universiti Malaya (UM), the use of biodiverse edible school practices in liberal education curricula was previously lacking. In the past, the campus's role in food production and consumption, and its connection with local biodiversity, were often overlooked. However, the UM campus community has experts to cater opportunities for students to better understand both urban nature and healthy food, allowing them to meet the 17 SDGs at the same time. Effective from the end of October 2023, the UM Sustainability and Development Centre started integrating the 17 SDG elements through selected final-year projects among undergraduates. The program focuses on six sustainability clusters: waste, energy and climate change, water, transportation, good health, and wellbeing and setting and infrastructure. In this study, the Introduction to Green Chemistry (IGC) course at UM is designed for students from diverse faculties. The aim of implementing the biodiverse edible school in the course is to provide students with a hands-on, practical approach to understanding sustainable agricultural practices and their connection to waste management, renewable resources, and alternative energy.

1.3 Objectives

In this study, we seek to extend biodiverse edible school concepts to higher education. The specific objectives are as follows:

- (1) To investigate food and agricultural educational models and examples based on biodiverse edible school concepts in university general education curricula.
- (2) To evaluate the impact of biodiverse edible school teaching practices on achieving course learning objectives.
- (3) To assess students' perceptions of food, agriculture, and sustainability in the educational process.

2 Materials and methods

2.1 Overview of educational schemes

The educational schemes in this study were conducted at NTU, Taipei, Taiwan, and UM, Kuala Lumpur, Malaysia. The activities involving the concepts of biodiverse edible schools (Fischer et al., 2019) were integrated into liberal education courses designed for undergraduate university students from various backgrounds using a variety of languages. This study included three courses in Taiwan and one course in Malaysia: Introduction to Agriculture in Taiwan (IAT), Organic Agriculture (OA), and Taiwanese Conversations in the Rural Life (TCRL) at NTU and Introduction to Green Chemistry (IGC) at UM. Each course was scheduled for a 2-hour session per week, granting students two credits. During the 2023-Fall semester, the IAT, OA, and 2 classes of TCRL (TCRL-23-01 and TCRL-23-02) were conducted. Additionally, two more TCRL classes, which use the same pedagogical approaches, were included in the subsequent 2024-Spring semester for the investigation (TCRL-24-01 and TCRL-24-02). The IGC course was

conducted during semester I of the 2023–2024 academic year. Three languages are used in these courses: IAT and IGC are in an English-medium instruction environment (Dearden, 2014; Richards and Pun, 2023), OA instruction is conducted in Chinese (Mandarin; Wang, 1973; Kane, 2006), and for TCRL, the primary language of communication is Taiwanese (Taiwanese Southern Min; Taiwan Southern Min; Iun et al., 2005; Hsieh, 2014; Chappell, 2019; Lau and Tsai, 2020). Each course syllabus is provided in Supplementary Table 1.

2.2 Participants

The participants in this study included instructors, teaching assistants, and students. The instructor of the courses in Taiwan is the first author, whereas the instructor of the course in Malaysia is the second author. One teaching assistant is assigned to each class, with the exception of IGC. The student participants of the IAT, OA, TCRL-23-01, TCRL-23-02, TCRL-24-01, TCRL-24-02, and IGC courses consisted of 36, 36, 37, 38, 44, 41, and 32 university students, respectively, from 18, 17, 20, 21, 21, 21, and 6 departments. The students' backgrounds for each class are detailed in Table 1. There was a greater proportion of freshmen in the IAT, OA, TCRL-23-01, TCRL-24-01, TCRL-24-02, and IGC classes, whereas sophomores dominated the TCRL-23-02 classes. Additionally, a few graduate students were enrolled in the OA, TCRL-23-01, TCRL-24-01, and TCRL-24-02 classes. The student body of the IAT was diverse, with students from Taiwan, America, France, Indonesia, Israel, Japan, Korea, Malaysia, and the Philippines, whereas almost all the students in OA, TCRL-23-01, TCRL-23-02, TCRL-24-01, and TCRL-24-02 were Taiwanese. The students in the IGC course were all Malaysian except for one international student from China. The classification of the students' major fields followed the International Standard Classification of Education (UNESCO, 2012). All the classes included students from various disciplines, such as "social sciences, business and law," "science," and "engineering, manufacturing and construction." The IAT and OA classes had the highest number of students majoring in "agriculture"; TCRL-23-01, TCRL-23-02, and TCRL-24-02 had the highest number of students majoring in "social sciences, business and law"; TCRL-24-01 had the highest number of students majoring in "engineering, manufacturing and construction"; and IGC had the highest number of students majoring in "science" (Table 1).

2.3 Implementation of biodiverse edible school teaching practices

Agricultural-related topics and concepts of biodiverse edible schools (Fischer et al., 2019) were incorporated into the teaching materials and student activities of our university courses. Depending on the course learning objectives and students' backgrounds (Tables 1, 2), some classes focused on brainstorming potential farm and food options suitable for campus, whereas others adapted similar outdoor vegetation survey activities from

TABLE 1 The background of participants in the liberal education courses.

Course name		Frequency	Percentage (%)
Introduction to Agriculture in Taiwan (IAT)			
Gender	Female	22	61.1
	Male	14	38.9
Grade	1	22	64.1
	2	10	27.8
	3	3	8.3
	4	1	2.8
Fields	Social sciences, business, and law	8	22.2
	Science	3	8.3
	Engineering, manufacturing, and construction	6	16.7
	Agriculture	11	30.6
	Health and welfare	8	22.2
Organic agriculture (OA)			
Gender	Female	17	47.2
	Male	19	52.8
Grade	1	12	33.3
	2	7	19.4
	3	7	19.4
	4	9	25.0
	Graduate student	1	2.8
Fields	Humanities and arts	1	2.8
	Social sciences, business, and law	7	19.4
	Science	6	16.7
	Engineering, manufacturing, and construction	2	5.6
	Agriculture	17	47.2
	Health and welfare	3	8.3
Taiwanese conversations in the rural life 2023-01 (TCRL-23-01)			
Gender	Female	17	45.9
	Male	20	54.1
Grade	1	12	32.4
	2	11	29.7
	3	1	2.7
	4	11	29.7
	Graduate student	2	5.4
Fields	Humanities and arts	5	13.5

(Continued)

TABLE 1 (Continued)

Course name		Frequency	Percentage (%)
	Social sciences, business, and law	13	35.1
	Science	5	13.5
	Engineering, manufacturing, and construction	9	24.3
	Agriculture	1	2.7
	Health and welfare	4	10.8
Taiwanese conversations in the rural life 2023-02 (TCRL-23-02)			
Gender	Female	17	44.7
	Male	21	55.3
Grade	1	6	15.8
	2	21	55.3
	3	3	7.9
	4	8	21.1
Fields	Humanities and arts	4	10.5
	Social sciences, business, and law	17	44.7
	Science	1	2.6
	Engineering, manufacturing, and construction	10	26.3
	Agriculture	3	7.9
	Health and welfare	3	7.9
Taiwanese conversations in the rural life 2024-01 (TCRL-24-01)			
Gender	Female	23	52.3
	Male	21	47.7
Grade	1	17	38.6
	2	14	31.8
	3	4	9.1
	4	8	18.2
	Graduate student	1	2.3
Fields	Humanities and arts	6	13.6
	Social sciences, business, and law	11	25.0
	Engineering, manufacturing, and construction	20	45.5
	Agriculture	3	6.8
	Health and welfare	4	9.1
Taiwanese conversations in the rural life 2024-02 (TCRL-24-02)			
Gender	Female	20	48.8

(Continued)

TABLE 1 (Continued)

Course name		Frequency	Percentage (%)
Grade	Male	21	51.2
	1	15	36.6
	2	10	24.4
	3	5	12.2
	4	10	24.4
	Graduate student	1	2.4
Fields	Humanities and arts	5	12.2
	Social sciences, business, and law	18	43.9
	Science	1	2.4
	Engineering, manufacturing, and construction	11	26.8
	Agriculture	4	9.8
	Health and welfare	2	4.9
Introduction to green chemistry (IGC)			
Gender	Female	20	62.5
	Male	12	37.5
Grade	1	30	93.8
	2	2	6.3
Fields	Humanities and arts	6	18.8
	Social sciences, business, and law	2	6.3
	Science	16	50.0
	Engineering, manufacturing, and construction	7	21.9
	Services	1	3.1

Fischer et al. (2019) to expand their knowledge of the edible plant diversity on university campuses.

Over the 16-week duration of each semester (Supplementary Table 1), assignments were issued to students in the IAT, OA, and IGC courses, whereas the IGC and TCRL classes featured specific outdoor educational activities on the campus. In the IAT course, the case study in Fischer et al. (2019) was briefly introduced in weeks 3 and 4, preceding midterm assignments where students worked on written and oral reports, either individually or in groups. Upon completion of tasks in week 10, an associated field trip at Taipei Botanical Garden was carried out in week 11 to strengthen learning. For OA, students formed groups and were tasked with delivering a final oral report expanding on Fischer et al. (2019) in the context of organic agriculture. Details of the assignment and group formation were provided for week 5. Following lectures and discussions on organic

TABLE 2 Learning objectives of the courses in this study.

Course	Learning objectives
Introduction to Agriculture in Taiwan (IAT)	Students will be able to acquire basic knowledge and a variety of aspects about agriculture in Taiwan through lectures, discussion, and participation.
Organic Agriculture (OA)	1. Students will be able to identify the principles of organic agriculture, management techniques, the impact and biological application within agricultural systems, policy regulations, product assurance systems, and other professional knowledge. They will also possess the ability to search for information related to organic agriculture and extend its application. 2. Upon completing the course, students will be able to distinguish the similarities and differences between organic agriculture and non-organic crop production systems.
Taiwanese Conversations in the Rural Life (TCRL)	Students will get the ability of using various Taiwanese digital resources; be able to introduce themselves in Taiwanese, try to use Taiwanese in daily life or express opinions, and be able to appreciate diverse cultures.
Introduction to Green Chemistry (IGC)	1. Students should be able to explain the principles and concept of green chemistry. 2. Students should be able to report the applications of green chemistry in Malaysia and globally such as waste, catalysis, environmentally benign solutions, renewable resources, alternative energy sources, synthesis and nanoscience, and supercritical carbon dioxide as green solvent. 3. Students should be able to elaborate the challenges of applying green chemistry concepts.

farming technologies, final oral reports were presented in weeks 15 and 16.

For the IGC course, the assignment and formation of student groups were explained at weeks 8 and 9. Students were informed about the principles of green chemistry and their linkage to agriculture. The concept was narrowed down to the campus environment where they study and further discuss it in the context of Malaysia. For the formation of student groups, they were asked to choose group members from different departments to gain exposure to diverse backgrounds. Furthermore, to adjust the learning objective of the IGC course, each group was given a specific topic determined by the course instructor. To apply the concept of agriculture and the principles of green chemistry in this IGC course, the students were first asked to perform an extracurricular activity in week 8. They were asked to find information on fruits, vegetables and edible trees that are found on the UM campus. They assembled according to their respective groups and spread out in different areas. This activity coincided with the implementation of the school's teaching practice of edible biodiversity. The time allocated for the activity was ~1 h and was performed in the evening. The temperature in the campus area was ~35°C, with clear weather. Students were asked to identify the items that could be eaten and know the name of the items. They were also asked to record the results of these outdoor activities and make a casual presentation

in the classroom in the ninth week. Presentation/seminar activities and delivery of final assignments for the IGC course, according to the respective groups, were held at the 13th and 14th weeks. The report had to comply with the learning objectives of the course (Table 2).

In the four TCRL classes, a blend of classroom and outdoor activities on the campus, namely, the “Agri-food campus tour in Taiwanese,” was implemented in the fifth week. The class began with an introduction to the legislative context of the Food and Agricultural Education Act in the nation, as well as the contents of edible landscaping (Zheng and Chou, 2023b) and biodiverse edible schools (Fischer et al., 2019). The eight groups of students in each class subsequently participated in collaborative activities focused on the exploration of edible plants and local biodiversity on campus for 40 min. They documented their observations through taking photographs or footage and later communicated their findings in the classroom using Taiwanese, in accordance with the course’s language focus (Table 2). The activities related to the topic in the TCRL classes were completed within 2 h. According to weather records from the Taipei Astronomy and Weather Station, the outdoor average temperatures during the TCRL-23-01, TCRL-23-02, TCRL-24-01, and TCRL-24-02 classes were 25.1, 24.7, 15.0, and 15.4°C, respectively. It also rained during the TCRL-24-01 outdoor activities, with a recorded precipitation of 1 mm.

To summarize the biodiverse edible school teaching practices at NTU, the course observation data of IAT, OA, and TCRL during relevant weeks were collected using COPUS, the Classroom Observation Protocol for Undergraduate STEM (Smith et al., 2013). The observation process involved reviewing videos recorded by the automatic lecture recording system installed in the classroom, under the platform of the NTU Course online (NTU COOL; Shih et al., 2021; Shen et al., 2023) by the instructor and teaching assistants. The instructor’s behaviors of presenting (lecturing, real-time writing, demonstration), guiding (follow-up/feedback on an activity, posing a question, posing a clicker question, listening to and answering student questions, moving and guiding, one-on-one discussion), administration, and others were recorded, whereas the students’ behaviors of receiving, working (individual thinking, discussing clicker questions, working in groups, other group activities, making a prediction, taking tests), talking in class (answering questions, asking questions, engaging in whole-class discussions, presenting to the entire class), and others were recorded (Smith et al., 2013; Reisner et al., 2020). Behaviors were visualized at 2-minute intervals using COPUSprofiles.org and categorized based on the anatomy of the teaching method used in science, technology, engineering, and mathematics (STEM) courses (Stains et al., 2018).

2.4 Data collection and analysis

Practical examples were extracted from the works of the IAT, OA, and IGC courses. The biodiverse edible school cases worldwide, on a regional scale, and within the campus were explored collaboratively by the participants. The authors examined the written assignments and all the recorded materials, summarizing the findings after the teaching practices.

Students’ perceptions were surveyed before and after the intervention of biodiverse edible school teaching practices. The intervals between the two questionnaires for the IAT, OA, and IGC were 8, 11, and 4 weeks, respectively, whereas the interval for all the TCRL courses was 1 week. Baseline attitudes in each class included students’ perceptions of the ecosystem, biodiversity, weeds, and attention to agricultural topics. Students’ understanding of the number of edible plants on campus was assessed using a five-point scale and elaboration of a list of edible plants both before and after our intervention, reflecting the special plant survey activities described in Fischer et al. (2019). After the implementation of biodiverse edible school teaching practices, the students were surveyed regarding the intended goals of the activities and courses. The questions measured their comprehension of biodiversity and agriculture, willingness to consume seasonal agricultural products, and achievement of course learning objectives (Table 2). The responses were rated on a seven-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = neutral, 5 = slightly agree, 6 = agree, and 7 = strongly agree. The data were analyzed using R (<https://www.r-project.org>). Analysis of variance (ANOVA) was employed to determine significance levels, and Tukey’s honestly significant difference (Tukey HSD) test was used for *post hoc* comparisons. Additionally, students’ attitudes toward the linkage of agricultural activities in each class to SDGs (Sachs, 2012; Sachs et al., 2019) were surveyed.

3 Results

3.1 Preintervention attitudes of students

The baseline attitudes of students before the introduction of biodiverse edible school teaching practices are outlined in Table 3. Students in different classes exhibited similar attitudes toward questions regarding ecosystems on school campuses and weeds in crop-producing fields (Q1 and Q2, not significant). Students in the IAT class scored higher on the question about their attention to agricultural news than those in the TCRL-24-02 class did (Q3, $P < 0.05$). Furthermore, the IAT students rated themselves higher in terms of their knowledge of the number of edible plant species on campus, whereas the TCRL-23-01 students scored significantly lower (Q4, $P < 0.001$). Additionally, OA students reported a greater number of edible plant species on the school campus, whereas the TCRL-23-01 class listed fewer edible plant species (Q5, $P < 0.01$).

3.2 Teaching and learning processes

The recorded teaching and learning processes in the IAT, OA, and the four TCRL classes during the selected weeks using biodiverse edible school practices at NTU are summarized in Figure 1. The instructor and students’ behaviors noted in the figure correspond to those in Smith et al. (2013) and Reisner et al. (2020). During weeks 9 and 10 of the IAT course, the model of the processes was a combination of lectures on agricultural topics and students’ midterm oral reports about biodiverse edible schools (Figures 1A, B), corresponding to the “interactive lectures” of clusters 4 and 3 in Stains et al. (2018). In the OA course, there was a workshop

TABLE 3 Questions and responses related to students' baseline attitudes in each class before interventions.

Do you agree with the statement of ...	IAT	OA	TCRL-23-01	TCRL-23-02	TCRL-24-01	TCRL-24-02	IGC	Pr (>F) in ANOVA
Q1: There are many different ecosystems in school campuses and the ecosystems are important parts of biodiversity.	6.55 (1.15)	6.26 (0.92)	6.06 (1.28)	5.94 (1.67)	6.12 (1.48)	5.95 (1.36)	6.03 (1.19)	0.497
Q2: In crop-producing fields, weeds should be removed.	5.42 (1.62)	4.97 (1.30)	5.23 (1.31)	5.00 (1.47)	5.12 (1.42)	5.31 (1.30)	5.27 (1.36)	0.804
Q3: I usually pay attention to news and topics related to agriculture.	5.00 (1.35)	4.63 (1.34)	4.09 (1.38)	4.22 (1.64)	4.29 (1.50)	3.83 (1.54)	4.30 (1.44)	0.027
Q4: How many species of edible plants do you know on your school campus?	2.64 (1.48)	1.74 (1.20)	1.26 (0.66)	1.44 (0.94)	2.33 (1.59)	1.83 (1.38)	1.63 (1.13)	<0.001
Q5: Write down some edible plants you know that can be found on your school campus.	2.00 (1.50)	2.18 (2.79)	0.91 (1.04)	1.03 (0.88)	1.17 (1.38)	1.29 (1.58)	1.27 (0.94)	0.003

IAT, Introduction to Agriculture in Taiwan; OA, Organic Agriculture; TCRL23-01, Taiwanese Conversations in the Rural Life 2023 class 1; TCRL23-02, Taiwanese Conversations in the Rural Life 2023 class 2; TCRL24-01, Taiwanese Conversations in the Rural Life 2024 class 1; TCRL24-02, Taiwanese Conversations in the Rural Life 2024 class 2; IGC, Introduction to Green Chemistry. A 7-points Likert scale is used for Q1–Q3 (Scale = 1–7); a 5-points scale is used for Q4 (Scale 1: 0–5; Scale 2: 6–10; Scale 3: 11–15; Scale 4: 16–20; Scale 5: >21); the numbers in Q5 are the counts for numbers of names of edible plants written by individual students. The values are shown as means; followed by standard deviations in parentheses.

on organic farm design adapted from activities in the Organic Youth Forum of IFOAM Asia (Willer and Lernoud, 2019) in week 12 (Figure 1C) and a final oral report session in week 15 (Figure 1D). The workshop class and the students' report class were classified into cluster 7, the "student-centered" style, and cluster 1, the "didactic" style, respectively (Stains et al., 2018). The four TCRL classes conducted the activity of "Agri-food campus tour in Taiwanese" in week 5, with students separated into eight groups with similar teaching and learning processes (Figures 1E–H). They all belong to the style of interactive cluster 3 in Stains et al. (2018). The average outdoor activity times of the TCRL-23-01, TCRL-23-02, TCRL-24-01, and TCRL-24-02 classes were 34.1, 33.6, 29.8, and 35.5 min, respectively. Most of the groups documented edible plants and local biodiversity on the experimental farm and along campus roadsides, whereas one group at TCRL-24-02 explored milk-producing cattle housing at the Department of Animal Science & Technology, NTU.

In the IGC course of UM, group formation resulted in 11 groups. Each group consisted of three students of which at least one student was from a different department. Each group could be all male/female students or a mix of male and female students and was given a topic related to the 12 principles of chemistry. There were three topics in total, namely, zero waste, alternative energy sources and renewable resources. The outdoor activities of IGC were as follows: Before the concepts of a biodiverse edible school were absorbed or integrated into student learning, the students were asked to perform activities outside the classroom. Students

choose their own workplace locations on campus to explore fruits, vegetables, and edible plants. There were five locations for students to choose from, namely, Tasek Varsiti (varsity lake), Rimba Ilmu Botanic Garden, Ladang Mini ISB (ISB Mini Farm), around the Faculty of Science, and UM residential colleges. The students recorded the results of their observations and reported them orally in week 9. The purpose of this activity was to enable students to identify types of local edible food and relate it to local biodiversity. Students performed an analysis according to the learning objective of the course from the 10th week to the 12th week. Presentation and writing assignments were done at the 13th and 14th weeks.

3.3 Exploring practical examples of biodiverse edible school concepts in undergraduate liberal education

Using Fischer et al. (2019) as a "primer" reference, students in the IAT course applied biodiverse edible school concepts with inventive approaches on the university campus, whereas those in the OA course extended the ideas by integrating organic agriculture into their surroundings. They explored practical examples both internationally and within local regions, and subsequently proposed ideas through brainstorming.

Many IAT students found inspiration in both global and regional cases. Learning from the Edible Schoolyard Program

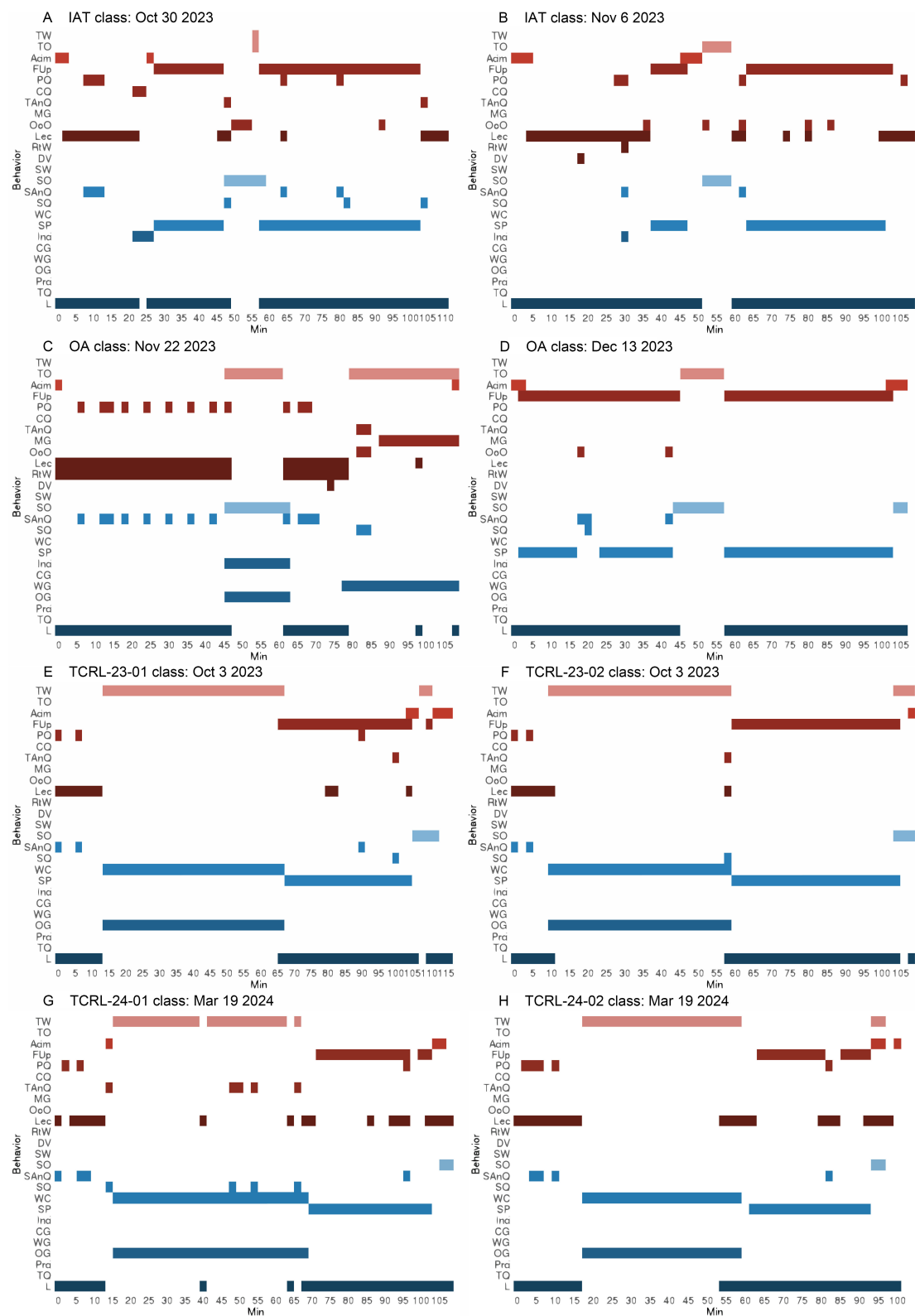


FIGURE 1

Observation of teaching and learning processes during selected weeks at National Taiwan University using COPUS, the Classroom Observation Protocol for Undergraduate STEM according to [Smith et al. \(2013\)](#). (A, B) Introduction to Agriculture in Taiwan class, (C, D) Organic Agriculture class, (E–H) Taiwanese Conversations in the Rural Life class. Red bars represent the behaviors of the teacher and blue bars indicate students' behaviors.

in American middle schools (Laird, 2013), they explored the value of hands-on learning, cultivating healthy eating habits, engaging in environmental stewardship, and promoting nature education. Expanding from the open-door pantry community model (The Open Door, 2024), the students envisioned their imaginary “Campus Garden to Table” initiative, which may serve as a vibrant platform for students, faculty, and staff to participate in sustainable practices. In light of experiences such as the biointensive vegetable gardens in school in Cavite Province, the Philippines (Monville-Oro et al., 2020), the links to nutrition education and the diversification and conservation of indigenous vegetables were emphasized. Similarly, examples from Japanese school lunch programs (Ishida, 2018; Waida and Kawamura, 2022) suggest that these approaches may contribute to food education, enhance the understanding of local food culture, and help preserve traditional culinary cultures. Taking a closer look at regional culture, traditional Korean dishes such as bibimbap, comprising rice, various vegetables, and sauces (Chung et al., 2015; Mun et al., 2023), could be integrated into cultural events during university festivals to promote interest in vegetables on university campuses.

Both the IAT and OA participants focused on practical cases of biodiverse edible schools and food and agricultural education in Taiwan. Local communities, such as the San-He community in Taoyuan city, were cited as exemplary examples of promoting edible landscapes, which extend the food production system to tourism and environmental education systems in a hilly, Hakka-culture based suburban area (Zheng and Chou, 2023a). Various forms of community-supported agriculture (Brown and Miller, 2008; LaCharite, 2016), crucial for supporting organic agriculture in Taiwan (Pisarn et al., 2020; Lee, 2023), were elaborated upon to be included in the perspective movement toward university campus-supported agriculture (Wu, 2018; Pisarn et al., 2020). In addition, several cases across Taiwan featuring food and agricultural education activities from elementary school to senior high school, including Daan elementary school, Leye elementary school, Longdu elementary school, and Chien Kuo high school, are highlighted in the reports. Their alignment with the ideas of biodiverse edible schools in Fischer et al. (2019) is summarized in Table 4. All four schools demonstrated components of collaborative activities with multiple stakeholders and school gardens for producing local food (Table 4).

In the NTU, recent efforts to implement biodiverse edible schools in accordance with the conceptual framework have been outlined through the collective work of the IAT and OA participants. Table 5 provides current and previous examples of collaborative activities, school kitchens, school gardens, and wild sites. With respect to collaborative activities, there is significant involvement from teachers and university students at the Experimental Farm of the College of Bioresources and Agriculture. Courses such as “Hand-on Experience of Modern Agriculture” designed for students at the College of Bioresources and Agriculture and “Hand-on Experience of Field Life” for students from other majors have been taught for more than 20 years. (https://nol.ntu.edu.tw/nol/coursesearch/search_result.php). Additionally, certain “student service education” courses, such as those in the Department of Agricultural Economics, require students to engage in rural service during summer vacation.

Furthermore, student clubs such as “NTU Roots & Shoots” promote consideration of the wellbeing of all life on earth in their activities. Another group, “Ptumaw,” focuses on using indigenous plants to enhance the understanding of ethnic cultures, and their members also manage the edible garden beside the Student Activity Center on campus. Some groups also participate in guerrilla gardening (Reynolds, 2008; Adams et al., 2015; Hardman et al., 2018) and various other undertakings. The College of Bioresources and Agriculture of the university manages the Agricultural Exhibition Hall and farmlands, offering activities such as Spring plowing and rice transplanting, farm-to-table experiences during the Azalea festival (National Taiwan University, 2008), and guided tours of the farm environment in the environmentally certified facility (Lee et al., 2020), effectively broadening outreach to a larger community. Additionally, the college collaborated with the Yunlin County Government to organize the Farmers’ Market on campus in 2023, promoting local produce through University Social Responsibility projects (Vasilescu et al., 2010; Yang, 2023). With respect to school kitchens, the college manages the Agricultural Products Sales Center, where school-produced items such as milk, bread, steamed buns, eggs, tea, and beverages are sold. Previously, a farm-operated drink shop offered Aiyu jelly beverages sourced from local jelly figs (Srisai et al., 2023), but it is presently closed. There seems to be a lack of cafeterias and regular production of boxed lunches using exclusively local ingredients on the campus. The details of the school gardens and wild sites in the surroundings are presented in Table 5, which expands on the students’ exploration.

The brainstorming results using the concepts of biodiverse edible schools in the IAT and OA courses in the NTU are also presented in Table 5. With respect to collaborative activities, departments can develop service-oriented educational programs and food and culture courses emphasizing local food and biodiversity, particularly for incoming freshmen. Encouraging cross-generation green urban learning, university students can engage in required, elective or voluntary teaching and learning exchanges with children from the affiliated preschools of the NTU. Moreover, “event-week booths” are frequently organized near lecture buildings and squares. “Healthy food weeks” and similar events can be held by members from departments, student clubs, associations, and other groups to advocate for biodiverse edible schools. Additionally, community-based partnerships employing a community-supported agricultural model can be established on campus, involving local farmers to supply seasonal produce for various campus events. By utilizing university resources, such as a college’s experimental farm, a campus can serve as an outdoor classroom not only for university students but also potentially for neighboring schools and the public. To improve the ability of school kitchen to prepare local and fresh food, cooperation between regional small-scale farmers and campus cafeterias can be initiated. The student cafeteria serving a vegetarian meal is considered a good starting point to prioritize. Promotional strategies, such as seasonal menu guides, posters, and discounts, could be employed to nurture culinary culture. These efforts could be integrated with liberal education courses, cooking classes, and activities organized by student clubs focused on culinary arts, dessert making, and cake crafting. Considering the discontinuation of the college-managed shop selling Aiyu jelly beverages, a campus café offering popular

TABLE 4 Cases in Taiwan summarized in reports from Introduction to Agriculture in Taiwan (IAT) and Organic Agriculture (OA) courses and their alignment with the concept of biodiverse edible schools.

Category	Daan elementary school	Leye elementary school	Longdu elementary school	Chien Kuo High School
Collaborative activities	Environmental education activities and ecological facilities supported by teachers, communities, and educational foundations	Outdoor education activities supported by teachers, workers, volunteers, Parents' Association, communities, university specialists, and educational foundations	Special teaching and learning events supported by teachers, associations, non-government organizations, communities, University Social Responsibility Program group	Sustainable dining table activities including food delivery for disadvantaged groups supported by home economics teachers, retired colleagues, volunteers, non-government organizations
School kitchens	-	Casual cooking courses	Program-based Satoyama Kitchen, clubs, and activities	Cooking in the courses
School gardens	Vegetables in greenhouses, rooftop gardens, and aquaponics	Rice paddy and vegetable garden in the playground	Rotation of rice and vegetables	Small allotments in the school
Wild sites	Wetlands and ponds	-	Neighboring mountain hiking trail and ecological park	Taipei botanical garden
Locality	Bade District, Taoyuan City	East District, Taichung City	Meinong District, Kaohsiung City	Zhongzheng District, Taipei City
References	Tseng et al., 2022 and this study	This study	Lin, 2017; Wu, 2022, and this study	This study

Collaborative activities, school kitchen, school garden, and wild sites are four components of biodiverse edible schools in Fischer et al. (2019). "-": not specified. The information of the schools about the relevant issues is from the students' engagement of the reports, regional news, and the listed references.

TABLE 5 Cases in National Taiwan University and brainstorming ideas summarized in reports from Introduction to Agriculture in Taiwan (IAT) and Organic Agriculture (OA) courses and their alignment with the concept of biodiverse edible schools.

Category	Current and previous cases	Brainstorming from the IAT reports	Brainstorming from the OA reports
Collaborative activities	Hand-on courses for university students; Rural services at summer vacation; NTU Roots and Shoots student club; Ptumaw; Agricultural Exhibition Hall; Farm workshops for the public; University social responsibility projects	Required courses for freshmen; Cross-generation learning; Healthy food weeks; Novel student clubs; Collaborative programs involve students and staff members; Seasonal farmer's markets	Additional food and culture courses for university students; Community-based collaboration; Community-supported agriculture in the university; Outdoor food and agricultural education classroom for nearby schools and the publics
School kitchens	Agricultural Products Sales Center; Aiyu jelly drink shop	Cooperate with cafeterias in the campus; Collaborate with small-scale farmers to serve locally-grown vegetables; Seasonal menu guides/posters; Blend school kitchen/cafeteria functions with culinary majors and cooking classes; Campus café	Prioritize collaboration with student cafeteria serving vegetarian meal; Use of discounts and promotions; Liberal education courses; Culinary courses; Bridging garden to table through student clubs in culinary arts, desserts, and cake crafting
School gardens	Experimental farm of College of Bioresources and Agriculture; The edible garden beside the Student Activity Center; Rooftop gardens; Guerrilla gardening	Integrating surroundings of dormitory, library, fitness park and more, into edible school gardens; Dispersed small-scale gardens; Permaculture designs	Establishing more rooftop gardens; Convert unused land into organic vegetable gardens in the campus
Wild sites	Undeveloped lands in the campus; Guanyin Hill Hiking Area near Treasure Hill; Fuzhoushan Park	Insect hotel	Interpretation of edible plants and biodiversity of the sites

Collaborative activities, school kitchen, school garden, and wild sites are four components of biodiverse edible schools in Fischer et al. (2019).

food items could be an alternative option. With respect to school gardens and wild sites, the spaces near dormitories, libraries, fitness parks, and rooftops could potentially be transformed into edible school gardens, even if they are experimental, temporal, or small scale. Both permaculture designs (Ferguson and Lovell, 2014) and organic farming management principles (Van Bruggen et al., 2016) can be applied in these cases. To increase the wilderness and biodiversity of these sites, the addition of insect hotels is a feasible option (Harris et al., 2021). Additionally, engaging in

environmental interpretation activities can draw attention to the habitats and niches that support biodiversity (Zuppingier-Dingley et al., 2014) in surrounding areas.

In this IGC course, students are introduced to the principles and concepts of green chemistry where they must be able to apply the concept of green chemistry in Malaysia. The course topics provided students with the foundational knowledge needed to engage in the Edible School Program's activities, such as identifying edible plants on campus and brainstorming potential sustainable

farm or food options. Concepts such as waste management, renewable resources, and alternative energy were particularly relevant, as they helped students understand how organic waste could be repurposed for composting, how renewable energy could support sustainable food production, and how green chemistry principles could reduce the environmental impact of farming. Identifying edible plants on campus offered a practical application of these concepts, allowing students to see how local resources could be utilized in a sustainable way. The brainstorming session for campus food options encouraged students to creatively apply their learning to real-world challenges, considering how green chemistry could contribute to more sustainable, waste-reducing, and energy-efficient farming practices. These activities were specifically chosen to link theoretical knowledge with hands-on experience, helping students connect classroom learning with local solutions for food security and environmental sustainability. Over the semester, they studied and described the challenges of applying green chemistry concepts concerning zero waste, renewable resources, and alternative energy sources. Their research theme is closely related to agriculture and biodiverse edible school concepts (Fischer et al., 2019). Students have successfully observed the presence of edible plants on campus. They felt positive because from this course they had gone through the process of learning about the types of plants that can be eaten with colleagues from different departments. They were asked to make an oral presentation of the results of the observation at the selected location. The plants found on campus include rambutan, blackberry, papaya, young ferns, turmeric, pandan leaves, curry tree, banana, lime, coconut, ginger, jackfruit, chili, bluberry, pineapple, guava, star fruit, sugarcane, sapodilla, mango, cempedak, nangka, rambai istana, blue pea flowers, ara beringin, jambu air, screwpine, wood sorrel, palm tree, durian, pala, and belimbing buluh. The students were able to classify plants as tropical medicinal plants, local edible plants, or local edible fruits. In addition, they were able to identify the local names of these plants.

As a result of the experience from this extracurricular activity on the UM campus, they have successfully made written reports and face-to-face seminar presentations on assignments involving 12 chemical principles, with their respective topics focusing on zero waste, alternative energy sources and renewable resources related to Malaysia agriculture. Here, out of the 11 student groups formed, the zero-waste theme includes four student groups, the alternative energy sources theme comprises as many as three groups, and the renewable resources theme comprises the remaining four student groups. For the waste category, they reported that smart farming should be implemented in Malaysia agriculture. The use of smart farming applications can help farmers predict yields, minimize costs and waste resources. For example, drones and soil sensors are able to detect tree health and soil moisture during cultivation. A notable example of this smart farming is the collaboration between UM and private companies to support the growth and cultivation of black thorn durians in Malaysia (Banoo, 2023). In addition, the use of biofertilizers in agriculture, such as compost, may advance zero-waste practices, uphold the principles of green chemistry, and promote sustainability. One of the zero-waste student groups reported that composting is a key

component of sustainable local food initiatives, as it improves soil health, reduces environmental impacts, promotes efficient resource use, and fosters community engagement. Integrating composting practices into local agriculture contributes to the overall resilience and sustainability of food systems. In addition, sustainability through innovation in agricultural activities in Malaysia has been reported by another group in their final assignment. In this case, the edible cassava starch is processed to produce biodegradable and compostable packaging materials (Jumaidin et al., 2024). The brainstorming of the group members, also reported the prevention of waste from coconut leaves. Here, the leaves of the plant are used in traditional crafts, such as brooms, mats, baskets, and food wrappers. In addition, the trunks of coconut trees can be used as construction materials to build furniture and bridges.

With respect to the renewable resources in agriculture in Malaysia, one of the student groups emphasized solar benefits in sustaining farming practices. The introduction of solar-powered irrigation systems and efficient drying technologies has led to a commitment to addressing water scarcity and promoting energy-saving awareness (Safri et al., 2020). To address renewable resources, another group of students debated on biomass. One of the green revolutions toward sustainable farming practices is the utilization of biomass as a renewable energy source. Biomass is an organic material derived from edible plants such as maize, sugarcane, and paddies. It can be used as an alternative to fossil fuels. Biomass can be converted into bioenergy through various processes such as combustion, gasification, and fermentation. This bioenergy can replace non-renewable resources to meet on-farm energy needs by generating heat, electricity, and biofuels.

When alternative energy sources are used, energy-efficient greenhouses are recommended for agriculture in Malaysia. Energy-efficient greenhouses play a pivotal role in revolutionizing modern agriculture by combining the principles of green chemistry with advanced technology. In Malaysia, the use of energy-efficient greenhouses has gained traction as the agricultural sector strives to increase productivity and sustainability. One notable example is the adoption of controlled environment agriculture technologies, including high-tech greenhouses, in the Cameron Highlands (Idzni and Chia, 2021). This region, known for its cool climate, has implemented energy-efficient greenhouses equipped with advanced climate control systems, automated irrigation, and energy-saving lighting. These greenhouses enable year-round cultivation of crops such as strawberries, tomatoes, and flowers, optimizing growing conditions and minimizing the environmental impact. Excerpts of student reports with their respective group topics are collected in Table 6.

3.4 Students' perceptions of teaching practices

The participants' perceptions of various questions related to the diverse edible school teaching practices are summarized in this section. These questions covered their understanding of the number of edible plants on campus, attitudes toward biodiversity and agriculture, willingness to consume seasonal agricultural

TABLE 6 Excerpt report from Introduction to Green Chemistry student assignments that parallels the theme of agriculture with their biodiverse edible school and green chemistry concepts in Malaysia.

Area	Current cases in Malaysia	Brainstorming from group of students	Challenges of applying Green Chemistry concepts
Waste	In Malaysia alone, ~13.95 million tons of solid waste were generated in 2015. This includes waste from households, industries, commercial establishments, institutions, and construction activities.	Zero waste initiatives involve the development and execution of sustainable local food strategies that integrate principles aimed at minimizing waste, optimizing resource utilization, and fostering a circular economy. Cassava starch can be used to produce biodegradable and compostable packaging materials. Banana waste can be converted into biodegradable plastic. Oil palm cultivation can contribute to lower greenhouse gas emissions compared to other oil crops due to its high yield per hectare. Local farmers also can compost to create their nutrient-rich organic fertilizer for agriculture from coconut waste such as husks, leaves, and shells. The husk and shell of coconuts can be repurposed for various uses as the husk fibers can be processed into coir, a versatile material used for making brushes, mats, and soil amendments. Coconut shell charcoal is used in the production of activated carbon, which has applications in water filtration and air purification.	Highlight precision agriculture, biopesticides, biofertilizers and waste reduction; Utilizing technology like drones. Drones have the capability to precisely distribute fertilizers or pesticides only where needed, optimizing the use of these resources on the farm. Additionally, drones offer the benefit of early detection of issues such as plant diseases, soil analysis, and weed detection. The use of biodegradable resources like banana peels that is simple, lightweight, and recyclable packaging materials, greatly aids in reducing plastic pollution and constructing a more sustainable future. Transform plants into something new like recycling to minimize waste in our world. Avoid burning unwanted plants
Alternative Energy sources	Malaysia aims to utilize a substantial portion of palm oil biomass as an alternative energy to coal. In October 2018, new biogas plants under waste-to-energy project have successfully implement green practices in the industry. The collaboration between the Federal Land Development Authority (Felda) and Concord Green Energy Sdn Bhd (CGE) involves the establishment of biogas plants at 14 of Felda's palm oil mills. The initial phase of the project focuses on four "green field" palm oil mills, two located in Pahang and two in Johor. These biogas projects by CGE aim to generate electricity from palm oil mill effluent, utilizing Felda's existing biogas systems	Discussions on transformative potential of harnessing renewable energy to cultivate a greener and more resilient future for Malaysian agricultural landscapes; These biogas projects by CGE aim to generate electricity from palm oil mill effluent, utilizing Felda's existing biogas systems. Instead of merely managing waste, millers participating in the project can convert biogas into electricity, benefiting from the Feed-in-Tariff (FiT) incentive. This initiative not only provides additional income for the millers but also contributes to increased revenues, global recognition, and higher productivity for the companies involved. With an estimated potential to generate 5,000 MW of electricity at 40% operational efficiency, this biomass has the capacity to replace Malaysia's annual dependence on coal.	Mitigate greenhouse gas emissions; combining alternative energy sources such as solar, wind and biomass energy with sustainable farming practices which may have a profoundly positive impact; The successful implementation of this alternative energy source is crucial for achieving sustainable and environmentally friendly power generation in the country. The Sustainable Agriculture Education Association (SAEA) is a group of educators, researchers, students, and farmers who are interested in alternative energy integration and green chemistry practices in sustainable agriculture. In Malaysia, the SAEA has collaborated with local schools, community groups, and farmers to implement educational outreach programs on alternative energy integration and green chemistry practices in agriculture.
Renewable resources	Malaysia focuses more on biodiesel production, which comes from vegetable oils or animal fats. In Malaysia, the oil palm plant produces about 5 tons of palm oil per hectare, significantly more than rapeseed (1 ton) and soybean (375 kg) on the same land area. Using renewable energy sources like solar, wind, biomass, and hydropower is a key component of sustainable energy in agriculture; Coconuts are Malaysia's 4th and the world's 12th most important industrial commodity. Johor, a state famous known for its largest coconut plantations. Soil erosion is a common issue faced by farmers, where soil quality declines can lead to accumulation of toxic chemicals and environmental issues.	The most common sources for biodiesel production in Malaysia are palm oil and coconut oil. Biodiesel is biodegradable, non-toxic and environmentally friendly compared to petroleum. Palm oil, being the main feedstock for biodiesel, suits the economic structure of the country as it is constantly produced. It can be harvested throughout the year and is slightly affected by the season or weather. Photovoltaic technology incorporated into the drying systems to generate a fan, which is then converted into battery power to produce hot air. This innovative system serves as a valuable tool for promoting energy-saving awareness, aiming to reduce the impact of pollution on the wellbeing of future generations. Coco peat has favorable physical properties for plants, including the ability to inhibit a variety of fungal diseases.	Biofuel laws (for example, the National Biofuel Policy or the Malaysian Biofuel Industry Act) have been passed at the governmental level and have raised biofuel production in their aim to reduce the country's reliance on fossil fuel; Informing Malaysian farmers about the advantages and application techniques of biopesticides may increase its usage; The case of Malaysia exemplifies the success and potential of integrating solar energy into various agricultural facets, from irrigation systems to drying processes; Due to the non-favorable situations, coco peat, derived from coconut husks, serves as a versatile and sustainable solution in various applications.
Biodiverse edible school	Universiti Malaya campus; Tasek Varsiti (varsity lake), Rimba Ilmu Botanic Garden, Ladang Mini ISB (ISB Mini Farm), around the Faculty of Science and UM residential colleges	Discussions on edible plants and biodiversity of the sites; Make compost fertilizer from goat manure of the ISB farm and organic waste. Cooperation of prepared compost to improve the growth of the plants in the farm, such as rambutan, durian trees and crops for livestock (chicken, sheep, goat and others). Adoption of solar farming in alternative energy resources. Proposed anaerobic digestion of organic matter in anaerobic environments. Anaerobic digesters could be implemented where wastes can be converted into renewable energy	How to determine the composting method must be further debate. Collection of green materials is mandatory. Location for composting. Patience in harvesting the compost; incorporating solar farming educational modules into school curriculums to foster environmental consciousness. Educational outreach Programs to reduce greenhouse gas emissions and increase renewable energy generation. Promote biomass sources into high-energy biogas. Additional research on these by-products

(Continued)

TABLE 6 (Continued)

Area	Current cases in Malaysia	Brainstorming from group of students	Challenges of applying Green Chemistry concepts
		biogas and the final solid residue is converted into nutrient rich fertilizers. Implementation of Biopesticides in agriculture. The use of coco peat for farming and gardening. Specifically designed solar drying systems for drying agricultural products and herbs. Various materials, such as kenaf, seafood (including seaweed), medical herbs, and sliced tamarind, can be dried in these areas within a short period of 2–3 days.	may reveal greater utility of these waste and aid in effective sustainable agriculture. Sustainable energy in agriculture. Greenhouse drying system.

products, achievement of course learning objectives, and linkage to the SDGs.

To assess participants' understanding of edible plants on campus, we compared their responses regarding the number of edible plants they could identify before and after the activities. For the question "How many species of edible plants do you know on your school campus?", we observed varying results across different classes. In the IAT class, there was a decrease in average responses after the activities ($P < 0.05$), suggesting that participants may have felt less confident in their knowledge post-activity. In contrast, the OA class showed no significant change, indicating stability in participants' perceptions. Notably, participants in the IGC class reported a significant increase in their knowledge ($P < 0.01$), along with substantial increases in the TCRL-23-01 ($P < 0.001$), TCRL-23-02 ($P < 0.001$), TCRL-24-01 ($P < 0.01$), and TCRL-24-02 ($P < 0.001$) classes (Figure 2), suggesting that the activities were effective in enhancing their understanding among these groups. For the open-ended question "Write down some edible plants you know that can be found on your school campus," we found no significant differences in responses before and after the interventions in the IAT and OA classes. However, participants in the IGC class showed a significant increase in their ability to identify edible plants ($P < 0.01$), as did those in all the TCRL classes ($P < 0.001$; Figure 3), indicating that specific teaching practices in these classes may have successfully engaged the students and expanded their knowledge.

When asked whether "This course enhances my understanding about biodiversity," the participants generally agreed that the activities enhanced their knowledge of biodiversity, with the highest score of 6.4 in the TCRL-24-02 class and the lowest score of 5.9 in the OA class (Figure 4A). Similarly, for the question "This course enhances my understanding about agriculture," the participants indicated an overall positive response, with the highest score of 6.5 in the OA class and the lowest score of 6.1 in the IGC class (Figure 4B), reflecting a consensus among participants that the course content effectively contributed to their understanding of both biodiversity and agricultural concepts. With respect to the question "After the agricultural-themed activity in this course, I'm more willing than before to prioritize consuming locally and seasonally produced agricultural products," the participants expressed increased willingness, with the highest score of 6.2 in the IAT class and the lowest score of 5.8 in the IGC class (Figure 4C), suggesting that engagement with local food systems may have positively influenced participants' attitudes toward sustainable consumption. Furthermore, when asked if "The

agricultural-themed activity in this course contributes to achieving my learning objectives," the participants agreed that it contributed to achieving the learning objectives, with the highest score of 6.5 in the IAT class and the lowest score of 5.7 in the IGC class (Figure 4D), indicating that the students recognized the relevance of these activities to the educational goals.

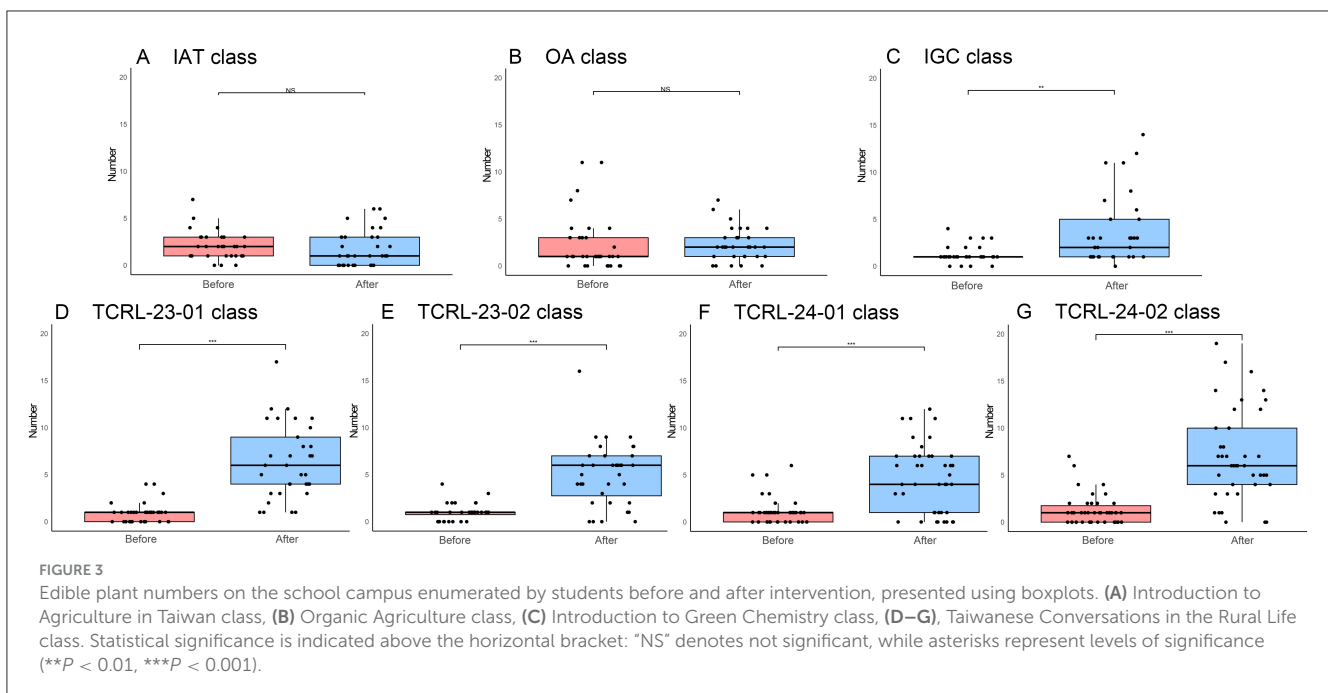
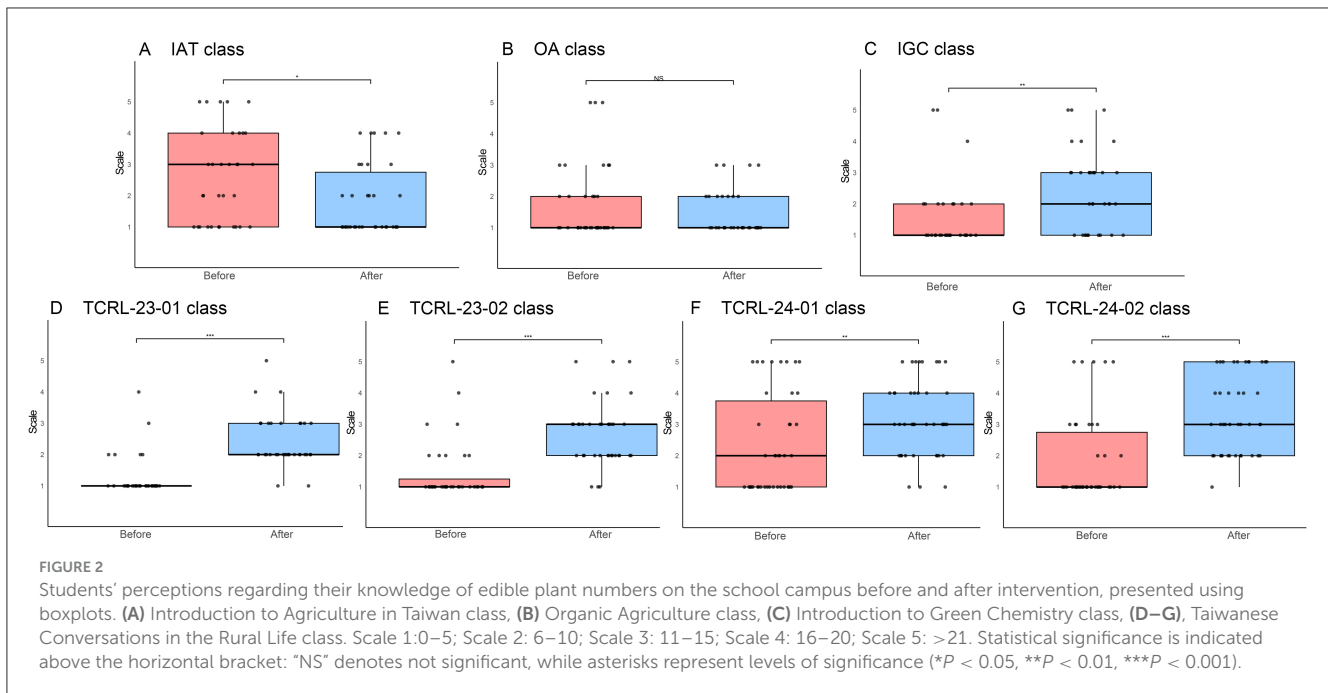
Finally, the participants considered that the biodiverse edible school teaching practices in the study corresponded to the SDGs, with the highest agreement for Goal 2 (zero hunger). This was followed by Goals 12 (responsible consumption and production), 15 (life on land), and 3 (good health and wellbeing) (Table 7), highlighting not only an enhanced understanding of biodiversity and agriculture but also an awareness of how these practices contribute to broader global goals.

4 Discussion

This study aimed to improve learning outcomes for undergraduate students in liberal education courses at universities through the inclusion of biodiverse edible school concepts. They were introduced in six classes in Taiwan and one in Malaysia, providing practical examples related to biodiverse edible schools in East Asia and Southeast Asia. These pedagogical approaches effectively enhanced students' understanding of biodiversity and agriculture, increased their willingness to consume local foods, and helped them achieve course objectives across various fields, including agriculture, language, and green chemistry (Figure 4; Table 2). In addition to the application cases for children (Fischer et al., 2019), our teaching and learning experiences serve as pioneering examples for integrating biodiverse edible school concepts into university education. These findings demonstrate that biodiverse edible school concepts can be effectively incorporated into higher education curricula.

4.1 Implementing biodiverse edible school concepts increases learning outcomes for university students in Taiwan and Malaysia

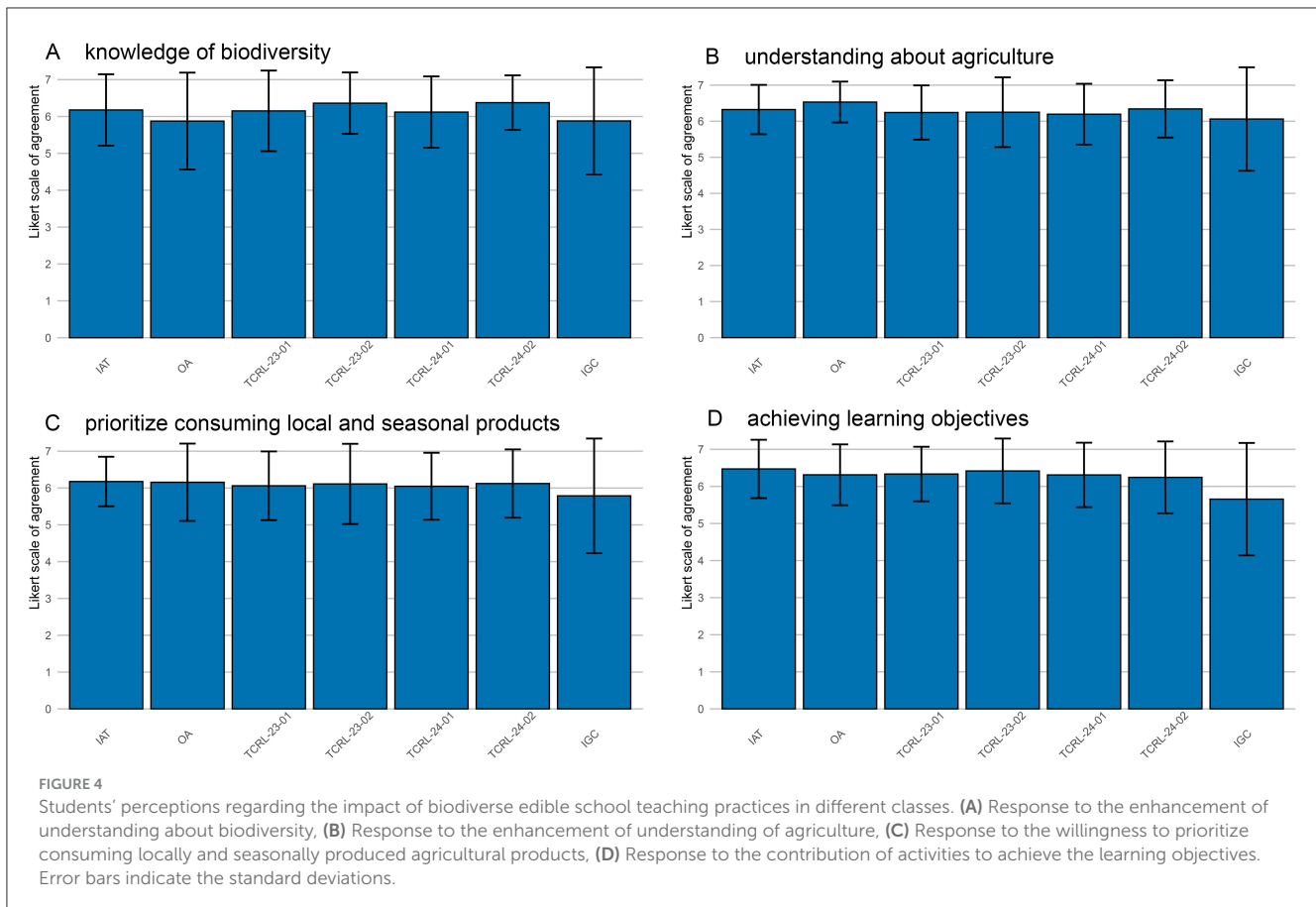
Biodiverse edible schools have shown significant potential in transforming student learning experiences across various academic settings in Taiwan and Malaysia. This approach has been successfully applied to a range of courses, including a specialized



agricultural-focused class (e.g., organic agriculture), low-pressure agricultural-focused classes (e.g., introduction to agriculture and conversations in rural life), and a non-agricultural-focused class (e.g., green chemistry). Furthermore, it is adaptable to multiple instructional languages (English, Chinese, and Taiwanese) and can be integrated into both indoor and outdoor educational activities.

At National Taiwan University, the implementation of biodiverse edible school concepts involved interactive lectures on relevant topics, student-centered edible plant search activities, and didactic report assignments incorporating brainstorming sessions, covering all three broad instructional styles in STEM teaching

in [Stains et al. \(2018\)](#). Similarly, the teaching practices employed at UM were considered to encompass all these teaching styles. Following [Fischer et al. \(2019\)](#), the teaching and learning process related to biodiverse edible schools can be structured around three core themes: (1) Biodiversity, which includes recognizing cultivated edible plants, wild edible plants, and non-edible plants. The concept can be expanded to cover all campus wildlife observed by university students. (2) Food: This theme emphasizes the experiences of locally grown, organic, nutritious, seasonal, and fresh food. It can be effectively integrated into food and agricultural education within university courses. (3) Students or participants: While [Fischer et al.](#)



(2019) focused on younger children, biodiverse edible schools in a university setting can provide education on environmental and food awareness, health and wellbeing while achieving specific learning objectives for each class.

Our findings from practical examples and the students' brainstorming ideas suggest a range of strategies for incorporating biodiverse edible schools into university environments (Tables 4–6). These strategies range from developing university courses and community partnerships to creating edible gardens and improving campus food services. While the feasibility of some approaches still needs to be assessed, the experiences learned from Taiwan and Malaysia may offer important directions for implementing biodiverse edible schools in higher education.

Interestingly, students' understanding of the number of edible plants on campus varied before and after our interventions. This variation may be attributed to the different tasks assigned: reporting assignments for the IAT and OA courses, reporting assignments combined with outdoor activities for the IGC course, and outdoor educational activities for the TCRL classes. The IAT and OA students did not elaborate more edible plant species on campus after more information was gathered (Figures 2A, B, 3A, B). In contrast, IGC students demonstrated increased knowledge (Figures 2C, 3C). Furthermore, students' perceptions of their knowledge of edible plant numbers on campus significantly improved after they participated in the language-learning “Agri-food campus tour” outdoor activity across the four TCRL classes (Figures 2D–G, 3D–G). These findings suggest that direct

outdoor observations and interactive teaching methods can effectively enhance learning outcomes related to biodiversity, food, and agriculture.

While our study provides valuable information for the application of teaching practices, it has limitations in that it relies on self-reported learning measures. Future research could complement these measures with more objective assessment methods to provide a comprehensive evaluation of the effectiveness of educational interventions.

4.2 Connecting outdoor experiential learning activities with biodiverse edible school teaching practices for greater effectiveness

The biodiverse edible school teaching practices in the TCRL classes integrated outdoor exploration and classroom discussions on the university campus. This is in line with the food studies course described in Lehrer (2024), which employs experiential learning (Kolb, 1984) in food and agricultural education. Such practices facilitate self-reflection, critical thinking, and help achieve learning goals (Lehrer, 2024). The study results also agree with previous work on developing experiential learning activities using student farms in sustainable agriculture education (Parr and Trexler, 2011), as well as our previous experiences in a

TABLE 7 Students' feedback on the relevance of the biodiverse edible school teaching practices in each class to the SDG goals.

SDG goals	IAT (n = 34)	OA (n = 32)	TCRL-23-01 (n = 33)	TCRL-23-02 (n = 36)	TCRL-24-01 (n = 42)	TCRL-24-02 (n = 41)	IGC (n = 33)	Total (n = 251)
1	5	6	3	4	7	12	7	44 (17.5%)
2	20	29	23	29	26	29	20	176 (70.1%)
3	25	15	13	16	14	22	13	118 (47.0%)
4	14	7	8	8	6	13	7	63 (25.1%)
5	5	1	5	7	5	8	7	38 (15.1%)
6	9	7	8	8	7	8	7	54 (21.5%)
7	8	4	7	11	7	11	16	64 (25.5%)
8	5	9	9	13	6	9	9	60 (23.9%)
9	9	1	2	4	3	5	9	33 (13.1%)
10	5	1	7	3	7	8	5	36 (14.3%)
11	8	3	8	7	2	9	18	55 (21.9%)
12	16	25	23	22	25	25	18	154 (61.4%)
13	12	3	9	5	4	8	16	57 (22.7%)
14	7	4	8	9	4	11	8	51 (20.3%)
15	21	23	17	22	23	19	20	145 (57.8%)
16	2	12	4	4	4	11	6	43 (17.1%)
17	5	3	4	4	5	7	6	34 (13.5%)

IAT, Introduction to Agriculture in Taiwan; OA, Organic Agriculture; TCRL23-01, Taiwanese Conversations in the Rural Life 2023 class 1; TCRL23-02, Taiwanese Conversations in the Rural Life 2023 class 2; TCRL24-01, Taiwanese Conversations in the Rural Life 2024 class 1; TCRL24-02, Taiwanese Conversations in the Rural Life 2024 class 2; IGC, Introduction to Green Chemistry.

vegetable disease course, completing the experiential learning cycle encompassing concrete experience, abstract conceptualization, reflective observation, and active experimentation (Kolb and Kolb, 2009). The use of experiential learning may enhance teaching and learning effectiveness in liberal education (Shen et al., 2023). Notably, outdoor weather can significantly influence student learning. In this study, the TCRL-24-01 class, which was affected by both low temperature and rain, had a relatively shorter average outdoor activity time (<30 min) and a slightly lower increase in learning outcomes (Figure 2F). In contrast, the TCRL-24-02 class, which experienced only low temperature, had an ordinary duration of activity and did not appear to be significantly affected (Figures 2G, 3G). The finding that rain is a critical adverse weather condition for outdoor educational activities is consistent with Wagner et al. (2019) regarding outdoor exercise behaviors. In combination with the learning experience in the environment and discussions in the classroom, which are focused on the objectives of language learning, the concepts of biodiverse edible schools (Fischer et al., 2019) can be extended as specific tasks to enhance students' learning, such as the agri-food campus tour in our study. Despite the potential shortage of language learning materials about agriculture on a regional scale (Usmansyah et al., 2019), this can be a new pedagogical model of task-based language teaching (Van den Branden et al., 2009; Van den Branden, 2016) both inside and outside the classroom, which is engaging and successful in achieving course objectives.

4.3 Integrating biodiverse edible schools with green chemistry for sustainable education in Malaysia

Many projects can be suggested within the concept of biodiverse edible schools and, in turn, enrich student learning outcomes. For example, to ensure the health and sustainability of terrestrial ecosystems, such as tropical medicinal plants, edible plants, and edible fruits around the campus, consistent monitoring of soil quality is crucial. The soil organic carbon level has become increasingly important in ensuring sustainable agricultural production. Other important indicators of soil quality include physical factors (water holding capacity, soil tilth, temperature, soil respiration, and porosity), biological factors (enzymes, microbial community, and total biomass) and chemical factors (pH, nutrient cycling rates, salinity, micronutrients, heavy metals, and available N/P/K; Bünemann et al., 2018; Sharma et al., 2023). Soil monitoring involves interdisciplinary activities, supporting the educational purposes of biodiverse edible schools and achieving many SDGs. A healthy and nutritious soil helps maintain water and air quality, improving animal and plant productivity and alleviating greenhouse gases. Soil is more complex than air and water because it comprises solid, liquid, and gaseous phases. Improving soil quality is important for protecting the environment ecologically and promoting sustainable agricultural development. These

approaches have the potential to enrich the learning outcomes for the IGC course by enhancing the understanding of food production, healthier diets, and the concept of biodiverse edible schools.

For students in green chemistry, the practice of composting organic waste closely aligns with the core principles of sustainable chemistry, particularly in terms of waste reduction, resource recycling, and minimizing environmental impact. By converting organic matter such as goat manure into biofertilizers, this process exemplifies biodegradation and biocatalysis, where microbial activity breaks down complex compounds into plant-available nutrients. Students can explore the underlying chemical reactions involved in nutrient cycling and the transformation of carbon, nitrogen, and phosphorus in the soil, emphasizing how these processes are governed by chemical equilibria and soil pH. Furthermore, the use of compost reduces the reliance on energy-intensive synthetic fertilizers, addressing resource efficiency and promoting the use of renewable resources a key tenet of green chemistry. This approach not only enhances soil health but also demonstrates how green chemistry can drive agricultural sustainability while mitigating harmful environmental effects, a concept that is increasingly crucial as scientific understanding and agricultural practices evolve.

For sustainable campus development to be on the right track, education incorporating agriculture is the right choice. For example, live waste compost or co-compost is a great example of a biofertilizer and a source of macronutrients and micronutrients. The addition of organic matter helps improve the soil structure, improves the soil's water holding capacity, reduces erosion, and alleviates fertilizer leaching. Moreover, feeding microbes helps increase soil biological diversity, which accelerates the breakdown of organic nutrients, and thus can be readily absorbed by plants (Rosman and Jamaludin, 2022). Currently, Ladang Mini ISB at UM is actively formulating compost fertilizer from goat manure and organic waste to increase soil fertility and promote the growth of durian and rambutan trees. Challenges in various areas, including renewable resources, arise through innovations and collaborations among students in biodiverse edible school practices. For example, the production of biomaterials from edible plants has led to the use of methylcellulose, a biodegradable material, in students' final year projects for sustainable energy storage applications (Shamsuri et al., 2024). Undeniably, the involvement of urban agriculture education in biodiverse edible school practices can create another step forward for UM policymakers to ensure the realization of the SDGs by the year 2030.

4.4 Universities' involvement in biodiverse edible school concepts

The original approach of biodiverse edible schools connects biodiversity, healthy food, and children together for environmental education in and near schools (Fischer et al., 2019). These concepts can be adapted to university settings by linking biodiversity, healthy food, and students within higher education programs. Considering the four components outlined by Fischer et al. (2019), collaborative activities, school kitchens, school gardens, and wild

sites, our results summarize and adapt these elements to the university context in Taiwan (Table 5). Unlike secondary schools, where principals, teachers, and parents play key roles, university instructors can guide students directly using project-based learning strategies (Kokotsaki et al., 2016) and similar approaches to achieve biodiverse edible school objectives. Although fixed school kitchens are uncommon on university campuses, stakeholders can collaborate with students and student clubs to promote access to healthy, local foods. With respect to school gardens and wild sites, diverse ecological niches in and around university campuses may offer opportunities for exploration and management by students and community stakeholders.

Biodiverse edible schools can feasibly be integrated into agriculture-based learning, food education, and agroecology content in higher education programs (Wezel et al., 2009; Kimura, 2011; Francis et al., 2003; LaCharite, 2016; Wang et al., 2023), as demonstrated in this study. Previous reports have raised the question of the need to modify learning activities and higher education curricula to address the ecology of food systems (Lieblein et al., 2007; Wezel et al., 2009). This study establishes pedagogical models incorporating biodiverse edible school practices for university students. In addition to combining biodiversity, agriculture, and liberal arts (LaCharite, 2016; Wezel et al., 2009; Francis et al., 2003), the teaching and learning practices in this study incorporate practical examples such as campus gardens, community-supported agriculture, farm-to-table initiatives, and transdisciplinary cases in liberal education. The involvement of biodiverse edible schools in higher education virtually enhances students' understanding of biodiversity, agriculture, and potentially responsible actions.

Although initially designed for younger students, biodiverse edible schools have been adapted for university settings to provide students with practical, real-world applications such as green chemistry and sustainability principles. By involving students in activities such as identifying campus edible plants and brainstorming campus-based food production solutions, the program promotes critical thinking about sustainable agriculture, waste reduction, and renewable energy. This finding supports the recommendation of Orr (1994) to include agriculture as a part of a complete liberal arts education for college students.

We further recommend extending these concepts to a broader range, including studies in urban agriculture, edible cities, and sustainability transformation (Sartison and Artmann, 2020; Sardeshpande et al., 2021; Ayoni et al., 2022). In our study cases, the campus and surrounding areas of NTU have already been hotspots for urban farming (Zhou et al., 2023), potentially serving as satellites for urban gardens in Taipei city, benefiting both local and non-local participants (Hsiao, 2021; Mabon et al., 2023; Zhou et al., 2023). It is suggested that university campuses in urban areas can further act as reservoirs of biodiversity (Liu et al., 2021) and offer people unique restorative effects that promote mental health, wellbeing, and quality of life (Van den Bogerd et al., 2018; Gulwadi et al., 2019; Ha and Kim, 2021). Although the educational and various benefits of different types of urban agriculture have been categorized (Wadumestrige Dona et al., 2021), further studies are needed to understand how biodiverse edible school infrastructures and programs can benefit students, local communities, and urban sustainability.

4.5 Advancing sustainable development through biodiverse edible school concepts

Biodiverse edible schools should contribute significantly to reaching several SDGs. From our perspective, biodiverse edible schools not only contribute to fostering SDG 2 of ending hunger, as seen in edible urbanism (Russo and Cirella, 2019), but also promote responsible consumption and production (Goal 12), biodiversity on land (Goal 15), and good health and wellbeing (Goal 3) for students, communities, and urban environments. The mention of the SDGs in this report underscores the university's commitment to integrating global sustainability efforts into its educational initiatives. By aligning with the SDGs, UM demonstrates its dedication to addressing environmental, social, and economic challenges both locally and globally. For example, this work promotes zero hunger (SDG 2) through promoting local food production. It contributes to good health and wellbeing (SDG 3) by providing access to fresh, healthy food, and sustainable cities and communities (SDG 11) by incorporating urban agriculture into campus life. Additionally, these initiatives contribute to responsible consumption and production (SDG 12), climate action (SDG 13), and quality education (SDG 4) by fostering sustainable agricultural practices, reducing waste, and providing students with hands-on learning opportunities. The integration of the SDGs into final-year projects at the UM Sustainability and Development Centre further emphasized the university's role in preparing students to address global sustainability challenges through interdisciplinary expertise and innovative solutions.

This study has important implications for higher education policy, particularly in incorporating biodiverse edible school concepts in different regions such as Taiwan and Malaysia. When higher education institutions establish their sustainability visions according to the SDGs or regional laws such as the Food and Agricultural Education Act, biodiverse edible schools can serve as a guiding roadmap for implementation. This approach supports institutions in developing essential resources and designing effective pedagogies for Education for Sustainable Development (Wade, 2008) following the framework in Kioupi and Voulvoulis (2019). Our findings offer policymakers with practical models that combines food, gardens, and biodiversity in educational schemes across university campuses. In particular, incorporating outdoor experiential learning activities into curriculum design should boost students' active participation and pro-environmental attitudes (Sehar et al., 2025). To maximize impact, it is recommended to design teaching practices to meet both course-specific learning goals, from agriculture to chemistry topics in this study, while also addressing the broader SDGs, using biodiverse edible school concepts acting as a bridge. In addition, establishing strong partnerships with educators, school staff, student organizations, local communities, and governmental bodies is key to successful execution. From the university's perspective, the sector worked as sustainability offices can allocate funding for campus green spaces as living laboratories and offer grants for student-led campus sustainability projects, analogous to efforts in biodiversity preservation and sustainable development in higher education in Yerokhin et al. (2024) and Franco et al. (2019).

In conclusion, this study presents compelling educational examples of how biodiverse edible school concepts can be

effectively integrated into university curricula. Educators (teachers and instructors) and university students, whether through student clubs, in-class tasks, or self-directed activities, can make critical use of their school environments without relying heavily on external resources. These implementations have the potential to enhance students' learning outcomes across a wide variety of courses. The inclusion of teaching strategies that explore biodiverse edible school elements—such as edible plants, local biodiversity, and school gardens, as well as neighboring wild sites—not only increases students' understanding of biodiversity, food systems, and sustainability but also promotes closer connections between students and their environment. This study demonstrates that biodiverse edible schools can be successfully adapted to higher education, providing new ways to integrate these topics into university curricula and contributing to significant advancements in sustainability education.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

Ethical approval was not required for the studies involving humans because the participation in the study was voluntary, and informed consent was provided prior to the commencement of the assignment. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MS: Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing. GC: Methodology, Writing – review & editing. HW: Methodology, Writing – review & editing. CH: Methodology, Writing – review & editing. NJ: Writing – review & editing. MK: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1472179/full#supplementary-material>

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Systematic literature review: a typology of Sustainability Literacy and Environmental Literacy

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Creating awareness about Sustainability Literacy (SL) and Environmental Literacy (EL) across educational institutions has increasingly captured the attention of researchers. Given the growing yet fragmented literature about SL and EL across academic disciplines, there is a need to expand and connect this knowledge. This research aims to examine the definitions of SL and EL, their association with Education for Sustainable Development (ESD) and Environmental Education (EE) as well as to present a coherent typology of definitions of SL and EL. The study employs a qualitative thematic analysis approach and the PRISMA guidelines for Systematic Literature Reviews (SLRs) using a sample set of 38 articles from the *Scopus* and *Web of Science* databases. The results provide a significant understanding of the notions, typology, and learning outcomes of SL and EL in the context of Education for Sustainable Development (ESD), as well as the most cited SL and EL definitions, the most associated concepts to SL and EL, and the most representative collaboration networks by countries. The findings reveal the interconnection of EL, Environmental Education (EE), ESD, and curriculum design, underscoring the need to integrate sustainability principles into the educational curriculum, as well as the integration of SL and Sustainable Development Goals (SDGs) in Higher Education. Finally, this study uncovers an urgent call to enlarge global and local collaboration networks to expand sustainability knowledge worldwide.

KEYWORDS

sustainability literacy, environmental literacy, systematic literature review, education for sustainable development, sustainability curriculum, sustainability learning outcomes, global citizenship education, sustainability competencies

Introduction

The historical context of Environmental Education (EE) and Education for Sustainable Development (ESD) implies a shift from an approach focused on environmental issues to a broader integration of environmental, social, and economic dimensions aimed at achieving sustainable development. In this transition, the concepts of Environmental Literacy (EL) and Sustainability Literacy (SL) become important to tackle sustainability global challenges as they are outcomes from EE and ESD, respectively. According to [UNESCO \(2022\)](https://unesco.org/en/articles/2022/04/20/energy-demand-projected-to-grow-by-50-percent-by-2050), by the year 2050, energy demand is projected to grow by 50%, food demand by 35%, and water demand by 30%. These substantial increases in essential resources highlight critical sustainability challenges that must be addressed to achieve a fair and thriving global society. Understandably, educational institutions play

a fundamental role in spreading sustainability awareness (Ahel and Schirmer, 2023; Chen C. et al., 2022; Ferrer-Estévez and Chalmeta, 2021; Ling et al., 2021; Murray and Cotgrave, 2007). However, one of the major challenges that higher education institutions face is enhancing SL (Dallaire et al., 2018; Nolan et al., 2021). Given the increasing number of publications on ESD since the launch of the SDGs in 2015 (Araujo et al., 2020), the literature on SL has become fragmented. Therefore, this research aims to examine the definitions of SL and EL and their associated concepts. The research questions addressed in this SLR are:

1. What are the most cited definitions of SL and EL found in this SLR?
2. How can a coherent typology of definitions of SL and EL be structured?
3. What are the most associated concepts to SL and EL?
4. What are the most representative collaboration networks by countries?

Environmental education and education for sustainable development

In the world today, expanding knowledge of sustainability is essential for promoting ESD and SL. To illuminate the evolution of ESD, the Stockholm Conference in 1972 was the first international conference that acknowledged the need for EE (UNESCO, 1972), indicating EE plays an important role addressing environmental issues (Lo et al., 2002; Sterling, 2013; Thomas et al., 1999). Followed by the Tbilisi Declaration that specified “EE should be provided for all ages at all levels” (UNESCO, 1978, p. 244), UNESCO (1978) mentioned that EE refers to “...knowledge, values, attitudes, and practical skills to participate in a responsible and effective way in anticipating and solving environmental problems” (p. 2). With this international endorsement, the term EE became increasingly widespread in the following decades. Arguably, during the 1970s and 1980s EE had a clear boundary on environmental issues, environmental interpretations, and environmental science (Sterling, 2013). To understand the change in terminology, accompanied by key milestones of ESD, Figure 1 illustrates a timeline with an overview of the evolution of ESD.

It is important to highlight the emerging interconnectedness between EE and other themes such as peace, justice, inequality, human rights, and development. As a result, the Brundtland Commission Report defined Sustainable Development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987, p. 41), linking the concepts of “environment” and “development” in the contextualization of EE and ESD respectively. Consequently, as the Rio Summit stated, “the need to re-orient Education for Sustainable Development (ESD)” (United Nations, 1992), during the 1990s a broader perspective of EE arose. Subsequently, on December 20th, 2002, the United

Nations General Assembly declared 2005–2014 as the Decade of Education for Sustainable Development (DESD) (UNESCO, 2004; ESD Section, 2007).

In three decades, from 1972 to 2002, the concept of EE evolved into ESD. Currently, the UNESCO Office Venice, and Regional Bureau for Science and Culture in Europe (2024) states that ESD “gives learners of all ages the knowledge, skills, values and agency to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources, and inequality” (p. 11). Since ESD encompasses environmental, social and economic dimensions, the use of the term ESD has gained increasing influence worldwide, particularly after the United Nations launched Agenda 2030 including 17 SDGs (United Nations, 2022).

Although EE, Education for Sustainability, and ESD are utilized in the literature as interchangeable terms (Adlong, 2013; Rukmana et al., 2023; Sterling, 2013), it is relevant to mention that consensus on the terminology of EE, Sustainability Education, Sustainable Education, and Education for Sustainability has not yet been reached. For instance, while Barkemeyer et al. (2014) noted that sustainable development discourse tends to emphasize environmental over social aspects, Kopnina (2014) argued focusing on social aspects often overlooks the environmental perspective.

In addition, Sterling (2013) highlighted various perspectives in the ongoing debate regarding the terms EE or ESD: some argue EE is synonymous with ESD, others contend ESD is a component of EE or vice versa, and some suggest ESD is a holistic term while EE should be discarded. For example, whereas De Andrade Guerra et al. (2018) found commonalities between the two terms EE and ESD and treated them as synonymous, Ilovan et al. (2019) utilized the terms of EE and ESD with defined characteristics, and Holm et al. (2015) employed only the term ESD, leaving out term EE. Despite these differing viewpoints, the transition from EE to ESD remains an evolving topic.

Acosta Castellanos and Queiruga-Dios (2022) confirmed two predominant currents in the literature: EE and ESD, noting that Europe is the most noticeable geographical region transitioning from EE to ESD. However, this result does not imply that EE is outdated, as the other regions in the world (Asia, North America, Oceania, Africa, and Latin America) still produce publications using this term (Acosta Castellanos and Queiruga-Dios, 2022). Consequently, it is expected that scholars continue to generate research on ESD, which is the most prominent stream (Acosta Castellanos and Queiruga-Dios, 2022), as part of the agenda 2030 that includes the global efforts to work on the sustainable development of goals.

As UNESCO (2017) stated, ESD should be integrated into all curricula in formal education across all levels. Even though the labels are important to achieve coherence and a shared understanding of the meaning of ESD, there is an urgent need to develop training and expand sustainability knowledge that translates to pro-sustainable behavioral change (Kuehl et al., 2021; Chen C. et al., 2022; Décamps et al., 2017; Sanchez et al., 2024) as well as embrace SL at all education levels (Potter-Nelson and Meyers, 2022; Leiva-Brondo et al., 2022; Sanchez et al., 2024).

Abbreviations: EE, environmental education; EL, environmental literacy; ESD, education for sustainable development, SDGs, sustainable development goals, SL, sustainability literacy.

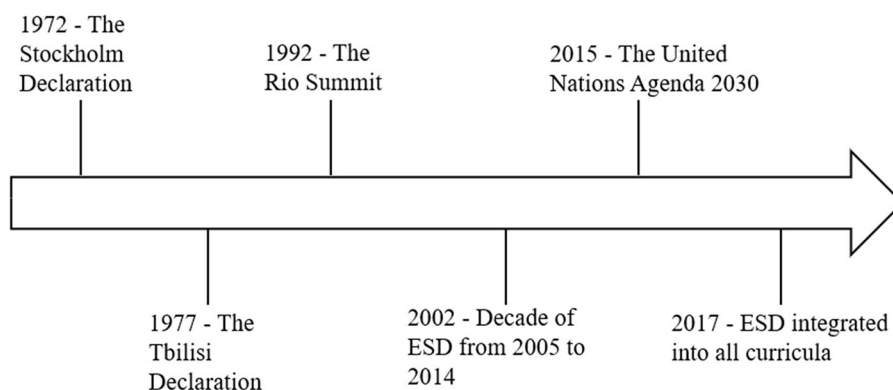


FIGURE 1
Evolution of education for sustainable development timeline.

Environmental literacy and sustainability literacy

The conceptual dialogue surrounding SL is intrinsically linked to the United Nations' SDGs and the framework of ESD, all of which are crucial in accomplishing sustainable development and achieving the SDGs (Ahel and Schirmer, 2023). Systematically, SL is an outcome of ESD (Décamp et al., 2021), and EL is an outcome of EE (Elder, 2003; Moody et al., 2005). Since the literature about the definition of SL is fragmented, this research contributes to a better understanding of the notion of SL and EL in the context of ESD. To clarify the concepts and learning outcomes of SL and EL, this study will develop a SLR that serves as a robust and comprehensive methodology for critically appraising research, positioning it on par with high-caliber primary studies (Petticrew, 2001).

Previous studies have focused on EL and the eco social crisis (Martínez-Aznar et al., 2022) as well as studies probing the modeling of EL among university students (Aighewi and Osaigbovo, 2010; Teksoz et al., 2012). Therefore, this literature review embarks on a pioneering effort to explore the notions of SL and EL, highlighting the most cited definitions, associated concepts, and the most representative networks and author collaborations.

Methods

This qualitative SLR study employs a thematic analysis to examine the definitions of SL and EL and structure a typology of EL and SL based on their learning outcomes. To select a relevant sample of articles, this SLR follows the Preferred Reporting Items for Systematic reviews. The authors sourced and curated relevant articles on SL and EL from databases like *Scopus* and *Web of Science Core Collection*. *Scopus* is the most comprehensive academic database accepted worldwide (Nuryana et al., 2023) and *Web of Science* is one of the most prestigious databases in the scientific community (García-Buendía et al., 2021). As a result, *Scopus* and *Web of Science* were selected due to the high-quality

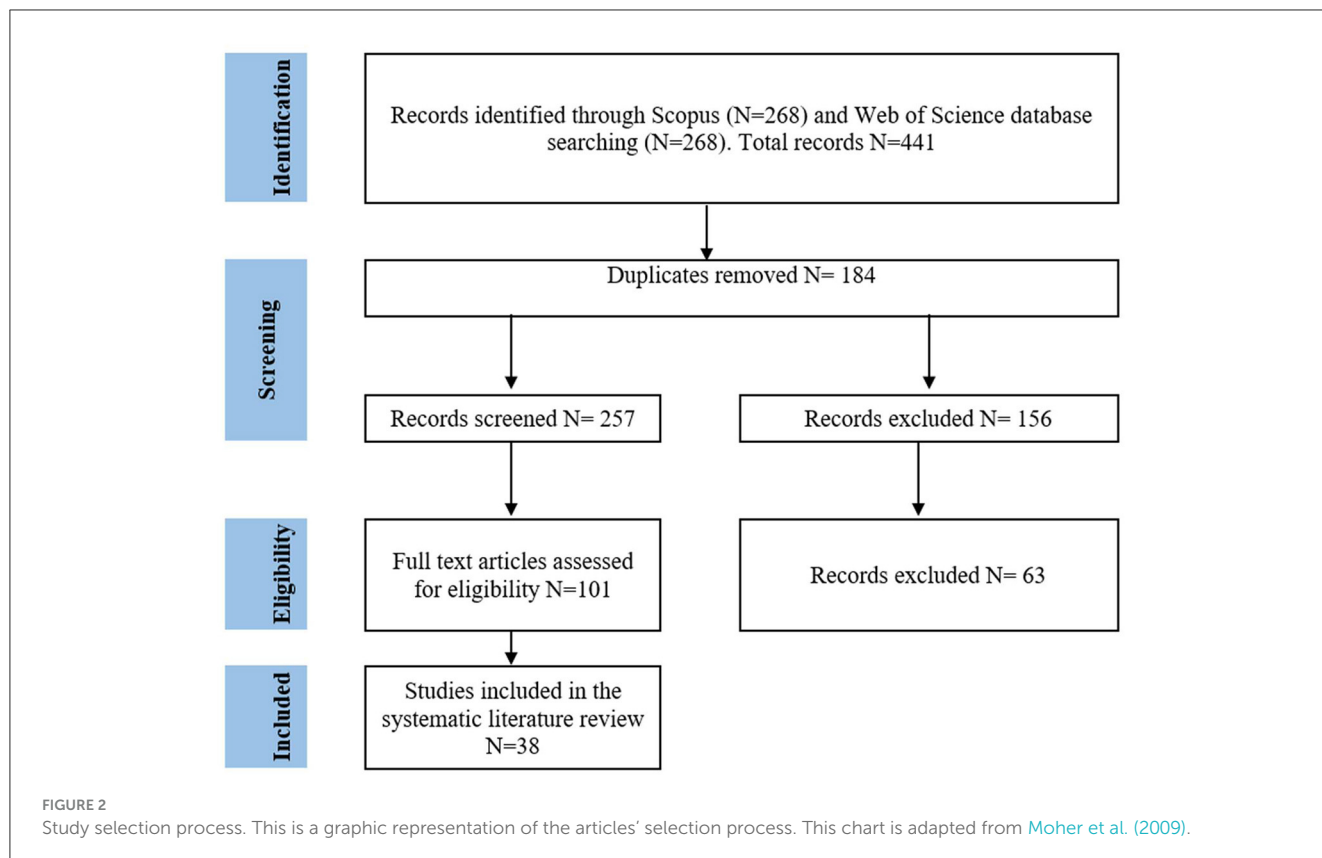
peer review, rigorous methodological standards, and reputation in the community of scholars.

The search strategy

Adhering to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021; Liberati et al., 2009), the search strategy was conducted between August 2023 and September 2023. The search for articles was conducted in two specific databases, *Scopus* and *Web of Science*. Google Scholar database was not utilized to search for the articles. This SLR employs high-quality journals. Fleming et al. (2014) mentioned that these journals generally offer higher methodological quality. In addition, high-quality journals typically undergo rigorous peer-review process (Abushouk et al., 2021), which enhance validity, reliability, and relevance of the research they publish. Moreover, these journals often require informing adherence to reporting standards and checklists such as EQUATOR, PRISMA, or MOOSE to ensure transparency and rigor (Abushouk et al., 2021). Furthermore, high-quality journals are more likely to publish research that meets rigorous scientific and methodological standards, providing robust statistical analyses and meaningful contributions to the field.

The search strategies were highly targeted and precisely designed to examine SL and EL definitions in scholarship conducted or associated with higher education institutions. Therefore, the search equation comprised ("Universit*" OR "higher education institution" OR "institution of higher learning") AND ("sustainability literacy" OR "sustainability-literate" OR "sustainability literate" OR "sustainability proficiency" OR "environmental literacy" OR "sustainability litera*" OR "sustainability literacy assessment" OR "sustainability literacy measurement" OR "environmental litera*"). These search terms resulted in 441 articles from the selected databases (*Scopus* and *Web of Science*).

Figure 2 summarizes the stages of the article's selection process. Initial results reported 441 articles from both databases,



encompassing quantitative, qualitative, and mixed methodologies studies published between 1982 and 2022.

Inclusion and exclusion criteria

The authors reviewed all 441 articles of the initial search and removed 184 duplicates, leaving 257 articles. Subsequently, we screened the abstracts of these 257 articles to ensure their relevance to the objectives of the systematic review. After carefully reading the abstracts, we excluded 156 articles that were not relevant to the research focus, resulting in a final set of 101 articles that aligned with the purpose of the study. The abstract screening helped us initially filter articles for relevance before proceeding to a full-text review. Articles were excluded based on irrelevant topics or focus, poor reporting, or methodological flaws.

Initial inclusion criteria were set for articles published in journals and papers in their final stage that offered full text and were subjected to peer-review and available in either English or Spanish. Essential details like title, abstract, keywords, authors' credentials, journal designation, and publication year of the discerned records were cataloged in a Microsoft Excel spreadsheet. Next, the authors read 101 articles searching for definitions of SL and EL. As a result, 27 publications were excluded because they did not provide definitions of either SL or EL.

Subsequently, 74 articles underwent evaluations, categorizing them based on relevance to the topic. To ensure sources were of the highest quality and rigorously researched and reviewed, the

next set of selected papers were those that had been published in journals ranking in the Journal Citation Report (JCR) or Scimago Journal Ranking (SJR) quartile 1 (Q1) and quartile 2 (Q2). This classification helps to understand credibility, impact, and standardized evaluation of the articles selected. A meticulous investigation of the remaining articles was conducted to further validate their pertinence, culminating in a final list of 38 articles. This research aimed to examine peer-reviewed journal articles as opposed to other sources that may contain SL and EL information, such as university and departmental mission statements or instructor syllabi because these items are more difficult and elusive to obtain, are unstandardized, and can be changed and updated frequently. Relying on high-quality, well-researched published materials is a more reliable way to incorporate previous researchers' findings. The eligible sample is composed of 38 articles published in high quality journals ranked in Q1 and Q2 by the JCR and the SJR.

Thematic analysis and intercoder agreement

This study adopted PRISMA guidelines set forth by [Page et al. \(2021\)](#) to develop a structured literature review which employed a qualitative thematic analysis approach ([Miles and Huberman, 1994](#)) to analyze the data. Data was coded using the software ATLAS.ti version 23. The process to analyze the definitions of SL and EL is as follows:

1. Identification of the final sample following PRISMA guidelines for the SLR.
2. Review of the final sample composed of 38 articles that included definitions of SL and EL.
3. Preliminary definitions of SL and EL were identified and coded in the software ATLAS.ti.
4. Analysis of the data required the review of background literature, descriptions found in the sample, and additional literature from the reference lists.
5. An iterative process of evaluating the definitions of SL and EL was carried out by the authors.
6. Data on the specific definitions of SL and EL was grouped.
7. The final number of citations for each definition was extracted from Google scholar database.

The authors used deductive coding, in which themes were identified and reviewed. The principal investigator read the full-texts articles, developed the coding system, communicated the coding strategy to the co-authors, trained the co-authors to perform the thematic analysis, and assigned a data set to each member. To ensure reliability, the data were coded independently by two co-authors. Each coder saved the coding in an independent bundle file, which afterwards was merged into the master file. To reduce any bias in the analysis, the Inter coder Agreement (ICA) percentage was calculated using ATLAS.ti version 23. As a result, the Krippendorff's c-Alpha-binary was 0.94.

Results

The most cited definition of environmental literacy and sustainability literacy

The concept of EL proposed by Roth (1992) is the most cited definition which states, “the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or improve the health of those systems” (p. 10). Table 1 shows the most cited definitions of SL and EL in the literature subject to this study. Even though SL and EL are related concepts, the concept of EL precedes SL. In addition, the definition of SL is more consistent with the broader concept of sustainability. In this sense, the foundational concept and framework of SL encompasses vital insights into social, environmental, and economic sustainability, which increases the complexity of the concept. As a result, Nolet (2009) mentioned, “Sustainability literacy is construed generally here as the ability and disposition to engage in thinking, problem solving, decision making, and actions associated with achieving sustainability” (p. 421).

The typology of definitions of SL and EL based on specific learning outcomes provides a framework to understanding the similarities and features supported in the literature. Thus, this research illuminates the prevailing discourse of the notion of SL, highlighting its definitions and specific learning outcomes to the ESD. As it is exhibited in Table 2, the foundational concept of both SL and EL includes knowledge, awareness, attitudes, skills, and behaviors toward sustainability,

TABLE 1 Definitions of sustainability literacy and environmental literacy.

Definition	Source	Cite*
“Environmental literacy is essentially the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore, or improve the health of those systems” (p. 10)	Roth, 1992	1252
Environmental Literacy “is distinct from simple awareness or personal conduct knowledge because of its depth of information and the actual skills (thinking and doing) that are imparted” (p. 55)... “Knowledge must be deep, skills must be developed, and experiences made real for EE to work at its best” (p. 116)	Coyle, 2005	624
“...environmental literacy is to empower people with a belief in their ability to contribute to environmental solutions through personal behavior, either as an individual or part of a group” (p. 47)	Pe’er et al., 2007	596
“Environmental literacy is built on awareness by the acquisition of greater knowledge and understanding of the components of the system, the links between them and the dynamics of the system” (p. 250).	Smyth, 1995	244
“Sustainability literacy is construed generally here as the ability and disposition to engage in thinking, problem solving, decision making, and actions associated with achieving sustainability” (p. 421).	Nolet, 2009	364
Sustainability literacy indicates “the skills, attitudes, competencies, dispositions and values that are necessary for surviving and thriving in the declining conditions of the world in ways which slowdown that decline as far as possible” (pp. 10-11)	Stibbe, 2009	387
“Sustainability Literacy which can be defined as the knowledge, skills, and mindsets that help compel an individual to become deeply committed to building a sustainable future and allow him or her to make informed and effective decisions to this end” (p. 141)	Décamps et al., 2017	199

*The table shows the most cited publications that contained definitions of Sustainability Literacy and Environmental Literacy in Google Scholar as of April 8, 2023.

being the environmental dimension the intersection between EE and ESD.

In addition, Appendix A shows the description of the 38 studies analyzed, the classification of those articles according to the definition of either SL or EL, and the methodology used in each paper. The 38 articles contain 25 articles focused on EL and 13 articles focused on SL. The most predominant research design in the sample of articles is quantitative research design. Six articles used mixed methods (MM) research design, four employed qualitative design (QUAL), and 20 used quantitative design (QUAN). Most of the studies were published in journals that focused on sustainability and education; environmental, cultural, economic, social sustainability; and policy and practice research. The audiences are mainly researchers, scholars, academics, students, teachers, and policy makers.

TABLE 2 Typology of sustainability literacy and environmental literacy specific outcomes.

ESD learning outcomes	SL and EL learning outcomes	Sources
SL	Sustainability knowledge	Akeel et al., 2019; Chen X. et al., 2022; Décamps et al., 2021; Ferrer-Estévez and Chalmeta, 2021; Ling et al., 2021; Micklethwaite, 2022; Dallaire et al., 2018; Tunji-Olayeni et al., 2023
EL	Environmental knowledge	Chen et al., 2020; Janoušková et al., 2020; Moody and Hartel, 2007; Pan and Hsu, 2022
SL	Awareness and knowledge in sustainability issues	Lau, 2010; Décamps et al., 2017, 2021; Winter and Cotton, 2012
EL	Awareness and knowledge in environmental issues	Elder, 2003; Kroufek et al., 2015; Liu et al., 2019; Moseley, 2000; Teksoz et al., 2012; Tuncer Teksoz et al., 2013
SL	Knowledge, skills, attitudes/ dispositions/ feelings, values, behaviors	Bloyd Null et al., 2021; Chen C. et al., 2022; Cotgrave and Kokkarinen, 2011; Décamps et al., 2021; Dent and Dalton, 2010; Murray and Murray, 2007; Nolet, 2009; Radwan and Khalil, 2021; Swaim et al., 2014
EL	Knowledge, skills, attitudes, behaviors	Chen et al., 2020; Coyle, 2005; Dada et al., 2017; Disinger and Roth, 1992; Fang et al., 2018; Owusu et al., 2017; Hines et al., 1987; Hsu and Roth, 1998; Husamah et al., 2022; Joseph et al., 2013; Liang et al., 2018; Morrone et al., 2001; Mullenbach and Green, 2018; Orbanic and Kovač, 2021; Pan and Hsu, 2022; Roth, 1992; Teksoz et al., 2012; Tuncer et al., 2009; Tuncer Teksoz et al., 2013

Sustainability literacy and environmental literacy in non-English-speaking contexts

The discourse on SL and EL in non-English speaking countries is influenced by both global and specific contexts, as well as unique educational settings. This SLR included research applied in countries where English was not the primary language, such as China, Taiwan, Brazil, France, Nigeria, and the Czech Republic. A commonality among all those studies is the alignment to the global concern of expanding sustainability and environmental knowledge.

The research applied in non-English speaking contexts is associated with the ongoing international debate of using the terms SL or EL. In countries such as Brazil, Nigeria, France, and Czech Republic, the common term used was SL. In contrast, China and Taiwan used the term EL. On the one hand, Fang et al. (2018) highlighted the need to train environmentally conscious citizens with high-quality EL in Taiwan. On the other hand, Caldana et al. (2023) mentioned the importance of establishing more formal rules and educational policy to integrate SL throughout the business management, economics, and accounting curricula in Brazil. In addition, Akeel et al. (2019) pointed out the need to improve SL in Nigeria, and Tunji-Olayeni et al. (2023) noted the dearth of

studies focused on SL in Nigeria. Décamps et al. (2021) cited the need to measure sustainability knowledge worldwide. The research identifies how non-English speaking countries are working on SL and EL to address local and global problems as well as to contribute to the SDGs.

Associated concepts to environmental literacy and sustainability literacy and the co-occurrence of authors' keywords

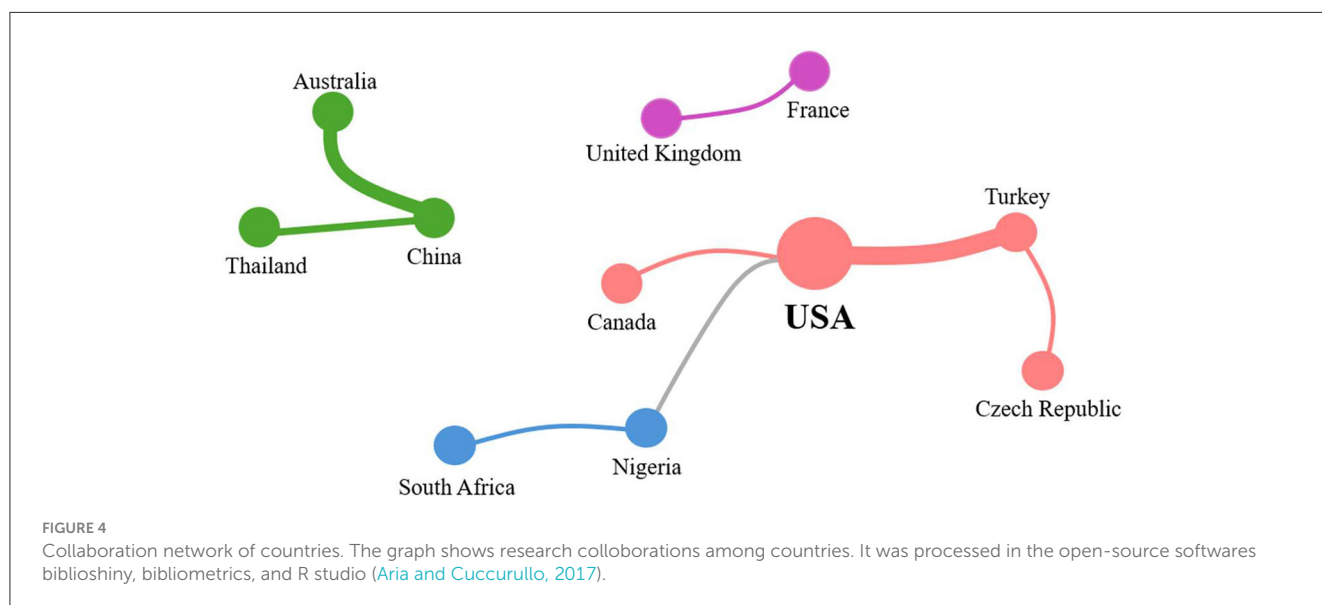
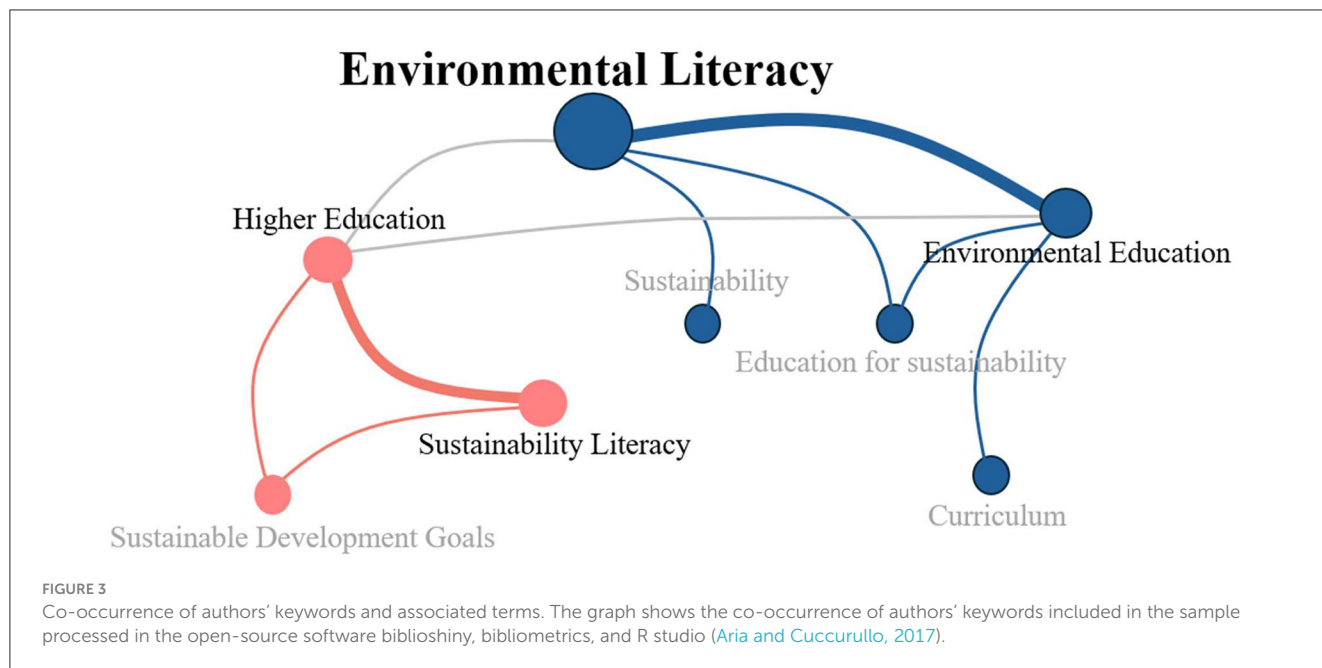
The co-occurrence of the authors' keywords was applied to the sample of the 38 articles. To gain a better understanding of the associated concepts to SL and EL, the authors conducted a co-occurrence network analysis. Data was analyzed using the R Studio software version 4.3.0, biblioshiny, and bibliometrix, which are open-source computer software (Aria and Cuccurullo, 2017). Figure 3 shows two clusters of the co-occurrence network. Cluster 1, shown in red, is composed of three major words: higher education, sustainability literacy, and sustainable development goals. Knowledge is one of the major outcomes of SL. Increasing SL in higher education institutions implies expanding students' sustainability knowledge which is directly related to enhancing students' knowledge of sustainability development goals. There is a strong relationship among SL, sustainable development goals, and higher education.

On the other hand, Cluster 2, shown in blue, exhibits the interconnection among the following terms: EL, EE, sustainability, education for sustainability, and curriculum. EL is a learning outcome of EE; likewise, SL is a learning outcome of Education for Sustainability or ESD. The central node, EL, is consistent with literature in the sample because 21 out of 38 articles were directly related to the concept of EL.

Collaboration network by countries

In this study, the collaboration network by countries refers to how authors from different countries collaboratively work on a research topic based on co-authorship patterns. These collaborations allow the creation of connections through joint publications on an international scale and identify which countries have the greatest connections and which countries are leading research on a specific topic.

Exploring the social structures of the field, collaboration among scholars across countries is an important factor in strengthening research networks. Understanding how scholars interact among themselves helps to map potential clusters and institutional partnerships to enhance research (Donthu et al., 2021). Figure 4 illuminates these collaboration networks by countries. The United States shows a greater effort in strengthening collaborative research bonds with countries such as Turkey, Canada, and Nigeria. Nigeria extends connections with South Africa, while the United Kingdom and France are working together on sustainability research projects. Finally, researchers in China tend to collaborate with scholars from Australia and Thailand.



Discussion

This research provides a review of current studies on SL and EL, providing an understanding of the current issues and implications for future research. Firstly, the most cited definitions of EL and SL give understanding of these concepts and their development. Roth (1992) and Coyle (2005) are the most cited definitions of EL. Roth (1992) emphasizes the ability to perceive and interpret environmental systems and take appropriate action. This definition highlights the importance of understanding environmental dynamics and the need for proactive actions to maintain or improve environmental health. Therefore, the definition, in addition to implying an understanding of the problems, suggests that actions must be taken toward solving problems effectively.

The typology of SL and EL reveals an overlap between SL and EL in terms of the learning outcomes they cover, indicating interconnection between ESD and EE. As stated in the literature, “education for sustainability,” “education for sustainable development,” and “sustainability education” are interchangeable terms (Wu and Shen, 2016). Moreover, Briggs et al. (2018) mentioned EE and ESD are overlapping concepts. EE was prior to ESD and focuses on preparing individuals to deal with environmental issues. ESD extends its scope to prepare people to cope not only with environmental but also social and economic issues (UNESCO, 2007). In this sense, SL encompasses a broad range of outcomes like knowledge, skills, attitudes, values, mindsets, and behaviors to achieve sustainability from an integrative approach that includes dealing with and finding solutions to environmental, social, and economic issues.

The conceptualization of SL and EL has significant implications for higher education policy and practice. For instance, integrating SL and EL into higher education contributes to the advancement of the SDGs as part of the 2030 Agenda launched by the United Nations and adopted by all United Nations Member States in 2015 (United Nations, 2022). The SDGs established by the international community are “action oriented, global in nature, and universally applicable” (UNESCO, 2014, p. 3). However, the ongoing debate surrounding the terms EE and ESD, the transition from EE to ESD, and the lack of a clear definition of these concepts have made their integration and implementation in educational institutions challenging. As a result, a common understanding of how to structure ESD across educational institutions, how to foster ESD among students, and how to assess the progress of ESD integration is needed.

Additionally, the co-occurrence analysis of authors’ keywords shown in Figure 3 illustrates the interconnections related to concepts and themes within the literature by grouping the keywords into two clusters. One group highlights the intersection of higher education, SL, and the SDGs, and the other group points out the interconnection of EL, EE, and curriculum design. These interconnections underscore the necessity of integrating sustainability principles into the educational curriculum. This finding aligns with previous studies that emphasize the need to incorporate SL into higher education curricula (Ceulemans et al., 2011; Pappas, 2012; Sanchez et al., 2023, 2024). In addition, these clusters correspond with international policies and global initiatives promoting ESD. For instance, in alignment with the SDGs launched by UNESCO in 2015, SDG Number 4 highlights the need “to achieve inclusive and equitable quality education and promote lifelong learning opportunities for all” (UNESCO, 2017, p. 6). In this regard, the aim of target 4.7 of this SDG states, “By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through Education for Sustainable Development...” (UNESCO, 2017, p. 8). Consequently, there is an urgent need to foster ESD, as SL raises awareness among current and future generations of students to engage with global sustainability challenges.

Moreover, the collaboration network among countries illustrates the need to strengthen connections between local and global scholars, allowing outreach beyond academia to business corporations as an additional approach to expanding SL worldwide. Décamps et al. (2017) and Hansen et al. (2021) show an example of a collaborative initiative to support and assess SL in higher education by the creation and development of Sulitest (the Sustainability Literacy Test). Sulitest is a collaboration with the Partnership Exchange for the United Nations’ SDGs (Décamps et al., 2017, p. 9) which facilitates higher education institutions and organizations to have access to a free online instrument to assess sustainability knowledge. Sulitest is a global initiative that has fostered SL across the globe.

Furthermore, the common and fundamental “feature of the 2030 Agenda for Sustainable Development is its universality and indivisibility” (UNESCO, 2017, p. 6). As all member states of the United Nations agreed to the 2030 Agenda launched in 2015, “Governments are expected to take ownership” and develop “national frameworks” and policies to achieve the SDGs (p. 6). In this sense, achieving quality education for all requires expanding national and international collaboration networks and

involves governments, educational institutions, civil society, private and public sectors. Strengthening these relief efforts can foster knowledge sharing, interdisciplinary research, and innovation in sustainability education.

Conclusions

SL has increasingly been recognized globally as pivotal in shaping the trajectory of ecological, political, socio-cultural, and economic advancements. To truly achieve sustainable development, education is paramount to equip students with the knowledge and skills necessary to take actionable steps toward a more sustainable future. SLRs shed light on key conversations surrounding notions like SL and EL, pinpointing gaps and constraints that challenge educators, students, and staff in effecting meaningful shifts in individuals’ knowledge, perspectives, and actions.

It is important to note SL is an emerging research field, and as an outcome of ESD, there is increasing interest in studying SL in higher education. Even though SL is a complex concept due to the integration of environmental, social, and economic perspectives, in recent years, a growing number of publications about it has been detected. As a result, SL is a milestone for scholars and more research is needed to expand sustainability knowledge worldwide.

In addition, EL is a concept that has evolved over time and predates the concept of SL. Likewise, EE existed prior to the notion of ESD. Even though EL has spread through education and has now shifted to the concept of SL, the latter encompasses a broader scope. Research on EL and SL contributes to the advancement of ESD, as those concepts facilitate the dissemination of sustainability knowledge, SDGs, and their integration into higher education through curriculum design. In addition, to expand SL within educational institutions, a common understanding is needed of how to structure ESD across educational institutions, how to foster ESD among students, and how to assess the progress of ESD integration.

This SLR synthesized existing literature on ESD and identified key research gaps and outlines a foundation for advancing research and practice in sustainability education. This research underscored the existing discourse on the conceptions of SL and EL, highlighting varying definitions and learning outcomes; such insights pave the way for prospective research avenues and actionable interventions.

Limitations and future research

There are limitations when conducting SLRs (Yuan and Hunt, 2009, p. 1). Owens (2021) says the risks include “selection bias, inadequate blinding, attrition bias, and selective outcome reporting” (par. 9). Additionally, even top-tier databases like *Scopus* and *Web of Science* “cannot fully account for the influence of scholarly work on teaching, practice, and public knowledge” (Wilder and Walters, 2021, p. 1). As a result, the authors acknowledge that taking high-quality journals from these two databases may not capture the entirety of high-quality publications on SL and EL, which may introduce a certain degree of bias. To mitigate this limitation and reduce bias in the review process, this SLR has employed a rigorous methodology, adhering to PRISMA

guidelines, as well as presenting and calculating the Inter-coder Agreement (ICA) to analyze data.

For future research, it is important to recognize EE and ESD are relevant for higher education institutions in equipping the next generation of students with the competencies needed to address sustainability-related issues. More research is needed regarding ESD in schools and higher education institutions as well as the integration of SL into existing curriculums in both developed and developing countries. Additional studies in contrasting and assessing educational interventions to promote ESD, SL, and pro-environmental behaviors in rural and urban areas as well as global and local regions are crucial. Further studies are essential to provide a common understanding of how to structure ESD across educational institutions, how to foster ESD among students at all educational levels, and how to assess the progress of ESD integration within schools and higher education institutions. Expanding scholarship and collaboration networks to advance these integrations of SL, sustainability competencies, and sustainability related learning outcomes into curriculum provides new avenues of research. This research's findings confirm that SL is an emerging field, and it is indeed necessary to increase collaboration research networks to strengthen emerging scholarship on ESD.

More studies are needed to address strategies for designing, developing, and assessing sustainability competencies and sustainability learning outcomes across different academic disciplines and curricula. Experimental and quasi experimental interventions that analyze the advancement of students' sustainability learning outcomes are also needed. Quantitative and qualitative studies that measure and expand sustainability knowledge for faculty and students are needed to enhance ESD worldwide. Moving forward, it is vital to continue exploring innovative pedagogical approaches and fostering interdisciplinary collaborations to enhance ESD and empower students, faculty, and staff in higher education institutions to become agents of positive change in creating a more sustainable world.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

S-JS: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Conceptualization,

Investigation, Methodology, Project administration, Software, Supervision. YP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. J-SM: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. DR: Conceptualization, Writing – review & editing. SA: Writing – original draft, Writing – review & editing. TG: Conceptualization, Formal analysis, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1490791/full#supplementary-material>

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