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ARTICLES FOR UTM SENATE MEMBERS

"Integrating Climate Education and Sustainability into University Curricula: Challenges and Strategies"

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Climate literacy for students in higher education: a case study from the University of the West of England (UWE), Bristol, in the United Kingdom

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Abstract

Purpose – One of the crucial roles of universities is to encourage students to learn about climate change issues and put strategies into practice to enhance climate literacy. Despite the urgency of the situation, implementing climate change education in universities has not yet achieved the required success. This study aims to examine the significance of climate literacy activities and sustainability practices for students on campus to support them in transferring their knowledge into action.

Design/methodology/approach – This research involved a case study from the University of the West of England (UWE), Bristol, in the United Kingdom, which serves to investigate inner educational transitions that efficiently embed climate literacy activities into the curricula. Data collection was designed around semistructured qualitative interviews, including postgraduate students and staff, to develop a list of recommendations for universities to strengthen their students' climate literacy.

Findings – The findings illustrate that students still face challenges translating their understanding of climate change science into action. Climate literacy should extend beyond basic knowledge about climate science to

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building students' skills via activities that will support them in making sound decisions in adapting to climate change concerns and empower them to create concrete action.

Originality/value – This paper has identified the university's significant role in developing a teaching and learning strategy to legitimise climate literacy activities in the curriculum and provide a resource bank of quality teaching materials to effectively deliver sustainability and climate literacy in all provisions. The paper's recommendations are not only beneficial for universities at an institutional level but also for the individual stakeholders involved, including students and staff.

Keywords Climate literacy, Education for sustainable development, Higher education curricula, SDG 13: Climate action, SDG 4: Quality education

Paper type Case study

1. Introduction

The Paris Agreement encourages countries to improve climate change education, offering professional training in climate literacy for students at universities, increasing individual awareness and motivating public involvement to access climate change information and scientific knowledge (Horowitz, 2016). In addition, the Paris Agreement calls for the development of new educational programmes and initiatives in various fields. This would allow future generations to have a deeper understanding of environmental sustainability and climate change crises and therefore become equipped to offer innovative solutions for alleviating climate change issues (Molthan-Hill *et al.*, 2019; Mochizuki and Bryan, 2015). Several UK institutions have made crucial initial steps in the right direction, but many challenges remain, and universities need to actively implement different approaches to enhance climate literacy (Mihaela *et al.*, 2021; Leal Filho *et al.*, 2021).

Shafer (2008) stated that climate literacy recognises the scientific knowledge of climate science and how having a clear understanding of climate change consequences influences people's behaviour and attitude to accelerate significant action for climate change. Therefore, one key approach to fostering social adaptation to climate change is the knowledge, experiences and practices of university students in promoting climate action (GP, 2009; Yeh *et al.*, 2024). Thus, universities should invest in practical activities and training that interactively develop students' understanding of climate change and build their climate emergency literacy skills to respond to climate change risks (Knussen and Yule, 2008).

An integrated approach to climate literacy requires aligning educational frameworks with internationally recognised standards (Kumar et al., 2025). For instance, the principles of ISO 9000 emphasise the importance of structured processes, continuous improvement (Muleva et al., 2025), and a systematic approach to quality management. Embedding these principles into climate literacy frameworks could enhance the coherence and effectiveness of climate change education by ensuring that the initiatives are systematically implemented, assessed and improved over time (Taufek, 2025). By applying the ISO 9000 PDCA (Plan-Do-Check-Act) cycle, universities can focus on continuous improvement and innovation. This method helps create a more engaging and dynamic learning environment for both students and educators, moving beyond the limitations of traditional teaching approaches (Orihuela-Gallardo, 2025; Kayyali, 2025). Gough (2016) mentioned that "Despite efforts over the past 40 plus years, environmental sustainability is still on the margins of the curriculum in most countries". Therefore, the universities should use their cultural and social strength to enhance climate literacy and embed climate change topics in curricula (Leal Filho *et al.*, 2021). The significant goals of the higher education institutions are typically stated in their vision and mission, such as advancing knowledge, strengthening society, furthering the future for the next generation and fostering the capacity to promote proper decisions. The sustainability activities are not limited to classes and labs for achieving these objectives must

extend beyond the confines of the universities or colleges campuses to the larger communities (Serafini *et al.*, 2022).

Climate literacy has not effectively developed in institutions despite increased efforts in the last decade to embed climate change topics into curricula across disciplines and communication channels (Anderson, 2012; Leal Filho et al., 2021). The most significant limitations to enhancing climate literacy at universities are the lack of capacity to make substantial changes and the lack of specialised frameworks, resources, and strategies to put climate action plans into practice (Molthan-Hill et al., 2022). Therefore, universities must implement new methods to empower students to participate in climate change activities and provide professional practical training in climate literacy to enable students to make informed decisions to improve their quality of life (Cooper et al., 2019; Arto-Blanco et al., 2017). Masson-Delmotte et al. (2021) stated that it is essential to link information and scientific knowledge of climate change with social and economic factors. This perspective is similar to that of Hempel (2014), who believes that climate literacy should incorporate various disciplines to encourage all students to take action against climate change via activities and promoting sustainability initiatives. Hempel (2014) mentioned that "experiential learning, the knowledge of personal and social responsibility and understanding of the roles of governance and effective communication in climate action" are keys to "moving from knowledge into action".

The current study aims to achieve an in-depth understanding of climate literacy and the university's mission and action to successfully prepare students to take action and leadership roles in climate change adaptation and implement mitigation measures to enhance climate literacy in the future (Reimers, 2021; Cordero *et al.*, 2020). Klapp and Bouvier-Brown (2021) emphasise that the awareness of developing strategies and approaches to understand climate change science for university students is no longer debateable; Neenan (2021) stated that it is yet to be widely used and documented in academic literature. Three objectives were formulated to achieve this aim; *OBJ1*; Critically review the significance of promoting climate literacy among students in universities. *OBJ2*; Examine the importance of students' activities to combat climate change in universities to improve the climate literacy. *OBJ3*; Develop a list of recommendations for universities to improve the climate literacy of their students.

Rousell and Cutter-Mackenzie-Knowles (2020) stated that literature reviews fail to discuss methods to effectively integrate climate literacy with activities to help students transfer their knowledge into practice to take action in the fight against climate change. Thus, this study utilises an abductive approach to move back and forth relative to existing academic literature regarding the importance of developing climate literacy in universities. Additionally, this study critically reviews the role of the universities to identify the best strategies to effectively build learning networks and teaching frameworks to overcome climate literacy limitations. The steps specified by Spens and Kovács (2006) are followed in this study. The abductive approach is conducted: first, a review of existing academic literature is conducted, second, real-life observations are made (primary data collection), and third, propositions are suggested based on the existing academic literature and real-life observations. The qualitative approach is considered suitable. It allows an in-depth investigation of the significance of enhancing climate literacy to identify the universities' roles in taking significant steps to create climate literate students for a resilient future.

2. Literature review

The significance of enhancing climate literacy at universities should go beyond enriching students' knowledge and understanding of the fundamental concepts of climate change and

IJSHE earth science (McCowan et al., 2021; Hempel, 2014). Thus, universities have the potential to play a significant role in promoting climate literacy by providing practical methods to solve the climate change problems that our globe faces today (Fantauzzi et al., 2021). For instance, it is essential to comprehend the various approaches implemented by institutions to develop new strategies and innovative frameworks to address climate change (Bilodeau et al., 2014; Barreda, 2018). Although there is an increasing body of work and progress in embedding sustainability and climate change topics into curricula at universities, many challenges remain in fostering climate literacy for students (McCowan *et al.*, 2021). Thus, there is an urgent need to more comprehensively analyse the many types of impacts that institutions have on the environment and society. Examples include sharing knowledge about climate change, student participation in sustainability initiatives, delivery of relevant services. student awareness of the climate crisis and sustainability activities on campus. Hence, various educational initiatives for climate change have been launched in the last few decades to enhance climate literacy and build resilience to combat climate change. For instance, the carbon literacy project at "Manchester University" managed by the "Community Interest Company Cooler Projects", and Living Lab techniques are significant initiatives that have been implemented to improve innovative research, student participation, and active learning (Molthan-Hill *et al.*, 2022). This type of initiative has significant benefits for students, empowering them to gain a deeper understanding and knowledge of the consequences of climate change and providing them with the skills needed to make a substantial change in developing climate literacy (Helferty and Clarke, 2009).

2.1 The need for new strategies for enhancing climate literacy

Developing climate literacy requires partnership and cooperation to create capable and skilled teachers who are comfortable covering complex climate change topics and conducting sustainability activities for students. Therefore, implementing new approaches, enhancing innovative climate change frameworks, and implementing climate literacy projects in institutions will facilitate the development of practical skills in adapting to climate change consequences (Reimers, 2021; Diaconescu, 2024; Reimers, 2024). Institutions must enhance climate literacy by improving the action competence learning process. This involves encouraging students to engage in long-term active learning and sustainability activities interconnected across different disciplines in universities. Thus, students will be capable of linking numerous complex scientific concepts of environmental and climate knowledge to take action to address ecological challenges (Bybee, 2008; Shepardson et al., 2011; Afrin and Saha, 2024). Implementing new strategies in learning and teaching about climate change will improve students' behaviour in implementing the climate change knowledge outcomes. This, in turn, will facilitate students to make sound decisions and create a positive vision of the future, empowering them to take action both now and in the future (Duan and Fortner, 2005). Thus, institutions should implement sustainability principles into their practices, frameworks, policies and climate change resources to achieve the significant change of reaching low or zero carbon institutions (Lukman and Glavič, 2007).

Educational climate change strategies and approaches that seek only to encourage "analytical thinking" without any connections to potential solutions to climate change challenges cannot be considered adequate and effective (Vaughter, 2016). Thus, higher education institutions need to explore alternative techniques because depending only on students' knowledge often results in a cognitive gap. In such a situation, students will have a higher level of conceptual understanding of climate change and potential solutions (learning to understand), but limited skills and abilities to implement these solutions into action (learning to do and act via activities) (Ahmadian F.F *et al.*, 2017). Enhancing climate literacy

at universities should not only go beyond preparing only students to understand climate consequences but also encompass practical training for teachers to boost their confidence in teaching climate change topics. This will afford them a solid understanding to teach and develop new learning styles to encourage students to develop their vision (creative thinking) and evaluate new ideas to make a significant change in enhancing climate literacy (Leal Filho *et al.*, 2021; McCowan *et al.*, 2021).

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2.2 Limitations and obstacles of climate literacy

Recent decades have seen increased attention on how climate literacy is achieved since it has become a significant phenomenon. However, climate literacy has been dubbed "incomplete" and "limited" by recent studies because it fails to improve effective networking, students' participation in climate change activities, implementation of sustainability strategies in action and sufficient knowledge and experience among students and teachers (Aguaded, 2011; Lehtonen and Cantell, 2015). Furthermore, the major challenge for teachers is that the subject matter is so complicated and ambiguous that they are considerably aware of their own lack of knowledge and understanding of climate change information and various misconceptions (Ratinen, 2016). Minimising the cognitive gap between climate change knowledge and student engagement in climate literacy activities and training is more challenging without extensive efforts from institutions (Cooper *et al.*, 2019). Thus, understanding only fundamental concepts of climate change science may not always lead to socially and ecologically informed decisions to achieve significant progress in climate literacy (Schreiner *et al.*, 2005).

The main obstacles facing universities today are financial, logistical, technical, and political, including "no specific climate change and sustainable development budgets, unsuitable materials in climate change education, inadequate space and poor infrastructures for climate change activities and initiatives" (McCowan et al., 2021). Leal Filho et al. (2021) mentioned that not all higher education institutions are fully equipped to improve climate literacy, which requires extensive efforts from universities and the government to promote sustainable campuses and develop students' understanding of climate change. Thus, climate literacy activities, curriculum design, climate change courses, and training in sustainability throughout the range of academic fields are significant areas that must be enhanced in the future.

2.3 Significance of training teachers in climate literacy education

Universities should enhance climate literacy by providing professional climate literacy training for teachers and developing appropriate curricula that include sustainability and climate change science for all disciplines. This will boost their confidence and enthusiasm for teaching climate change science topics and complex concepts in sustainability (Ennes *et al.*, 2021). Offering the training to teachers could enrich their experience and prepare them with sufficient knowledge to confront climate change misunderstandings and enhance their teaching methods (Drewes et al., 2018; Plutzer et al., 2016). Implementing innovative teaching and learning styles by investing time and financial resources for teachers will enhance new visions of various opportunities in teaching students confidently and encourage students to understand climate change topics and engage in sustainability activities on campus (Hestness *et al.*, 2014). Therefore, teachers should be familiar with climate science topics, aware of various teaching styles and willing to implement new strategies in teaching, such as transformative learning and engagement for climate action (Kubisch et al., 2022). This will encourage students to develop their skills and competencies for effective transformative participation in enhancing climate literacy. Dupigny-Giroux (2010) proposed the significance of promoting transformative learning and engagement for climate action by implementing climate literacy initiatives, work-based learning, and sustainability activities. Such strategies will support professional visions, intellectual development, and the generation of new ideas for students to overcome the lack of motivation and misconceptions that come with learning climate science through traditional learning styles. Thus, universities should take significant steps towards a whole institution's innovative approach by including the concepts of experiential learning, reflective thinking, and the development of practical skills, while promoting knowledge exchange between students and teachers to effectively implement climate literacy initiatives and sustainability projects on campus. The experiential learning approach related to climate change effectively connected educational content with practical and relatable real-world contexts (El-Sabagh, 2021; Kim, 2024). It empowered students to comprehend, reflect upon and advocate for environmental stewardship, fostering a deeper connection to climate change issues in their communities and beyond (Kim, 2024). The results demonstrated that the experimental group performed statistically significantly better than the control group (El-Sabagh, 2021).

3. Research approach

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A qualitative approach was selected for this research to get a depth understanding of a study topic rather than anticipated results, as is the case with positivist research (Denzin and Lincoln, 2011). This approach aims to increase knowledge by gaining a better grasp of people's knowledge and the values they attribute to those perspectives (Creswell, 2014). Generally, qualitative research assists in answering the key questions by analysing the main factors, causes and consequences that impact people's attitudes and experiences(Denzin and Lincoln, 2011; Sarhan *et al.*, 2024; Qasem and Alkhawatrah, 2024). Thus, the qualitative method not only helps in the investigation and analysis of data in a real-world setting but also assists in understanding the complexities of the actual conditions that may not be addressed by experimental or survey research (Zainal *et al.*, 2016). Thus, semi-structured interviews were used in this research to gain a comprehensive understanding from postgraduate students and staff about the university's role in enhancing climate literacy and to develop the study's findings.

Yin (2017) argues that the case study strategy is a holistic and suitable method to examine "how" or "why" qualitative research questions. The current study aims to answer the research questions "why is it essential to promote climate literacy among students in universities?", "how do the students' activities to combat climate change in universities impact climate literacy?" and "how can universities improve the climate literacy of their students?". Therefore, the case study strategy is most suited for primary data collection. Moreover, climate change and climate literacy are at the forefront of a global conversation and can therefore be considered contemporary events. This study was conducted at the University of the West of England (UWE), which has a strong commitment to sustainability and environmental education. UWE is recognised for its initiatives in embedding sustainability into its curriculum and campus operations, making it an ideal case study for this research (Cicmil *et al.*, 2017; Longhurst *et al.*, 2025).

The data for the case study in this research was collected from semi-structured interviews. Given that there are two predominant stakeholders of higher education at universities, semistructured interviews were conducted with 11 postgraduate students from the students' Union at UWE and eight staff from the Climate Action Hub, Knowledge Exchange for Sustainable Education and Environmental Management Department at UWE. The research will utilise an ideal number of members for each stakeholder group to maintain a balance between insufficient representation and extremely diversified, skewed or polarised opinions that a generalisation is not possible (Guest *et al.*, 2006). Since the abduction approach (collecting secondary data, making real-life observations and suggesting propositions) is used as the primary research approach for this study, the findings from semi-structured interviews will be discussed by moving back and forth relative to existing academic literature regarding the importance of developing climate literacy in universities. Taken together, the results will be used to propose new insights into the climate literacy framework in higher education.

The data collected from semi-structured interviews was analysed manually using an Excel spreadsheet to organise and group the responses systematically. This approach allowed for efficient tracking of patterns and themes, ensuring a clear and replicable process for data analysis (Mabesele, 2024). The analysis began with transcribing the interviews, after which the transcripts were reviewed to extract key phrases, recurring ideas, and relevant insights. These responses were then entered into an Excel sheet, with each row representing a participant's input and columns used to categorise the data based on emerging themes. Open coding was conducted by assigning initial labels to the data, capturing the essence of participants' responses (Saldaña, 2021; Saunders *et al.*, 2016). The Excel sheet allowed for filtering and sorting these codes, helping to identify patterns and clusters of similar ideas (Salmona and Kaczynski, 2024). As themes became more apparent, responses were grouped into broader categories aligned with the research questions, such as the university's role in promoting climate literacy among students.

According to the research strategy and to meet the study aim and objectives, postgraduate student participants were selected from the University of the West of the England students' Union to examine the importance of students' activities and scientific knowledge (climate change awareness and understanding) for improving climate literacy. Moreover, the roles and responsibilities of students in taking action to ensure sustainable practices at the university were identified. Furthermore, staff participants were selected from the Climate Action Hub, Knowledge Exchange for Sustainable Education and Environmental Management Department at the University of the West of England, all of whom had sustainability, climate change, and climate literacy backgrounds. Staff participation aimed to critically analyse the university's role or actions towards improving climate literacy among students and to identify the kinds of activities and initiatives that best support student engagement to enhance climate literacy.

4. Findings and discussion

4.1 The significance of climate literacy perceptions, knowledge and awareness of climate action The student interviews commenced with their perceptions of climate literacy. The postgraduate student interviewees stated that climate literacy that enables students to take urgent action requires a clear understanding of the impacts of climate change on local communities as well as awareness of both the requirements for mitigation and measures for adaptation. For example, one student from the Environmental Consultancy department said, *"Climate literacy is understanding the essential principles of earth's climate system, knowing how to assess scientifically credible information about climate, and communicating about climate change in a meaningful way"*. However, two students stated that climate literacy should extend beyond basic climate science. One student commented:

Climate literacy is a scientific knowledge that extends beyond the basic and into the functional and explains elements specific to and surrounding climate change. Additionally, it is how we may transfer knowledge into practice by having skills to make effective decisions and implement sustainable solutions for future generations.

Another student from the Environmental Management department reflected the same perspective:

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Climate literacy awareness is how we educate ourselves on adaptation and mitigation plans to combat the negative changes and calculate the risks by enhancing communication with sustainability experts and becoming involved in sustainable forums and webinars to create awareness. I think it is important to know how to translate our scientific knowledge into action and to show substantial steps in climate action.

Given the previous points, students require sufficient skills combined with knowledge to engage confidently in a wide range of sustainability activities to make responsible decisions in the fight against climate change in the communities (McNeal *et al.*, 2008).

The most common challenges highlighted by the student interviewees were cognitive gaps in how they could translate climate change information and their understanding into action, combined with a lack of motivation and skills to take action in alleviating the climate crisis and implementing novel future solutions. One student from the Civil Engineering department said:

I am challenged by what I learned about the adaptation and mitigation measures of climate change and how they could be implemented into action. Also, I do not have the motivation and skills to participate in any climate literacy workshops and sustainability discussion sessions. So, I think the climate change discussion sessions or the sustainability activities should be structured as an interactive activity where students across disciplines would share ideas and learn from each other.

Adding to this, another student reflected on the same barriers to participating in climate action "*I do not have the passion and time to participate in any climate change discussion or sustainability webinars*". Given this, and in response to the perceptions regarding the promotion of climate literacy among university students, the staff suggested that it is essential to understand students' perceptions, attitudes, and values concerning climate change to encourage them to take action. Recognising their perspectives might put pressure on the university to take action and employ innovative teaching and learning strategies while implementing a wide range of activities to overcome barriers to improving climate literacy (Wachholz *et al.*, 2014).

Offering another perspective on the impact of climate literacy on students' behaviour, attitudes and their desired sustainable future, one staff member from the Climate Action Hub said:

Theoretically, it will prepare them for a very different future by developing aptitudes, competencies, skills and capabilities. However, in practice, it is probably too early to see major impacts on behaviour linked to climate literacy action as today's students are already quite aware of the climate emergency.

Given this, all staff interviewees agreed that it is crucial for students to continuously gain new climate science knowledge and boost their skills to address climate change challenges in their societies to build low/zero carbon institutions. Thus, enhancing climate literacy requires the implementation of new educational methods ranging from large-scale awareness programs across disciplines to efficiently encouraging the students to participate in such programs and become climate literate students (Mochizuki and Bryan, 2015). Adding to this, one of the staff from the Environmental Management department pointed out:

Actuary life tables tell us that this year's graduates will have a life expectancy of 60 years' postgraduation. That will take them into the 2080s when much of the already committed change to the climate system will be manifested. They will have to live through these changes, so how will their higher education prepare them to cope with these issues in their professional and private lives? Understanding how to live sustainably, including carbon/climate literacy, will be the key to building a sustainable climate-resilient future, along with a focus on how the university could implement new strategies to foster climate literacy for students. Another staff member from the Knowledge Exchange for Sustainable Education argues for the importance of equipping all students to combat climate change:

It is crucial to make further steps in enhancing awareness of climate literacy by focusing on practical elements relating to their behaviours, such as food, travel, and energy usage. We want all students to leave the university empowered, skilled and enthused about taking positive action to address the crisis by also communicating with sustainability experts about new solutions.

Given the previous points, improving climate literacy will support students in making sound decisions to face environmental issues and effectively network with the public and sustainability experts about potential solutions for climate change challenges. However, students' perceptions and awareness of climate literacy require comprehension of climate change at various geographical and temporal dimensions because students who have a deeper understanding of climate science are more passionate and confident about taking action to address climate change threats (Leiserowitz *et al.*, 2013; Rebich and Gautier, 2005; McNeal *et al.*, 2008).

Furthermore, the staff interviewees mentioned that all students must clearly understand the science behind climate change, the consequences of climate change on their societies, and how it links to their personal and professional behaviours. Therefore, all students should have a basic appreciation and practical skills to effectively improve climate literacy. Given this, one of the staff from the Environmental Management department described the difference between the actions of the University of the West of England (UWE) and other institutions in enhancing climate literacy among students, saying:

I think the University of the West of England (UWE) is better than most institutions but many challenges remain to implementing new strategies for enhancing climate literacy for students and efficiently embedding climate literacy activities into curricula. Many institutions stick within narrow disciplinary boundaries and fail to see ramifications across disciplines and provide insufficient skills for students to transfer their knowledge into practice.

Adding to this, one staff member from the Climate Action Hub showed concern that universities do not take sufficient further steps to enhance climate literacy:

Universities are complacent and too slow to enhance climate literacy and to respond to changes in society. So, they need to take responsibility for this problem and ensure students are clear of the challenges of climate change.

Lorenzoni *et al.* (2007) highlighted the significant role of the universities in taking responsibility for preparing students and overcoming the barriers to developing climate literacy, including a lack of teaching and learning resources, inadequate student skills, and a lack of suitable frameworks to motivate students to engage in climate action. In line with this, all the staff interviewees stressed the responsibility of the university to implement new strategies for improving climate literacy for students and raising awareness of the climate crisis. Universities should support students to promote adaptation and mitigation measures against climate change challenges. Additionally, students should understand the impact of climate change on their lives and the lives of others, what actions they should take, and what the university needs to do to reduce the effects of climate change.

4.2 The level of student engagement in climate literacy activities

The student interviews delved into any activities or climate literacy training that students were partaking in to combat climate change and ensure sustainable practices on campus. Only five students out of 11 responded that they had participated in climate literacy activities, training, workshops or sustainability initiatives. Interestingly, they expressed their passion

and motivation for implementing climate literacy initiatives and were involved in a wide range of climate change activities led by the students' union to ensure green practices on campus. One of the students from the Sustainable Development in Practice department highlighted such experiences:

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I am obtaining my MSc in Sustainable Development, and this course teaches us how to implement green practice and sustainable development initiatives in the university. I am also part of the university's student-led sustainability committee and student union. I hope my efforts in both groups and participating in sustainability activities can positively contribute to combatting climate change and ensuring sustainable practices on campus. I hope these practices may also positively impact my lifestyle and behaviour.

Consistent with this, all the students who engaged in sustainability or climate literacy activities such as sustainability clubs or outdoor activities emphasised the significance of promoting these activities and practices across disciplines to expand their climate science knowledge and skills in creating new solutions and adapting to the climate crisis in the future (Leiserowitz *et al.*, 2013).

As the literature review demonstrates, students should not only be seen as victims of climate change; they should have new visions, skills, and responsibilities to take action to combat climate change, such as engaging in climate literacy activities to enhance sustainable practices on campus (Cumiskey *et al.*, 2015). For example, one student from the Environmental Consultancy department said, "*Engaging in climate literacy activities made me use climate awareness in everyday life, not just at university, and ensured sustainable practices become a priority in my life*". From another perspective, a student from Sustainable Development in Practice department discussed the potential barriers to implementing or enrolling in climate literacy activities:

It takes a lot of work and a lot of people to make a real change. In addition, there are workload pressures on staff and not everyone is willing to participate or take action to address climate change threats.

This supports the idea presented by Kalina and Powell (2009), that sustainability activities (e.g. active learning networks) would positively impact students' behaviour and attitudes while upskilling them to holistically understand climate literacy topics, find innovative solutions and communicate confidently with sustainability experts and scientists. This will support students in creating new activities and implementing climate literacy initiatives to ensure green and environment-friendly practices on campus.

Six student interviewees out of 11 from different departments answered that they did not engage in sustainability or climate literacy activities. They mentioned various barriers to participating in or implementing sustainability activities, including lack of motivation, insufficient skills and a cognitive gap between scientific knowledge and engagement in climate action. Additionally, one participant from the Civil Engineering department spoke about challenges in participating in activities:

I do not spend much time on campus, and I do not have the motivation to engage in climate literacy activities due to facing obstacles in finding information and lack of skills to promote sustainable practices on campus.

Another student talked about the same challenges in engaging in sustainability activities:

Most of the students are busy in their studies and it is therefore difficult to engage them in activities or attract their attention. So, I think the university should implement innovative and practical climate literacy activities to encourage all students to participate in climate action.

The experiential learning approach to climate change successfully bridged educational content with practical, real-world applications. This method enabled students to understand, critically reflect on, and champion environmental responsibility, strengthening their engagement with climate change issues both within their communities and on a broader scale Findings revealed that students in the experimental group outperformed those in the control group by a statistically significant margin (Kim, 2024; El-Sabagh, 2021).

Keeping the above observations in mind, the staff interviewees strongly recommended that all students (across disciplines) participate in activities such as online climate literacy courses, outdoor activities, interactions with environmental surroundings and climate literacy training. In addition, students must hear from scientists and sustainability experts on the importance of taking action to combat the climate change crisis and the consequences of delayed action. One staff from the Environmental Management department acknowledged the benefits of embedding climate literacy activities in the curriculum and implementing comprehensive training to improve climate literacy, saying:

It is crucial to include the climate literacy activities in the curriculum, supported voluntary sessions on specific issues. In addition, this can include the formal curriculum (workshops, seminars and lectures, field activities, assessment) and informal voluntary activities and professional training (scientific training, evidence of impact and examples of innovations linked to lowering carbon emissions) alongside the Students' Union-led actions.

Given this, it is crucial to equip students with effective climate literacy platforms, activities within the curriculum, and wide forums for discussion between students across disciplines and sustainability experts about practical methods to implement innovative solutions in the future. This will empower students to make significant changes in their life towards a more sustainable future, such as reducing their emissions and advocating for other individuals or organisations to reduce their carbon footprint (Lorenzoni *et al.*, 2007; Leal Filho *et al.*, 2021).

4.3 The main skills and resources required for staff to conduct climate literacy activities

The staff interviewees unanimously agreed that to achieve significant steps in enhancing climate literacy, the university must first fully equip all staff by offering comprehensive training on climate literacy and offering teaching resource supports. Thus, implementing climate literacy training or courses will need various resources (e.g. staff training to legitimise climate literacy as a component of all degrees). In addition, the university should build sufficient skills for all teachers to conduct activities and teach climate literacy as a part of the curriculum (Reimers, 2021).During the interview, one of the staff members from the Environmental Management department recommended that:

It is significant to offer general training packages to all staff such as comprehensive carbon literacy training, professional association communications, and climate literacy courses. This will overcome the barriers of insufficient skills for staff in teaching climate change topics or conducting climate literacy activities.

Another staff member from the Climate Action Hub emphasised that "*The most beneficial resources needed are time and financial resources to roll out comprehensive carbon literacy training for the staff.*"

There was common consent regarding the importance of the decision to encourage all students across disciplines to engage in climate action activities on campus. Thus, the university should implement an innovative learning process to support students in thinking critically and becoming motivated to participate in a wide range of sustainability activities to adapt to climate emergency issues. Therefore, traditional education that emphasises lecturing, knowledge of scientific facts and tasks led by teacher instruction contrast dramatically with an

"Inquiry-oriented approach via activities" (Manolas and Leal Filho, 2011). One of the staff from Knowledge Exchange for Sustainable Education (KESE) explained the significant benefits of providing professional training for staff to support them in implementing a creative learning network for conducting climate literacy activities:

Staff training on conducting climate literacy activities is a prerequisite to building skills, knowledge and confidence to include these issues alongside the disciplinary content. All disciplines must consider how their graduates can be given the skills and capabilities to cope with climate change challenges. Offering examples of how to do it in different contexts, disciplines and levels of study are essential to foster climate literacy in universities.

Another staff member from the Environmental Management department emphasised the significance of providing cross-departmental academic resources to build confidence for teachers: "Internal cross-departmental educational resources are essential to help staff grasp the subject and become confident". Thus, building teachers' skills and confidence is a radical and critical requirement for enhancing climate literacy and motivating all students to engage in a wide range of sustainability activities to develop their responsibility and leadership roles to take action in alleviating climate change consequences (Bell *et al.*, 2010).

This research mainly focused on teaching staff and their role in advancing climate literacy and sustainability within the university. However, non-teaching staff, such as management and administrative teams, were not included in this study. That being said, their role is undoubtedly important. These teams often shape the learning environment in ways that go beyond the classroom – through policies, resource allocation and the example they set in their day-to-day work. They can also influence how students and staff engage with sustainability, serving as leaders and role models. Including non-teaching staff in future studies could provide a richer understanding of how the entire university community contributes to student engagement and participation in sustainability activities. Their involvement would give a more complete picture of how different parts of the institution work together to address challenges like climate change.

4.4 The role of the university in improving the climate literacy of students

There was also a consensus among the staff that an important responsibility of the university is to improve climate literacy by embedding climate literacy activities in the context of all taught courses and institutional operations. During an interview, one of the staff from the Environmental Management department stated:

It is vital to embed climate change awareness, adaptation and mitigation measures across all disciplines and departments by promoting partnership across institutions and strengthening cooperation with international organisations (e.g. United Nations), businesses, schools, and UWE academics to foster climate literacy on campus. In addition, the need for scientific information and abilities is nowhere more pressing than in sustainability and climate literacy in universities.

Currently, this is not the case, as the students mentioned that the main barrier is a lack of clarity on how they could transfer their scientific knowledge into action to promote sustainable and green practices on campus. There was also a consensus that the main reason to foster climate literacy is to prepare students to mitigate the climate change crisis and to have a leadership role in implementing effective decisions in developing urgent new solutions.

Keeping the above observations in mind, for example, a student from the Environmental Management department described his experience:

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I have been pleasantly surprised by the number of students who care about sustainability practices (e.g. climate change initiatives) and are eager to do their part to help. However, getting other non-interested students across disciplines to join in sustainability-driven conversations and climate change clubs are challenging.

Commenting on this, one of the staff from the Climate Action Hub stressed that universities have a key responsibility to embed climate literacy in courses to encourage all students to participate in sustainability activities:

The main role of the university toward improving climate literacy is to take a policy position on it being a crucial part of embedding climate literacy in all courses and the student experience. This will motivate students to take action and become involved in climate literacy activities.

Furthermore, Levrini *et al.* (2021) mentioned that building a bridge between activities and epistemological knowledge of climate literacy is crucial to developing inquiry practice and collaborative learning via climate literacy activities. This will encourage all students across disciplines to be involved in shaping a sustainable future and creating solutions to respond to the climate change crisis. Figure 1 is a schematic diagram of the main research findings for the climate literacy framework in higher education, showing the climate literacy activities, resources for staff, and partnerships.

This study underscores the importance of integrating climate literacy into university operations and strategies. The linkage to the ISO framework, particularly the structured approach of the ISO 9000 PDCA (Plan-Do-Check-Act) cycle, provides a valuable pathway for institutions to systematically embed climate literacy into their policies and practices (Orihuela-Gallardo, 2025). By aligning with such internationally recognised standards,

Climate literacy Activities		Resources for Staff	Partnerships
-Formal curriculum: We climate literacy projects, collaborative team learnin in multidisciplinary group lectures, Active Classroor activities, Assessment and based learning. -Informal curriculum: v activities, COP26 confere professional climate litera alongside the Students' U actions.	orkshops, ng (students ps), ns, Field 1 Work- oluntary nce and cy training nion-led	-Provide comprehensive carbon literacy training packages, financial recourses and internal cross- departmental educational resources to build skills, knowledge and confidence for staff in implementing climate literacy activities	Strengthening partnerships and cooperation with the international organisations (United Nations), voluntary groups, private and public sector enterprises, businesses, Students' Union, NUS Responsible Futures Framework and UWE academics.
Climate literacy Framework in Higher Education	Embed clim as a manda translating t Implement strategy) to literacy acti Provide all wide range the skills an	ate literacy topics in curricula (across d tory subject integrated with climate lith heir scientific knowledge into action an innovative and attractive learning pro support students in participate in a with vities students with the opportunity for quali of activities and training on campus to d capabilities to cope with climate chan	lisciplines) and institutional operations eracy activities to support students in peess (develop a teaching and learning de range of sustainability and climate ty carbon literacy by implementing a ensure that all graduates can be given ge challenges.

Source(s): Authors' own work

Figure 1. Schematic diagram for developing a climate literacy framework in higher education

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universities can enhance their institutional strategies, ensuring that efforts to promote climate literacy are both effective and sustainable. In the context of higher education, fostering progressive intellectual capacity building requires a strong emphasis on quality education (Jackson *et al.*, 2006). Ensuring this quality relies on robust quality assurance and management systems, which are essential for higher learning institutions to meet the needs of their primary stakeholders effectively(Aithal and Maiya, 2023). By adopting the ISO 9000 PDCA (Plan-Do-Check-Act) cycle principle, which prioritise continuous improvement and innovation, universities can create a more dynamic and engaging learning environment for students and educators alike, surpassing the limitations of traditional "good enough" educational approaches (Jani, 2011; Kayyali, 2025). Future research could explore the practical implementation of this framework across diverse institutional contexts, further contributing to the development of structured approaches to climate education (Jani, 2011; Sirirattanchit, 2025).

The results of this study were derived from a qualitative approach, which was chosen to gain in-depth insights into the perceptions and experiences of university staff and students regarding climate literacy. While the findings provide valuable context-specific information, it is acknowledged that comparative analysis with studies employing quantitative approaches could further enrich the understanding of the topic. Quantitative methods could complement these findings by offering statistical evidence of trends and generalisable outcomes. Future research could integrate both approaches to explore the intersection of qualitative depth and quantitative breadth, providing a more holistic perspective on the promotion of climate literacy in universities.

5. Conclusions and future research

This research demonstrated the importance of promoting climate literacy among students because it is the youth who will be affected by climate change challenges more than any other generation. Therefore, the youth are among the groups that most urgently need to know about promoting climate literacy due to the environmental, economic, and social climate change consequences that will befall them in the future. Furthermore, the findings illustrated that students face challenges in translating their understanding of climate change science into action and lack sufficient skills and motivation to take action. Thus, climate literacy should extend beyond basic knowledge about climate science to building students' skills via activities that will support them in making sound decisions in adapting to climate change concerns. Therefore, enhancing climate literacy will open up new opportunities and expand visions to foster student participation in creating climate literacy initiatives on campus and implement climate literacy projects through future-oriented action.

This study was based on carefully curated subsets of two predominant groups of stakeholders (students and staff) of higher education at universities in the UK from the University of the West of England, Bristol (UWE) as a case study for semi-structured interviews. However, these cannot represent all possible cases. The study sample represents only a systematic collection of primary data feasible for a cross-sectional study, such as this one, that provides a snapshot view.

This research has highlighted the importance of implementing climate literacy activities and sustainability practices for students on campus to support them to transfer their knowledge into practice in adapting to climate change. Moreover, it identified the university's significant role in developing a teaching and learning strategy to legitimise climate literacy activities in the curriculum and provide a resource bank of quality teaching materials to effectively deliver sustainability and climate literacy in all provisions. Further recommendations for higher education institutions include implementing extensive efforts to explore and develop curriculum design to integrate climate literacy activities in all courses, considering the workload pressure on the staff, and creating innovative options of new additional activities to be suitable for all students across disciplines, to increase their motivation to engage in climate action and implement new project ideas to promote climate literacy. One limitation of this research is that it focused exclusively on students and staff from environmental-related programs. Future research could expand the scope by including participants from non-environmental disciplines or programs. Such an approach would allow for comparative analysis, offering insights into how perspectives and outcomes differ across disciplines, thereby enriching the understanding and applicability of the findings. Another limitation of this study is that it did not account for the timeline of how long students had been studying their program or participating in the hub. This was due to time constraints within the research process. Future studies could address this by examining how the duration of engagement in their programs or hubs influences perspectives and outcomes, providing a more nuanced understanding of the findings. Additionally, further research is required to explore the impact of climate literacy on student behaviours, values, and attitudes in the long term. There is currently very little robust evidence of its impact.

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Data Availability Statement: The scripts are available through the GitHub repository (https:// github.com/vmuccion/ClimateEducation_AI). Publications on the Dimensions API (https://www. dimensions.ai/) and the Web of Science, Core **RESEARCH ARTICLE**

A scoping review on climate change education

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Abstract

The growing urgency of the climate crisis necessitates innovative educational approaches to equip people with the knowledge and skills to address climate challenges and be able to influence policy effectively. Education can be a central asset to promoting climate action, yet the importance of climate change education has been underexposed in large and influential assessment reports such as those from the IPCC. This study provides a comprehensive mapping of the literature on climate change education with a particular focus on the time period 2008-2023. By combining human coding and natural language processing (NLP) techniques, we examined a diverse corpus of over 6'000 publications from the peer reviewed literature. The findings highlight the pivotal role of climate education across various disciplines and its alignment with critical climate research themes such as adaptation, mitigation, disaster risk management, and sustainability. Our analysis reveals three predominant topics within the literature which are related to effective learning methodologies, sustainable development education, and the importance of education in adaptation and resilience. Additionally, we identified emerging themes emphasizing the role of youth as change agents, the necessity of transformative educational practices and the importance of energy literacy. Through geoparsing, it was possible to infer country mentions and case studies. These appeared to be largely skewed towards the English speaking countries and in particular the United States and United Kingdom, underpinning the urgency of diversifying research funding and fostering an open data culture. The insights gained from this scoping review underscore the potential of climate education to not only enhance knowledge but also to drive community engagement and policy initiatives, thus contributing to broader climate action efforts. In essence, it suggests fostering innovative educational practices for cultivating an active and informed society capable of addressing the pressing challenges posed by climate change. Importantly, this study calls for the integration of climate change education themes into climate policy-relevant assessment reports.

Introduction

The climate crisis is making headlines every day [1, 2]. The increasing impacts and consequences of the climate risks predicted in the past decades are now a reality almost everywhere Collection (https://www.webofscience.com/) were screened based on titles, abstracts and key words until July 31st, 2023 using the string searches in square brackets [(((climat* AND chang*) AND education) OR ((global warming) AND education) OR ((climat* AND chang*) AND teach*) OR ((global warming) AND teach))]. To be included, publications had to be indexed in English and be of the type article or book. We excluded records that did not have an abstract or DOI and removed duplicates. For copyright reasons, the full metadata from WoS and Dimension cannot be published. To reproduce the analysis, it would be necessary to apply the search string and download the abstracts from WoS and Dimensions. The list of DOIs and the processed data to reproduce the analysis from the metadata can be accessed here https://zenodo. org/records/13939232.

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[3]. The latest IPCC reports emphasize the time-critical dimension of the climate crisis and that the coming years will be instrumental in securing a climate resilient future for generations to come [4, 5]. The already noticeable and widespread impacts of climate change have led to increasing climate anxiety in young generations across the globe [6].

It is not fully clear however how adults and children alike access and consume information to develop knowledge and understanding to be better equipped to handle these challenges. Social media platforms, blogs, and a growing number of communication channels have made it possible for science to have a more immediate, and broader reach and influence outside of the academic sphere [7–9]. The channels have however also led to the spread of misconceptions and fake news amongst the general public, slowing down positive action [10–12]. Yuan et al. [13] have analyzed more than 7 million tweets about climate change between 2019–2020 and found that aggressive tweets (although a small proportion of total tweets) were more likely to be retweeted and politicised.

To counteract misinformation and bolster action, interventions at the level of communications and education have been deemed essential [14]. Climate change education refers to the process of teaching and learning about the causes, consequences, and potential solutions to climate change [3]. Climate change education aims to enhance public awareness, understanding, and engagement in climate change issues, as well as foster adaptive capacity and support for climate action [15, 16]. Recent developments in university education are moving in the direction of including modules on climate change and the climate crisis as part of compulsory study programmes as a result of activism and public dialogue [17-20]. There are good examples of initiatives and online platforms that provide a broader scope of resources on climate or climate focused environmental education. For example, the EU education and training sector focus on green education https://education.ec.europa.eu/focus-topics/green-education [21] the Office of Climate Education, under the auspices of UNESCO [22]; or initiatives like the GLOBE (Global Learning and Observations to Benefit the Environment) Program, supported by US governmental agencies, which gives students and the public the opportunity to contribute to observations, research and analysis of global environmental data [23]. Existing successful models of climate-focused project-based learning have resulted in increased climate awareness and overall carbon reduction [24]. For example, significant carbon reduction was measured through student-consumer choices after five years of taking a university climate change course, indicating that even a small amount of climate change information and awareness introduced into school curricula has the potential to result in a significant effect [20].

Climate change education is not limited to formal educational systems, such as school and university curricula but is also present in vocational qualifications and informal settings like media and social media platforms [19, 25]. Communication and engagement strategies, such as experiential learning, climate games, and online courses have been described as effective and useful methods for reaching diverse audiences and fostering climate literacy [7, 26]. As a result, research is paying increasingly more attention to the role that education in its different forms plays on its power to catalyse action and empower citizens [27]. Some studies have found that although learning leads to knowledge and skills, the type of information and learning experience can have a profound effect on the outcomes of successful learning and behaviour change and whether there is lasting impact; this is especially true for climate change information where personal relevance to the issue or an engaged learning experience can be critical to solidifying a lasting change, especially for children and young people [17, 19, 20, 28].

On the other side, there is evidence that climate change education often emphasizes individual actions rather than addressing crucial policy actions on climate change as for example in terms of mitigation and adaptation [27]. Key elements such as the 1.5-degree limit envisioned by policy and extensively addressed in IPCC reports and beyond, as well as climate justice, are rarely discussed in educational programs. Along these lines, scholars have reported the considerable challenges when moving from climate change education to effective climate action, therefore arguing that there is still a gap and misconceptions within the teaching and student communities when it comes to climate change [29].

These diverse lines of evidence highlight the contested nature of climate change education and its relevance across various domains. As a result, the body of literature on climate change education is diverse and expansive, encompassing reviews that address the importance of giving children and young people a voice in climate change education [30], the role of health professionals in climate change education [31], and the integration of indigenous knowledge [32], to cite a few.

However, education has, so far, been sidelined in large environmental assessments such as the recent IPCC reports [3, 33]. The Summary for Policy Makers of the Working Group 2 on Impacts, Adaptation and Vulnerability [4] mentions "education" four times, whereas the Summary for Policy Makers of the Working Group 3 on Mitigation [5] mentions it three times. These summaries are the first policy stop for decision makers and therefore play a key role in leading to policy changes, which might apply to education policy leading to climate action. And yet, this angle is rarely explored by climate policy. The marginalisation in influential climate reports indicates a lack of consideration for educational strategies in bringing to the fore front the climate discourse, revealing a gap that demands attention.

In this paper we scope the research on climate change and education using systematic mapping of the peer-reviewed literature. Systematic mapping is an approach that seeks to give an overview of an area of research by identifying, categorizing and assessing the existing literature on a topic [34]. It is different from a systematic review whose scope it is to synthesize evidence, identifying strengths and weaknesses, usually with a very specific formulated goal [35]. A systematic mapping gives a high level overview or map of the research area, which helps to identify gaps and future research directions though visual summaries and mapping of classification categories [36]. The goal of our study is thus to take stock of the literature and explore the main themes, contextual influences, and relationships that emerge on a broad and global level through a systematic mapping. In particular, our scoping review addresses the following research questions: 1) where do we situate the research on climate education in the context of the broader climate change research? 2) what can we infer about the scope of such research 3) what are the main themes, gaps, and identified relationships that merit further attention? and finally 4) can we draw some conclusions on the links amongst education and climate action?

Owing to the exponentially growing number of publications on climate change, the methods for systematic mapping of the literature is situated in the context of big data and big literature [37–39]. This paper is organised as follows. The next section, Methods, describes the methodological approach for data collection and analysis as well as the data set used in our analysis. The Results and Discussion sections summarize and discuss the main findings of the paper, as well as offer some insight on future directions. Finally, we end with Conclusions.

Methods

Systematic reviews and mapping have been valuable assets to synthesize various key topics from the literature on climate change [40–43]. As the amount of literature on climate change has increased exponentially, machine assisted assessments of the literature have started complementing human efforts [37]. Machine learning has been used in assessing progress on human adaptation [38], to map the literature on climate change and health [44], to highlight global adaptation limits [45], for impact attributions [39] and to give insights on the topology of climate change research [37]. This paper adds to the mapping of climate change literature

by focusing on climate change education. The notebooks and data used can be found on GitHub [46].

Data collection, search and screening

Publications on the Dimensions API https://www.dimensions.ai/ and the Web of Science, Core Collection https://www.webofscience.com/ were screened based on titles, abstracts and key words until July 31st, 2023 using the string searches in square brackets [(((climat* AND chang*) AND education) OR ((global warming) AND education) OR ((climat* AND chang*) AND teach*) OR ((global warming) AND teach))]. To be included, publications had to be indexed in English and be of the type article or book. We excluded records that did not have an abstract or DOI and removed duplicates. Finally, only papers having both a non null abstract and DOI were selected. After merging the two database datasets and removing duplicates, 18'162 records were retained for further analysis using human coding of abstracts supported by supervised learning. Supervised learning is a type of machine learning algorithm where the model learns to make predictions by being trained on labeled examples [47]. The algorithm is given a set of input-output pairs, where the inputs are the features or attributes of the data and the outputs are the corresponding labels or target values. The goal of the algorithm is to learn a mapping between the inputs and outputs, so that it can make accurate predictions on new, unseen data [48, 49].

In our case, we randomly selected about 10% of the articles in our database of more than 18'000 (i.e. 1776) to create the training and test set. We then proceeded to manually label the papers as either relevant or non-relevant (eight records had to be removed from the train-test sample due to unreadable abstracts). Papers on "school environment" or "school climate" were labelled non-relevant because they had no relation with climate change or global warming. For some papers the relevance was not immediately clear. These papers often mentioned education in the context of broader themes or broad policy recommendation such as strengthening education or improving capacity without education being a main theme of the paper. In these borderline cases, we decided to examine the full text of the paper. This extra step added a layer of confirmation to our decision to exclude or reconsider exclusion for those abstracts and titles that addressed or seemed to address climate change and education in a tangential manner. Papers were labelled and reviewed separately by different authors until agreement was reached on their inclusion or exclusion. The final proportion of papers labelled as relevant corresponded to about 40%. It is important to mention here that in line with the scope of the study being that of big literature mapping, we did not assess the quality/strength of the evidence as it is often done in a traditional systematic review. We did however follow and record each stage of our literature selections using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The original PRISMA flow diagram has been adapted to reflect the combination of human and machine coding and can be found in Fig 1 and S1 File. The PRISMA checklist is given in S2 File.

Various supervised machine learning techniques were applied for the supervised task using the Scikit-Learn pipeline [50, 51]. The purpose of a pipeline is to streamline and automate the workflow of preprocessing data to apply machine learning algorithms. It allows to chain multiple steps together into a single, coherent process. A typical Scikit-Learn pipeline includes steps such as data preprocessing (e.g., scaling, dealing with missing values), feature extraction, and finally, the application of a machine learning algorithm. We first employ a selection of pipelines, where each pipeline performs the same set of concatenated steps but each pipeline has a different classifier [47]. In the first step, a count vectorizer transforms each document in a feature vector. Afterwards, term-frequency times inverse document frequency (TF-IDF)





transforms the document-feature matrix to scale down the impact of words (or tokens) which occur very frequently in a corpus but are not very informative. TF-IDF is a statistical approach for text mining and information retrieval from a large corpus of documents [52]. Term Frequency (TF) measures how frequently a term (word) appears in a document. It is calculated as the number of times a word appears in a document divided by the total number of words in the document. Inverse Document Frequency (IDF) measures how important or rare a word is across all documents in the corpus. It is calculated as the logarithm of the total number of documents in the corpus divided by the number of documents that contain the word. A classifier is then instantiated, the training data are fed through the pipeline, and finally predictions are made on the test set. Each classifier is trained on about 70% of the data and performance is tested on the remaining 30%.

	Precision	Recall	F1-Score	Accuracy
Multinomial Naïve-Bayes	0.72	0.66	0.56	0.66
Linear Support Vector Classification	0.81	0.81	0.81	0.81
Random Forest	0.79	0.79	0.79	0.79
Multi-layer Perceptron Classifier	0.80	0.80	0.80	0.80
Nonlinear Support Vector Classification	0.80	0.81	0.80	0.80
Climate-GPT-2	0.80	0.81	0.80	0.85

Table 1. This table gives a summary of the performance of each classifer model expressed as precision, recall, F1-score and accuracy.

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Further to this, a Generative Pre-Trained Transformer GPT-2 for climate change related topics (climate-GPT-2 models) is used for the supervised task [53]. The difference between the classifiers and the GPT-2 models lies in their foundational methodologies. Classifiers are based on traditional machine learning algorithms and require explicit feature engineering. In contrast, climate-GPT-2, a decoder transformer, uses the final token of the input sequence to predict the subsequent token. In climate-GPT-2 architecture the last token of the input sequence contains all the necessary information for prediction tasks. We utilized this information to make a prediction in a classification task rather than a generation task. In other words, instead of using the first token embedding to make a prediction as is normally done in encoder transformer models, we used the last token embedding to make a prediction (here in a classification task).

The performance of each model is assessed using a confusion matrix and classification report [54]. In a binary classification problem like the one here, the confusion matrix is a

square matrix of the type $\begin{pmatrix} TN & FP \\ FN & TP \end{pmatrix}$ where TN = True Negative, TP = True Positive,

FP = False Positive and FN = False Negative. The classification report provides the weighted averages for precision, recall, F1-Score and accuracy, where accuracy is the sum of the true predicted instances divided by the sum of all instances; precision represents the positive predictive value and is given by TP divided by the sum of TP and FP; recall represents the true positive rates and is given by TP divided by the sum of TP and FN. F1-Score is the harmonic mean of precision and recall. For a dataset like ours which is reasonably well balanced between positive and negative instances, accuracy is a good predictor of the model performance. The classification report is given in Table 1. Cross-validation with k-folds is also implemented. In this case, classification is performed on samples of different sets of data for testing and training each time (or for each fold) [50]. The k-fold increases performance of each classifier by a factor between 0.02–0.04. Climate-GPT-2 outperforms all other classifiers in terms of accuracy, whereas the other parameters are similar across all classifiers except Random Forest and Multinomial Naïve-Bayes. Therefore, we select Climate-GPT-2 to make predictions on the whole data corpus.

Data analysis

Our data analysis begins with a bibliographic examination to gain insights into the temporal distribution of publications, the scope of journals, and the citation patterns. In the subsequent stage, we leverage the spaCy library for abstract lemmatization. SpaCy is an open-source natural language processing (NLP) library designed for information extraction from extensive text corpora [55]. The lemmatized abstracts are then fed into the TF-IDF model for various purposes, such as enabling the visualization of words through word clouds. To map the scope of the literature we used topic modeling. Topic modeling is a type of unsupervised learning

method for text mining based on Bayesian probability which extracts meaningful topics from short and long texts [56, 57]. It requires domain knowledge to make sense of the topic clustering and it has been successfully deployed for topic mapping of the climate change literature [37, 39, 44]. Topic modelling allows to cluster the distribution of words into representative topics [44]. There are different algorithms to implement topic modelling. Here we follow an approach implemented in [37] and use non-negative matrix factorisation (NMF) [56]. In a nutshell NMF takes the TF-IDF vectorized text matrix and breaks it down in a feature matrix which contains the topics and a weight matrix which contains the weights of those topics. Based on the feature matrix, each abstract is labelled to the topic with the highest weight [58]. To improve the reliability of the topic modelling results, we performed several experiments where we changed the number of topics, the ngram range in the TF-IDF instantiated model and the alpha parameters in the MNF. We used this combination to aim at a convergence between 1) the domain knowledge of the authors refined through an analysis of the abstracts in the human classification task and 2) the coherence score which measures the relative distance of words within a topic [59]. The coherence score algorithm predicted 15 as the best number of topics in our corpus using ngramrange = (1,2). The topic clustering happened to be relatively robust by changing the regularization parameters alpha H and alpha W although better results were achieved without regularisation where the parameters were set to 0. We conducted a thorough review of the topics that emerged from our topic modelling, aiming to identify and categorize significant thematic clusters. We validated the final fifteen clusters through meticulous reviews within our research team.

T-distributed Stochastic Neighbor Embedding (t-sne) is then employed as a dimensional reduction technique to visualize the topic scores in a two dimensional space [37, 60, 61]. t-SNE works by mapping high-dimensional data points to a lower-dimensional space in such a way that similar data points are modeled as nearby points, and dissimilar points are modeled as distant from each other. To distill the core ideas of numerous abstracts, making it easier to grasp the central themes and research directions within each topic, we performed text summarisation using gpt-4–1106-preview, an OpenAI Large Language model, integrated in the open source framework LangChain. The approach involves a multi-stage summarisation process following custom prompts. Clarity and iterative development of prompts is essential to achieve good results as outlined also in [62]. This technique allows to process large quantities of texts by initially summarising each small chunk and subsequently merging summaries, we triangulate the machine-generated outputs with our domain expertise and insights from the manual classification tasks.

Finally, Geoparsing was used to collect information on where in the world the studies take place and how the topics are geographically distributed. Geoparsing is a technique that can determine the geolocation in unstructured text and has been used previously in the context of climate change impact attribution [39] and for climate health literature mapping [44]. We used the open source software Geotext to extract cities and country mentions from text [64].

We use Jupyter Notebook for our classification tasks and analysis. Our scripts are available on GitHub [46].

Results

After performing the supervised tasks and adding the records screened manually as relevant (706), a final dataset comprising a total of 6649 papers was retained for all remaining analyses. The split between relevant and irrelevant papers can be seen in <u>S1 Fig.</u> The dataset with the

relevant papers contains the following bibliometric information: article title, abstract, list of authors, publication year, journal title, DOI and number of citations.

Bibliographic and semantic analysis

The literature on climate change education started to appear more markedly around the last decade of the 20th century and the number of publications has increased by two orders of magnitude in the past two decades (S2 Fig). The number of publications recorded in 2023 has a cutoff date on 31st July. Given the steady increase but relatively low number of publications before 2008, it was decided to focus the rest of the analysis only on papers published between 2008–2023 (Fig 2). This amounts to 6379 papers.

Word cloud visualisations are used to infer the 500 most frequent single words (monograms) (Fig 2, bottom left) and pairs of words (bigrams) (Fig 2, bottom right). Word clouds are graphical representations of word frequencies, with more frequent words appearing larger



Fig 2. Publication per year and word frequencies. The top plots shows the number of publications per year for the period Jan 2008—July 2023. The bottom plot shows the word cloud of the first 500 most frequent words (left) and word pairs (left). The size of each word/word pairs indicates the relative weight from the whole corpus whose frequency is obtained from the TFIDF abstracts lemmatized using SpaCy.

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in the cloud. From the single words, *student* has the highest occurrence (the largest word shown), followed by *environmental*, *science*, *study* and *research*. Other words with high occurrence are also *health*, *knowledge*, *teacher*, *development*, *school* and *sustainability*. It is worth noting that although *school* has a reasonably high occurrence, *student* and *teacher* are higher (with *student* being by far the highest), *university* is less frequent, as opposed to *research* which scores very high. The word pairs cloud gives insight into key concepts. For example, the prevalence of *sustainable development* can be clearly seen, followed by *young people*, *case study*, *environmental issues*. The concept of COVID-19 frequently emerges in the literature examined within this study. In addition, we have calculated the word frequencies for two time slices, i.e. 1990–2010 and 2011–2023 to explore whether or not any major differences can be inferred. The results are available in the supplementary material (S3 and S4 Figs) and show good similarity across the word frequency for the two periods, albeit some terms in the first period such as *earth*, *scientific* or *model* seem to hinge upon a higher prevalence of papers on physical climate science and education.

In order to infer the influence that specific source titles have on the overall research domain we look at the number of publications per source title as well as the average number of citations (Fig.3). To assess who engages with this type of research, the top twenty journals per number of citations (top panel) and number of papers (bottom panel) are shown. In the climate focused research, high impact journals such as Climatic Change and Nature Climate Change score very high in number of citations, as does the topical journal Environmental Education Research. However, most of these climate focused titles score relatively low in number of publications (while the topical journal Environmental Education Research scores high). It also emerges that both proportion of publications and citations are very scattered with many titles representing less than 0.5% of the total citations.

Topics and clustering

A summary of the topics obtained via topic modeling, their associated 10 most important monograms and bigrams obtained from the lemmatized abstracts per topic is shown in Fig 4. We refer to each topic using word pairs that best capture the keywords. The topics are shown in descending order from top left to bottom right, according to Fig 5, which shows the proportion of papers per topic and topic trends over time. For the topic analysis, we initially defined a total of 15 topics (Topics 0–14), however for three clusters it was not possible to define a clear topic scope from the key words and therefore we classified these topic clusters as undefined (Topics 3, 8, 9; Topic 3 even included several German terms). These topics, in addition to Topic 2 (which had keywords related to physical geography), also had low overall counts of associated documents (with a total number less than 50 over the analysis period 2008–2023, see also Fig 5 for comparison). Given the relatively small size of these topic clusters, as well as Topics 3,8,9 being undefined, we did not consider Topics 2, 3, 8, 9 in subsequent analysis.

The proportion of the 11 different topics across our corpus of abstracts, summed over the analysis period, 2008—2023, is shown in Fig 5, top panel. Overall the most prevalent topics that make up more than 50% of the data corpus are Topics 10, 4, 5 and 0. The bottom panel of Fig 5 shows the evolution of the number of abstracts per topic over the analysis period. It can be seen that several topics experienced an exponential increase from approx. 2016. This is particularly the case for abstracts of the topics *Adaptation_Community* (light green), *Student_Learning* (brown) and *Sustainability_Sustainable* (dark green) (these topics also correspond to the top row in Fig 4).

In addition to identifying the keywords for each topic, we provide a text summary of the main themes in Fig 6.





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To understand the relationship between the topics, we visually render the topic clustering using t-SNE. This allowed us to explore the structure of our literature and to identify patterns in our complex dataset of abstracts. Fig 7 illustrates the topic clustering, with each colour representing a distinct topic and each dot representing an abstract. For instance, the cluster labeled *Science_Research* (blue) contains points that are grouped closely (also some grouped together as sub-clusters), with the proximity of the dots indicating more similarity in abstract





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Fig 5. Proportion of papers per topic and topic trends over time. This top figure shows the results of applying "argmax" to determine the most likely topic assignment for a specific paper. The "argmax" operation determines the topic with the maximum probability within a given paper abstract. The bottom figure shows the number of documents over time per each topic between 2008 and mid-2023.

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content. Some clusters slightly overlap (especially for *Science_Research* which overlaps with several other topics in the center), or where clusters are located near each other, indicating that their abstracts share similar topic content. For example, *Adaptation_Community* (light green) and *Disaster_Risk* (light brown) are located near each other, suggesting overlap in themes
Topic Label	Topic Summary
Student_Learning	Key themes identified are the importance of integrating climate change education into curricula, the impact of innovative teaching methods on student understanding and engagement, the role of technology in enhancing learning outcomes, and the significance of fostering critical thinking skills, scientific literacy, and sustainable practices among students. Additionally, the discussions underscore the imperative for educational institutions to prioritize climate change education, sustainability, and social responsibility in preparing students to navigate a rapidly changing world and contribute to positive societal transformation. The findings emphasize the need for interdisciplinary approaches, hands-on learning experiences, and the integration of sustainability concepts into education to empower students to address complex environmental challenges such as climate change.
Sutainability_Sustainable	Key areas of focus include the imperative for transformative action in response to global challenges, particularly climate change, the critical role of education in promoting sustainable development and addressing societal issues, and the significance of interdisciplinary approaches in tackling complex problems. Furthermore, abstracts also include the integration of sustainability principles into various disciplines, the importance of ethical considerations and values in education, and the necessity for community engagement and activism for sustainable development. The abstracts underscore the interconnectedness of environmental, social, and economic dimensions in fostering a more sustainable and resilient future.
Adaptation_Community	Key areas include awareness in addressing climate change, the pivotal role of community participation in adaptation endeavors, the necessity for stakeholder collaboration and the significance of cultural heritage. Other themes are climate change impact on vulnerable populations and the need to integrate indigenous knowledge in fostering climate resilience. The abstracts underscore the challenges inherent in implementing climate change adaptation measures, the criticality of communication strategies in conveying risks and instigating behavioral change, and the integration of scientific knowledge into policy formulation and decision-making processes.
Science_Research	Key areas include the urgency of climate change mitigation, the importance of transformative education and critical thinking in driving collective impact and the role of education in promoting scientific literacy and sustainability. Additionally, the abstracts underscore the value of community-driven science, interdisciplinary research partnerships, and the integration of socio-cultural learning theory in educational interventions. Some abstracts emphasize the impact of societal attitudes, political ideologies, and media communication on climate change discourse, as well as the potential for innovative approaches in science communication and education.
Environment_Behaviour	Key areas include the imperative of promoting pro-environmental behaviors through education, the influence of individual values and attitudes on sustainable actions, the impact of societal factors on environmental consciousness. Additionally, the significance of engaging diverse stakeholders, including youth, educators, and communities, in fostering environmental stewardship and addressing pressing environmental concerns emerges as a central theme. The intersectionality of environmental, social, and economic factors underscores the complexity of environmental challenges and the necessity for holistic and inclusive approaches to environmental education and advocacy. Ultimately, the findings highlight the urgency of cultivating a culture of environmental literacy, ethical responsibility, and proactive engagement to advance sustainability and mitigate environmental degradation.
Child_Young	Key areas explore key themes related to climate change education, youth engagement, community development, and environmental awareness. The overarching themes that emerge include the urgent need to address climate change impacts on vulnerable populations, particularly children, and the importance of education in fostering awareness and action on climate change, and the role of young people as agents of change. Additionally, ethical considerations, critical thinking, and innovative pedagogical approaches are emphasized as essential components in promoting environmental stewardship and sustainability. The summaries underscore the interconnectedness of climate change, education, social activism, and environmental stewardship, advocative, ransformative, and inclusive approaches to addressing challenges posed by climate change.
Teacher_Science	Key areas include the role of teachers in promoting literacy and the impact of teachers' beliefs on climate change instruction. The critical role of educators in fostering awareness, knowledge, and action on climate change and among students is highlighted alongside the need for ongoing support, training, and resources to effectively address these complex and pressing global issues in educational settings. The importance of integrating climate change into the curriculum and the challenges and opportunities in educating students about climate change are other aspects present in the abstracts. Other themes are the emphasis on critical thinking, evidence-based decision-making, and emotional responses in education, the multifaceted nature of addressing climate change and the various factors that influence teaching and learning in this critical area. The need for further research is also emphasised as a way to enhance teacher knowledge and practices in climate change education.
Medical_Health	Key areas identified include the recognition of climate change as a significant threat to human health, the importance of integrating climate change education into health professions curricula to address planetary health challenges. Additionally, the abstracts emphasize the impact of climate change on vulnerable populations and the need for adaptation and mitigation strategies as well as the importance of advocacy, leadership, and community partnerships in promoting sustainable healthcare practices. Furthermore, the summaries underscore the challenges in integrating climate change education into health professions curricula and the need for faculty development and resources to facilitate this integration. The importance of advocacy is also highlighted.
Energy_Mitigation	The main themes are the importance of sustainable energy solutions, climate change mitigation, renewable energy technologies, public awareness and behavior towards environmental issues, stakeholder engagement, energy literacy, transition to low carbon energy sources, policy support, technological innovation and societal engagement. Other abstracts underscore the urgent need for promoting renewable energy literacy, fostering citizen participation in sustainable energy initiatives, integrating sustainability principles into education and policy- making efforts, addressing misconceptions about energy, enhancing energy education, and promoting sustainable practices in various sectors. The summaries also emphasize the role of universities in promoting sustainability, challenges and opportunities in energy education, and the need for global cooperation in addressing energy and climate issues.
Disaster_Risk	Themes include the importance of education and training in disaster management, the impact of natural disasters on vulnerable populations, the need for community involvement in disaster preparedness, the role of schools in disaster risk reduction, challenges posed by climate change on resilience efforts, integration of climate change adaptation into disaster risk reduction strategies, value of indigenous knowledge in risk mitigation, significance of early warning systems in disaster response, interdisciplinary approaches. The media's role in raising awareness is also present.
Game_Gamification	Key areas include the use of games and simulations for educational purposes together with the development and evaluation of serious games for sustainability and climate change engagement. Other themes encompass the pedagogical potential of games in promoting climate change awareness and sustainable behaviors, the integration of environmental concepts into education through gamification, the effectiveness of serious games on increasing knowledge and attitudes towards sustainability, the use of gamified decision support systems for urban planning and climate education, the impact of serious games on learning, social learning, and policy changes, the importance of realism, educational potential, and real-world relevance in digital entertainment games, as well as the application of gamification principles to motivate individuals towards engaging in sustainable practices and addressing real-world problems.

Fig 6. Condensed topic summaries. This figure shows the condensed topic summaries for the abstracts falling within a given topic category.

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related to the adaptation community and disaster risk management (we can also see this in the overlap with the top 10 words from Fig 4, with the word "risk" high in importance for both topics). Conversely, distinct separation between clusters, such as Medical Health (light blue) and Game_Gamification (grey) which are distant to the other clusters (and each other) indicates that these abstracts share little to no overlap in topics (except interestingly, a few other topics (blue, green, brown dots) which overlap at the edges of the *Medical Health* cluster). The density of points within a cluster can give a rough indication of how extensive or prevalent a topic is within the dataset. Dense clusters like Teacher_Science (dark pink) suggest a significant number of documents within this topic have strong overlap, whereas sparser clusters might indicate that topics are more diluted as they overlap with others clusters. Some topics also have sub-clusters that are distant from the main cluster but closer or overlapping with other clusters, for e.g. *Energy* Mitigation (red), indicating closer similarities across some sub-topics with other clusters. Overall, we can recognise a pattern that places education related abstracts on the left of the diagram and more climate related abstracts on the right of the diagram. There are of course exceptions as for example abstracts that put equal weight on both climate and education have scattered dots in each section of the diagram. The closer to the center of the diagram the less the topic prevalence is and we have abstracts that identify less with distinct





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topics. Topic clusters including *Energy_Mitigation* (red), *Game_Gamification* (grey) and *Medical_Health* (light blue) follow a different pattern altogether being both quite distinct and far apart from the rest.

The heatmap in Fig 8 shows the correlation between two topics based on the NMF coefficients. Higher values (closer to 1) indicate that two topics are strongly positively correlated. For instance, *Student_Learning* and *Teacher_Science* have a stronger positive correlation (0.25), or as we've seen in the previous figures, *Disaster_Risk* and *Adaptation_Community* have a strong positive correlation (0.18) indicating that documents that are associated with adaptation also often address disaster risk concerns. This is also the case for *Child_Young* and *Game_Gamification* (0.14). Conversely, values closer to 0 indicate little to no correlation, while negative values (if applicable) suggest an inverse relationship. There are overall small positive (correlations) as well as small negative values (anti-correlation). For example, there is also





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positive correlation between *Disaster_Risk* and *Health_Medical* (0.15). Those showing anticorrelation, albeit a weak one, are papers belonging to the cluster *Adaptation_Community* with those belonging to the clusters *Student_Learning*, *Science_Research* and *Sustainability_Sustainable*. *Sustainability_Sustainable* is also anticorrelated with *Student_Learning* (-0.12) and *Science_Research* papers (-0.13). This can be interpreted as a disconnect amongst the research on sustainability and ESD (education for sustainable development) which in this cluster seems to



Geographical distributions of case studies

Fig 9. Geographical distribution of studies. The figure shows the geographical distributions of studies based on ISO country codes.

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be mainly applied to the university context and more general keywords of science (including social science) and research on climate change that are associated with *Science_Research*.

Geographic distribution of studies

To gain better insight into which countries were more actively involved in case studies or literature on climate change education (and which are lacking), we tagged country mentions in our analysis. Results are shown in Fig 9 and S5 Fig. Less than 40% of the abstracts however specifically mention countries and/or location. Among those abstracts that have explicit geolocations, the large majority are in the United States, followed by the United Kingdom and Australia (Fig 9 and S5 Fig). It is worth mentioning that the Geotext as setup here does not recognise political unions such as the European Union (or EU). Therefore, if the EU is mentioned with no mention of individual countries, it will not be tagged at the country level and is only identified at the continental level. Most of the countries and world regions are mentioned in at least one study, however there are noticeable gaps for African countries. The continental distribution (not shown, but can be inferred from Fig 9 and summing over the countries in each continent) indicates that Asia has the highest proportion of studies, with North America and Europe sharing a similar proportion, and South America having the least number of studies. It emerges that again Africa as a continent is poorly represented.

We also take a look at the association of countries with the major clusters of topics. For the sake of clarity we only show the countries that appear in more than 20 papers (Fig 10). The United States has the highest score for eight out of the eleven clusters. If we look beyond the United States, we can also see that Australia and United Kingdom are high for several topics including *Sustainability_Sustainable*, and *Child_Young* (also high for Germany), whereas *Energy_Mitigation* is moderately high for China. The *Adaptation_Community* cluster is high for many countries beyond the United States, including Bangladesh, Canada, China, Germany, Indonesia, Nigeria, South Africa, Australia and the UK. The clusters *Science_Research, Student_Learning, Sustainability_Sustainable* and *Adaptation_Community* are in general higher than average over most countries, and this is also reflected in the overall proportion of papers per topic (Fig 5).



Fig 10. Association of countries and clusters. The figure shows the country counts per each of the more prevalent topics. The darker the color, the higher the number of papers.

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Discussion

Climate change research is rapidly expanding [66]. In response to the increasing output, research syntheses in the form of systematic mapping, reviews and/or meta-analyses have become increasingly popular [37–39, 66]. These studies have benefited from the fast advances in natural language processing (NLP), which make it possible to process and analyse large corpora at reasonable speed and accuracy [37, 67, 68]. Such advances have been essential to inform large assessment reports such as those from the IPCC [4].

Our research is situated within this growing trend of research syntheses that make use of natural language processing (NLP) to make sense of growing literature output [37, 38, 68]. It is driven by evidence indicating that strengthening climate change education and engagement is one of six social tipping dynamics crucial for driving disruptive change toward positive societal transformation [69]. Given the importance of climate change education and an absence of a systematic and broad assessment of the literature to date, we have performed here a mapping of the literature on climate change education. Our mapping exercise has illuminated the main directions (topics and clusters) on the research on climate change education, their prevalence, intersections and geographical distribution.

From our analysis it emerges that climate change education is well represented in main stream climate research ranging from climate change adaptation and mitigation to health science and sustainability. Looking closer at the semantic analyses, climate education is not exclusively associated with natural science terms or education terms, but other important terms including community, sustainable, young people, development and health (Fig 2). This diversity is also confirmed by the topic clustering (Figs 4 and 7). These findings align with Callaghan

et al. [37], which analyzed over 400,000 climate change publications from the Web of Science, revealing a great diversity of topics. Similarly, another study examined approximately 130,000 international peer-reviewed climate change articles published between 1990 and 2021, and found a shift from traditional climate science to more interdisciplinary research on impacts and climate solutions [66] somewhat in line with our results in S3 and S4 Figs. From the temporal evolution of the topics in Fig 5 (bottom panel), 2016 represents a pivotal year in our analysis in the number of publications across most topics possibly due to crucial developments in climate policy and international cooperation with the signing of the Paris Agreement and the creation of frameworks such as UN Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals [70].

Topic modelling and visualisations allowed us to draw some conclusions on the extent to which specific themes are unique as well as the presence of common themes shown by the proximity and overlap amongst clusters (Fig 7). These topics are again aligned with the interdisciplinarity reported by extant research [37, 66] and underscore a wide array of themes linked to sustainability, public health, communication, and climate solutions. However, some patterns are discernible in the relations across topics, as for example there are topics closely related to education (i.e. *Teacher_Science, Student_Learning* and *Science_Research*) and others where climate change and environmental sustainability are stronger themes (*Environment_Behaviour, Sustainability_Sustainable, Adaptation_Community, Disaster_Risk*). This duality in the research pattern can also be seen in the bibliometric analysis with papers distributed amongst climate and education titles, shown in Fig 3. Notwithstanding, there are several abstracts that span several topics (indicated by the central dots in Fig 7). Meaningful topic proximity is found between *Science_Research* and a sub-cluster of *Student_Learning* given that both have keywords resonating with the scientific, research and tertiary education enterprise. However, there are also some themes that emerge from each cluster which are more distinct.

To have a more conceptual and nuanced understanding of each topic, we have used topic summarisation (Fig 6) which complement the semantic analysis in Figs 4, 5, 7 and 8. From these summaries, it is possible to infer that abstracts in cluster *Science_Research* provide a broader perspective on the role of education in promoting environmental literacy beyond the classroom, involving societal and policy dimensions. In contrast, abstracts of *Student Leaning* are more centered on the practical aspects of education, focusing on innovative teaching methods, the role of technology in enhancing learning, and hands-on learning experiences. Environmental and behavioural topics have some proximity to both Sustainability_Sustainable and Student_Learning. This proximity hinges on the centrality of education in shaping both environmental behaviours and education for sustainable development [71, 72]. Two unexpected, separated clusters are *Medical_Health*, including terms climate health and education related terms and that of Disaster_Risk in Fig 7. It can be inferred from the key words that Medical_Health is mainly about climate change literacy, nursing, medical schools and curricula. However, there is a correlation for certain themes as it can be seen in the heatmap (Fig 8). This could be the reasons why certain papers of *Disaster_Risk* overlap with the main cluster of *Medical_Health* (Fig 7), which is also discernible from the summaries, i.e. Medical Health topics are also concerned with themes of vulnerability and resilient health systems. In general, the evidence of harm to health from climate related disasters remains scattered and often focused on weather related displacement, whereas the large majority of health literature is mostly concentrated on heat health impacts and vector-borne diseases [73]. Moreover, several key themes emerge that are crucial for understanding advancements in research, particularly the role of children as both agents of change and those most affected by climate change. Firstly, the temporal evolution of the topic Child_-Young in Fig 5 confirms that this body of literature has gained traction since 2018, which most probably coincides with the publication of the IPCC special report on 1.5°C [33] which was

pivotal in inspiring the climate movement [74, 75]. Secondly, summaries for the topic on young people and children reveal the need to make climate change education more relevant and applicable to young people, while also using it as a tool to prepare them for future challenges.

Although a lot has been published on climate change education, and over many different domains, as it can be inferred from Figs 2 and 5, climate change education still remains a niche when it comes to promoting new educational policies which address the climate crisis [76–78]. This is even more compelling given that community participation, youth engagement, and societal attitudes in driving climate action and promoting sustainability are obvious themes in our corpus of abstracts in Fig 6 and hence in the literature [30]. Community-driven initiatives and the influence of political ideologies and media communication are other crucial areas of focus (see Fig 6). To enhance the effectiveness of climate change education, research suggests incorporating policy literacy to educate climate-literate citizens capable of engaging in public-sphere actions [79]. This shift in focus would better align climate change education with current research discourse and potentially lead to more impactful outcomes [20].

An important caveat to this study is that a lot of the primary literature or material on climate change education may be classified as other literature types (governmental reports, white papers, curriculum documents, and the like) rather than as peer reviewed publications or books [80], as we've addressed here. This is naturally due to the nature of climate change education and how this is written about or documented, and dominated by each country's own language (it is obviously more useful for teachers, lecturers and educators to have curriculum documents in their own language). The number of publications is also likely strongly related to the amount of governmental funding for academics in any given country (as well as the number of academics working on these topics), where countries that allocate more spending on these topics will rank higher in number of publications, and will likely also have research focused on case studies or other methods. For example the US, particularly NSF funding which tops the list when we look at the top funding agencies and grant amounts for our publication dataset (S1 Table) and that has a particularly high output of papers associated with the topic Science_Research (Fig 10). However, whether this increased research investment, output and country focused evidence have led to increased climate action to mitigate climate change is difficult to infer. There is certainly evidence of individually or locally motivated actions [81, 82], but a detailed look at the Emission Gap report for the US and the UK concluded that they are unlikely to meet many of their nationally determined contributions (NDC) targets [83]. For the rich climate education research exposed here to have a stronger resonance at national and global level, it is essential for influential assessment reports, such as those produced by the IPCC, to assess the critical role of climate education in both adaptation and mitigation action, since these reports feed directly into policy making process by informing on policy relevant science [84]. The inclusion of a dedicated chapter, sub-chapter, or cross-chapter box on climate literacy would be timely and beneficial as work on the 7th assessment cycle commences.

There are some limitations in the approach used here. First, the mapping of the literature did not allow to more deeply explore some themes that emerged in the analysis, for example why certain countries are more prevalent than others or why certain topics are closer to each other. Secondly, the classification algorithm, although it performs very well, still miss-classifies a small percentage of the papers. This is a recurrent limitation when doing reviews in big data fashion, and a topic that has already been highlighted in previous research [37–39]. In the context of extracting semantic information from the body of scientific literature, it is worth mentioning that topic modeling does not generate one-hot encodings. This means that although we assign each paper to its most prominently activated topic, papers could, in reality, be represented as amalgamations of multiple topics. With that being said, topic modeling remains a valuable tool for the purpose of content classification, relying on the inherent semantic

structure uncovered within the corpus. By leveraging the probabilistic distribution of topics within documents, it enabled us to discern underlying themes and categorize content according to their predominant topical associations. This method provides a nuanced and datadriven approach to organizing and classifying diverse textual information, enhancing our ability to identify patterns and uncover themes and their potential association from a large corpus.

In order to better assess our progress or impact on climate education on real action or policy outcomes, further studies would need to broaden the data scope used here. This could include other relevant literature, in addition to only research papers (as mentioned above), as well as other relevant datasets to better assess more specific questions related to climate change education outcomes. For example, a recent study [85] highlights global data availability (and gaps) that are needed to properly monitor our progress towards the Sustainable Development Goals (SDGs), including goals on *Climate Action* and *Education*. Using the SDG Monitor tool [86], we see that these goals, in terms of data availability for the period 2010—2023 for 193 UN Member States, reveal *Climate Action* to be ranked 16 (out of 17 goals, i.e., second to last) and *Education* ranked 12 (with *Energy* and *Health* ranked first and second, respectively). A mapping of the country level availability however reveals that developing countries tend to have higher data availability for the *Climate Action* and *Education* goals. This highlights data gaps and availability elsewhere, in addition to the research literature scope used here, which could complement further analysis, allowing more specific research questions and outcomes to be addressed.

In terms of methodology, the integration of machine learning and AI supported screening methods in the analysis of the rapidly expanding body of literature on climate change and education can significantly enhance research efficiency and resource allocation. As noted by van de Schoot et al. [87], these AI methodologies streamline the literature review process, allowing researchers to focus on synthesizing findings rather than spending excessive time on manual screening [88]. This capability is particularly crucial given the increasing volume of publications, where timely access to relevant studies can inform policy and educational practices. Moreover, the development of "living evidence synthesis platforms," as discussed by Sietsma et al. [89] would facilitate the continuous incorporation of newly published research into existing assessments. To this end, our database of abstracts, semantics and topic classification can serve as valuable resources for researchers and practitioners interested in climate education evidence synthesis. However, the use of AI in this context needs to be carefully evaluated since large language models carry the risk of providing outdated and misleading information. To this end, expert knowledge combined with machine capability, as we have proposed in this study, is essential to ensure reliable results [90].

Conclusions

This research provides a global mapping of climate change education literature which combines supervised and unsupervised machine learning methods assisted by human coding of the abstracts. We manually annotated 1776 papers from a corpus of over 18'000 papers obtained from the Dimensions and Web of Science database. Using supervised learning we selected more than 6000 relevant records spanning the past fifteen years, which we then analysed using text mining techniques such as semantic analysis, topic modeling, text summarisation and geoparsing [37–39, 44]. Our study reveals that climate change education is an interdisciplinary field of research embedded in key climate research topics such as climate change adaptation, disaster risks and education, mitigation and sustainability. In summary, we find that the bulk of the literature falls within three main topics that deal with 1) student and learning methods, 2) sustainability and learning/teaching for sustainable development, and 3) the pivotal role of education in adaptation and resilience. Furthermore other themes which are also important include promoting environmental conscious behaviours through education, the importance of transformative education and critical thinking in driving collective impact, youth engagement and the role of children/young people as agents of change. The role of teacher in promoting literacy and awareness is also highlighted. Topics which are also present are relatively smaller are the importance of education and training in disaster management and for climate change mitigation and gamification as vehicles to increase knowledge and awareness. The geographical distributions shows that English speaking countries produce the largest share of the research literature when it comes to case studies or country mentions. This could be an interesting topic to investigate further in order to guide policy, by looking more closely at the share of research funds for climate change education across the globe as well addressing data deficiencies to complement understanding of climate education outcomes.

Based on our results, we call for a key role for climate education as a crucial lever for climate action through its potential to enhancing knowledge, fostering engagement and promoting resilience. We anticipate that the research performed here will not only inspire the broader research community, as evidenced by previous works on big literature [91, 92], but will also lead to recognising the importance of incorporating climate education into synthesis and assessment research relevant to policy making. Last but not least, innovative educational practices across various levels of society should be made essential for cultivating a proactive and informed society capable of addressing the pressing challenges posed by climate change.

Supporting information

S1 File. PRISMA workflow adapted. The file shows the adapted PRISMA workflow that was used for mapping the literature on climate education. (DOCX)

S2 File. PRISMA ScR checklist. The file shows the PRISMA checklist according to [93]. (DOC)

S1 Fig. Paper split. The barplot shows the split between relevant and irrelevant papers from the total collection of papers. (EPS)

S2 Fig. Publications per year 1966–2023. Publications per year for the entire period from 1966—2023 (July 2023). (EPS)

S3 Fig. Word frequency bar plots for two time slices. Left panel shows a bar plot of the frequency of the first most frequent 100 words and word pairs between 1990–2010. Right panel shows a bar plot of the frequency of the first 100 words/word pairs between 2011–2023. (EPS)

S4 Fig. Word frequency word clouds for two time slices. Left panel shows a word cloud of the frequency of the first most frequent 500 words and word pairs between 1990–2010. Right panel shows a word cloud of the frequency of the first 500 words/word pairs between 2011–2023.

(EPS)

S5 Fig. Proportion of countries tagged in the abstracts. The figure shows the proportion of papers mentioning a given country out of the total of the papers mentioning any country. The

total of the paper mentioning a country or more in its abstract is 2261. (EPS)

S1 Table. The top funding agencies per country and grant amounts. The table shows the top funding agencies per country with the total number of grants, and aggregated funding amount for our publication dataset obtained with our search from the Dimensions API 2. Only funding amounts over 10 Million are shown (for the top 40 organizations). (TIFF)

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ARTICLES FOR UTM SENATE MEMBERS

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3) Climate justice The contribution of higher education institutions (2025)

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Research

Climate justice: The contribution of higher education institutions

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Abstract

The concept of climate justice extends traditional environmentalism by emphasizing the social dimensions of environmental issues. Recently, it has gained much attention due to the growing impacts of climate change, especially on vulnerable communities that contribute minimally to global emissions. Based on the need for research in this field, this paper reports on a study that examined how higher education institutions (HEIs) are integrating climate justice into education, based on a literature review and a set of case studies. These cases highlight actions undertaken by various HEIs to incorporate climate justice into education across the globe. Based on the increasing number of publications, the findings show a growing research interest in the topic and reveal that some countries such as the US, the UK, China, Australia, and Germany have a visible presence in the literature. It also provides a wide range of perspectives on educational practices in climate justice, including real-world examples of courses implemented in HEIs. The findings reveal that HEIs have significant potential to address climate justice in their educational programs, which may help to transform students' values and actions despite challenges.

Keywords Climate change · Climate justice · Education · Higher education institution · Sustainability · Sustainable development

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Fig. 1 Some drivers and tools to address climate injustice Source: The authors



1 Introduction

The term 'climate justice' integrates environmental conservation with human rights and social justice. It views manmade climate change as not only an environmental problem and technical challenge but also a political and ethical issue linked to equality, human rights, and social justice [1]. As an example of the appropriateness of this concept, countries and groups most affected by the consequences of global warming such as people in developing countries, particularly indigenous communities, women, and children, are often the least responsible for causing it [2, 3].

Climate justice endeavors to distribute the burdens and opportunities of climate change fairly across the globe. It acknowledges that industrialized nations have historically contributed the most to climate change and therefore have a greater responsibility for mitigating its effects [4]. The main perpetrators of climate change, industrialized countries and some emerging economies, not only need to drastically reduce their greenhouse gas emissions but also assist developing countries in coping with climate change impacts [5] and making the transition to a climate-neutral, sustainable economy and way of life [6].

Climate justice also intersects with other forms of social justice such as racial, economic, and gender justice, recognizing that climate impacts are worsened for people facing discrimination [7]. Other features of climate justice are as follows:

- 1. It advocates for sustainable development (SD) that satisfies the needs of the present without sacrificing the ability of future generations to meet their own needs.
- 2. It calls for action at all levels, from local community initiatives to international agreements, recognizing that global cooperation is essential.
- 3. It emphasizes the importance of involving all stakeholders, especially those most affected, in decision-making processes concerning climate change.

Implementing climate justice is a process characterized by significant barriers. Firstly, economic and political interests, particularly from fossil fuel-based industries, often resist policies that would reduce emissions but harm profits [8, 9]. Secondly, developing countries claim that they should not bear the same burden for decreasing emissions as developed countries, which have historically contributed more to climate change [3]. This creates a challenge in reaching global agreements that are perceived as fair by all parties [10]. Additionally, varying levels of awareness and attitudes across communities towards climate change make collective action or changes in lifestyle challenging [11]. Furthermore, climate justice requires integrating environmental policies with other social and economic policies [12], which can be complex and require coordination across multiple sectors and levels of government.

Addressing these barriers requires coordinated efforts at the local, national, and international levels, involving governments, businesses, non-governmental organizations, and communities [1, 13]. As shown in Fig. 1, governments

and organizations have the capacity to address climate injustice. Governments have authoritative and regulatory powers to implement specific actions and controls, whereas the latter can independently develop their social advocacy and community service to contribute to climate justice. As their social functions differ, each has different drivers and can use different tools to address climate injustice. Governments have more power to sanction practices that promote climate justice, but their inertia is, in fact, a driver of climate injustice, giving organizations the opportunity to engage with funding agencies to address inequalities derived from climate change.

Climate justice and education form a multifaceted nexus within the sustainability discourse, emphasizing the role of equitable education implementation in addressing global climate and environmental challenges. Education provides citizens and communities with the knowledge, skills, and awareness necessary to empower them to adopt a more equitable approach to climate action [14].

There is a perceived need for research on the topic of climate justice and its implementation in education. Against this background, this study aims to examine the extent to which climate justice is implemented by higher education institutions (HEIs) and to explore their practices in climate justice education. The findings inform and inspire HEIs to enhance their contributions to climate justice education. The specific research questions are as follows:

- 1. How is the theme "climate justice" discussed in the literature focusing on higher education?
- 2. What are the practices, including real-world examples, showcasing how climate justice is implemented into education at HEIs?

To address the research questions, this paper is structured as follows: Sect. 2 identifies the connections between climate justice and education; Sect. 3 outlines the study's methods; Sect. 4 presents the results, followed by the discussion in Sect. 5; and Sect. 6 draws the main conclusions.

2 Climate justice and education

Education can play a key role in situating human rights and social equity at the center of climate action [15, 16]. It can highlight how marginalized communities—those with less political, economic, or social power—are disproportionately affected by climate change. When people understand these intersections, they are more likely to support policies that promote justice and equity in climate responses. In this context, there is an urgent need to inform individuals about the causes and consequences of climate change, since these cannot be separated from issues of poverty, race, and global inequality. Table 1 presents the main connections between climate justice and education.

One of the significant advantages of teaching climate justice through education is that it is based on critical thinking, with an emphasis on participatory learning, leading to the development of civic competencies that enable individuals to understand the complex relationship between climate change and social justice [17]. This understanding is essential to develop the agency that motivates people to contribute to climate solutions [18]. It is a call to the deepest goal of education: a transformative process to change societies.

Climate justice component	Relevance to education
Empowerment	By equipping people with knowledge about climate change, education empowers them to make informed decisions and take action
Awareness and understanding	Education plays a critical role in enhancing awareness and understanding of climate justice and its importance
Influence on policies	Educated populations are more likely to advocate for strong climate policies
The capacity to adapt	Education systems can integrate climate justice into curricula, not only teaching about the problem but also offering practical skills for fostering it
Global and local perspectives	Education can foster a dual perspective: understanding global issues and their local implications
Fairness to future generations	By integrating climate justice into educational systems, future generations become better prepared to deal with the challenges of climate change

Table 1 Main connections between climate justice and education

Source: The authors



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Fig. 2 Number of publications on climate change and climate justice (2020–2023). Source: The authors



However, this approach often faces resistance due to the economic implications of the required actions and ideological concerns, or even skepticism regarding the scientific consensus on climate change. As such, the incorporation of climate justice into educational curricula requires a balanced interdisciplinary approach that combines science, social research, and ethics [19]. Its implementation is more effective through experiential project-based learning as it can facilitate a deeper understanding of the socio-economic dimension of environmental sustainability [20]. It also involves the development of scientific and socio-cultural educational materials that can compensate for the previously mentioned resistance [21].

Recent empirical studies have shown how educational institutions contribute to a more equitable understanding of climate issues [22]. The new curriculum designs based on climate justice principles offer students a better, more holistic understanding of climate change and its social antecedents and consequences [23]. New challenges of climate justice education are twofold: first is the need to increase teachers' knowledge and skills to effectively deliver climate justice education [20], and second is the need to elevate public policy sensitivity to promote the incorporation of environmental culture and values into educational settings to foster climate justice [24].

3 Methods

In order to ensure the robustness of the study, two methods were deployed. The first was an assessment of the latest literature concerning climate change and climate justice in higher education using a bibliometric analysis aimed at identifying and listing some of the key literature on the topic. It entails a compilation of citations to identify the impact of various categories on the topic, including the subject matters, periodicals where the papers were published, authors' home base, and a set of keywords. Although there are various databases from which the information could be gathered, the authors selected Scopus due to its comprehensive coverage of peer-reviewed publications.

As a first step, search strings were identified, which entailed relavent terms and the Boolean operators "AND" and "OR." The terms used for the investigation were: ("climate chang*" OR "climate justice") AND ("higher education" OR "universit*"). A total of 8,833 papers were initially chosen with the options of "article title, abstract, and keywords" and all types of papers. In the next phase, the publication years were limited to the period of 2020–2023 to assess

Table 2Five major journalsbased on the number ofpublished papers (2020–2023)

Journal title	Number of publica	tions Citations	Impact factor (2022)
Sustainability	113	656	3.9
International Journal of Sustainability in Higher Education	25	92	3.1
International Journal of Environmental Research and Public Health	22	104	3.2
Journal of Cleaner Production	15	209	11.1
Environmental Education Research	13	61	3.2

Source: The authors



the latest publications on the topic, which returned 2826 documents. In the next step, only peer-reviewed articles were considered, resulting in 1803 papers. Using "English" as the final criterion for selection, the sample included 1662 publications. The search was conducted on December 15, 2023. As a further step, the data was analyzed based on the number of publications by year, per journal, country, and subjects. Finally, a co-occurrence analysis of the keywords was carried out to identify the frequently used keywords on the topic with the support of VOSviewer software (version 1.6.20). This analysis examines the proximity between two or more terms within a text unit, enabling the identification of key research topics. Terms that frequently appear near one another are likely to be related and form thematic clusters based on their co-occurrence patterns (see [25]).

The second method used to complement the bibliometric analysis was an in-depth look at case studies, which provided examples of specific educational practices in climate justice. Conducted on December 18, 2023, a search for papers in the English language using the search string ("climate chang*" OR "climate justice") AND ("higher education" OR "universit*") AND ("case stud*") yielded 148 results for 2020–2023. Then, 11 journal articles that seemed most suitable for this study were selected. The authors initially planned to select twenty real-world examples of courses/ workshops on climate justice offered at HEIs worldwide; however, they could find only seven of them. Therefore, four additional case studies focused on learning through participatory action research were added to the seven case studies. The details of the eleven papers are illustrated in Table 3 in the following 4.2. Analysis of selected case studies section. All of these case studies that provide real-world examples of initiatives to foster the learning about climate justice at universities, increased the qualitative depth of the research. For the analysis of these case studies, the authors focused on the learning objectives, discipline(s), course content, pedagogical approaches, and outcomes of the courses and workshops under study.

4 Results

4.1 Bibliometric analysis

As seen in Fig. 2, over the period of 2020–2023 there was a noticeable increase in the number of papers published concerning climate change and climate justice. This attests the increased focus on the topic as part of university research. The most recent one year from 2022 to 2023 saw the increase from 442 publications (2022) to 504 publications (2023).

The data analysis reveals that the papers have been published in 160 different periodicals. It is noticeable that a set of five outlets are leading the conversation, particularly *Sustainability* with 113 papers and 656 citations and the *International Journal of Sustainability in Higher Education* with 25 papers and 92 citations (see Table 2 below).

As for the countries, Fig. 3 showcases that authors from the US (with 396 papers) are most widely present in the literature, followed by the UK (164 papers), China (145 papers), Australia (127 papers), and Germany (108 papers).

Concerning the subject areas, Fig. 4 shows that most of the publications are from the *Social Sciences* (680), *Environmental Science* (607), *Agricultural and Biological Sciences* (286), *Energy* (237), and *Earth and Planetary Sciences* (209).

As shown in Fig. 5, the result of the term co-occurrence analyis reveals five thematic clusters, with the red and green clusters being more developed, while others receive less attention. The red cluster includes keywords such as "food system," "indigenous knowledge," "climate justice," "energy," and "environmental education." The importance of indigenous knowledge in new university programs is also emphasized, promoting multidisciplinary approaches [26]. Notable examples include project-based learning initiatives such as the Isalab Workshop in Valencia [27] and water management training programs in India [28].

Key aspects of a research-society interaction involve citizen science and co-creation. Examples include ocean temperature measurements related to seismological activity in Australia [29] and rainwater harvesting in Arizona [30]. Co-creation extends to university design projects, like the University of Denver's Center for a Regenerative Future [31]. These initiatives aim to promote climate justice while addressing students' expectations [32], including capitalism's influence [33] and degrowth approaches [31]. Campuses as living labs and experimental arenas is also emphasized to propose innovative solutions and raise awareness about food security and sovereignty inequities [34].

The blue cluster connects education, climate change, environmental awareness, science communication, and health. Innovative educational approaches are emerging to address pressing environmental challenges [35]. Notable initiatives include the Evolution of Land Plants Garden at University College Dublin, serving as a living outdoor classroom to enhance students' understanding of plant evolution. Simultaneously, attention is growing toward the





Country	N	Country	N	Country	N	Country	N	Country	N
United States	396	Pakistan	48	Austria	30	Czech Republic	21	Colombia	14
United Kingdom	164	South Africa	43	Finland	30	Nigeria	21	Denmark	14
China	145	Turkey	43	Poland	26	Thailand	21	Chile	13
Australia	127	France	40	Saudi Arabia	26	Mexico	20	Ireland	13
Germany	108	Netherlands	37	Iran	24	Belgium	19	Kenya	13
Spain	96	Indonesia	36	Norway	24	New Zealand	19	Ghana	12
Canada	88	Portugal	33	South Korea	24	Greece	17	Jordan	10
Italy	84	Switzerland	33	Sweden	24	Taiwan	16	Romania	10
India	68	Japan	31	Russian Federation	22	Egypt	15	Slovakia	10
Brazil	50	Malaysia	31	Bangladesh	21	Viet Nam	15	United Arab Emirates	10

Fig. 3 Publications by countries on climate change and climate justice in higher education (2020–2023). * N refers to the number of publications. The countries with less than 10 publications are not included in this table. Source: The authors

intersection of biodiversity and health within educational settings worldwide [36], particularly in fields like public health, veterinary sciences, and medicine, though more integration and interdisciplinary collaboration are needed [37]. Moreover, studies among HEI students in universities of Canada and China shed light on their perceptions and behaviors regarding environmental issues [38, 39].

Fig. 4 Publications on climate change and climate justice in higher education by subject. Source: The authors



The yellow cluster explores the connection between health and sustainability in higher education. Initiatives like New York University's Environmental Health in a Global World [40] exemplify participatory learning, emphasizing



outdoor thermal comfort

Fig. 5 The result of the term co-occurrence analysis. Source: The authors



interdisciplinary perspectives and empowering students to address diverse environmental challenges.

Nursing education programs have successfully integrated environmental health content, impacting students' education and policy engagement [41]. However, medical education still lags in addressing climate change's health impacts [42]. Furthermore, while incorporating biodiversity in health education underscores the need for collaboration across disciplines [36]. Student-driven initiatives like the Planetary Health Task Force at Brown University demonstrate successful integration strategies [43].

The purple cluster emphasizes disaster risk reduction (DRR), resilience, and climate change adaptation (CCA). The causal relationship between climate change and disaster risk has been assessed and determined by considering exposure, vulnerability, and the resilience of a population to prepare for, respond to, and recover from its consequences [44]. Chandra et al. [45] articulate that despite the existence of CCA and DRR policies, there may be inadequacies in addressing non-economic loss and damage, stemming from areas including a lack of knowledge. To illustrate the significance of education in DRR practices, a community-based DRR program in Ottawa led by young individuals has developed DRR training modules designed to assist educators [46].

The development of local climate resilience strategies is imperative within communities [47], and climate change education serves as a pivotal instrument in bolstering their resilience [48]. Nature-based solutions (NbSs) are essential for reducing and adapting to the effects of climate change [49], which makes them essential to be incorporated into higher education [50] and campus management.

The green cluster covers SD, carbon footprint, GHG emissions, university campuses, energy efficiency, environmental impacts, and teaching. The escalating impact of global challenges such as climate change and population growth underscores the significance of the United Nations' (UN) 17 SDGs in fostering future peace and prosperity, with education emerging as a central catalyst for achieving these goals, though more attention is needed [51]. For instance, certain HEIs in Spain and Italy are actively promoting sustainability awareness among students and researchers through the implementation of environmental policies on university campuses [52].

Furthermore, there is a growing recognition for HEIs to play a more proactive role in addressing the UN SDGs [53], cultivating sustainability-aware designers [54] and engaging stakeholders. As such, HEIs must collaborate with regional actors to address societal challenges such as energy efficiency and climate change [55].

On the other hand, the carbon footprint resulting from university activities significantly contributes to climate change, presenting a notable challenge for SD due to the complexity of monitoring and evaluation tools for sustainability within universities [56]. However, various studies (e.g., Sun et al. [57]) highlight universities' efforts to quantify and mitigate their carbon footprint through practices such as aligning academic calendars with holidays [58].

In general, the analysis reveals that universities have a central role as agents of change in the face of global challenges by integrating sustainability, education, and climate action in their activities. Through higher education, innovative approaches that combine theory and practice are promoted, fostering connections between local contexts and global issues. Initiatives such as project-based learning, the inclusion of indigenous knowledge and the implementation of nature-based solutions are prominent examples of how institutions are moving towards more sustainable and transformative models. A cross-cutting aspect is the active participation of communities and other stakeholders through co-creation and citizen science. These practices strengthen the link between universities and society, enriching both learning and social impact. Climate justice and local resilience emerge as key priorities, highlighting the need for strategies that address structural inequities while adapting to ecological and social dynamics. In this sense, universities are called to lead with inclusive, transdisciplinary approaches that integrate diverse perspectives and foster contextualized solutions.

In addition, university campuses are consolidating as experimental spaces for sustainability. Their transformation into living laboratories allows for testing and scaling innovative solutions, such as carbon footprint reduction and environmental policy advocacy. However, challenges related to sustainability measurement and management persist, underscoring the need for more effective tools and broader collaborations. In education, the adoption of multidisciplinary pedagogical approaches is essential to prepare future generations for complex challenges. From environmental health to biodiversity, educational programs are evolving to integrate diverse knowledge and encourage action. However, areas such as medical education require greater attention to fully incorporate climate change impacts into their curricula.

Table 3 Selected case studies on research on climate justice in education

Case	Paper title	Focus	Reference
-	Broad spectrum integration of climate change in health science curricula	Advocates for the importance of the connection between the physical scientific basis of climate change and the aspects of vulnerability, adaptation, and mitigation concerning health impacts	[59]
5	Teaching about climate change impacts on health: Capturing the experience for educators	Explains how public health is not a discipline but is informed by an integration of thinking from a range of disciplines and perspectives	[09]
ŝ	Improving the capacity and diversity of local public health workforce to address climate impacts to health through community partnerships and problem-based learning	Emphasizes the importance of incorporating climate- and health-related content into courses that include social determinants of health, health communication, or epidemiological methods using problem-based learning	[61]
4	Planetary health pedagogy: Preparing health promoters for 21st-century environmental challenges	Offers the design and use of a resource and postgraduate micro-credential	[62]
2	The affective dimension of crisis subjects: Teaching environmental communication through intersecting crises	Investigates the affective implications of climate change, pedagogical approaches for the development of students'sense of agency, and strategies to empower students in their future roles	[63]
9	Environmental justice pedagogies and self-efficacy for climate action	Examines how employing social justice pedagogies in an environmental justice course supports college students' self-efficacy in combating climate change	[64]
7	Beyond colonial futurities in climate education	Offers an outline for climate education that enhances students' sense of social and ecological responsibility	[99]
ø	Data-driven and research-based learning approaches to environmental education in university contexts: Two case studies in Italy and Germany	Reports research-based learning strategies on environmental communication for environmental education	[67]
6	Community-based climate action planning as an act of advocacy: a case study of liberal arts education in a rural community	Examines community-based research involving university students trained in climate action planning	[68]
10	Building university capabilities to respond to climate change through participatory action research: Towards a comparative analytical framework	Explores initiatives from universities in Brazil, Kenya, and Fiji to address climate challenges through participatory action research	[69]
11	Creating meeting grounds for transdisciplinary climate research: the role of humanities and social sciences in grand challenges	Introduces a participatory research program that fosters collaboration across diverse disciplines to tackle the climate crisis	[02]



4.2 Case studies

In this section, we present and discuss a set of eleven papers concerning research on climate justice in education published in peer-reviewed journals (Table 3). They are divided into two groups: the first group includes case studies of either courses/workshops offered at HEIs on climate justice (#1–7) while the second group discusses learning through participatory action research (#8–11).

From an international perspective, a wide range of courses and workshops link climate change and climate justice to health and health education. Ogunseitan et al. [59] emphasizes the importance of connecting the physical science of climate change with vulnerability, mitigation, and adaptation concerning health impacts. For example, workshops were developed in the College of Health Sciences at the University of California—Irvine to foster learning about sustainability, barriers to incorporating new competencies into courses to train professionals, and theoretical models of curriculum integration. Strategies for implementing modules and case studies on climate change contents into the relevant curricula were discussed. One year later, participants presented how they had transformed their courses, discussed best practices, and shared specific difficulties.

It is important for public health to be guided by integrative thinking from various perspectives and disciplines. Lansbury et al. [60] stress the urgent need for indigenous knowledge in new university programs. The public health course "Exploring Wicked Problems in Health" illustrates how integrated thinking from various disciplines can illuminate public health issues. A course survey revealed strong correlations between interest and curiosity for learning and voluntary motivation to act, underscoring the importance of fostering students' intrinsic motivation.

The transformation of students' values and actions requires the effective integration of climate-health topics into curricula. Schmeltz et al. [61] highlight problem-based learning pedagogy employed by undergraduate students in the Department of Public Health at California State University at East Bay to address climate change impacts on local government organizations and communities. The outcome reveals mutual benefits, including increased knowledge and better responses to climate change in local communities. Similarly, Capetola et al. [62] present the postgraduate six-week course "Promoting human and planetary health" at Deakin University in Australia, designed to comprehend global and local challenges and facilitate the acquisition of knowledge and skills for planning co-benefits for both planetary and population health.

There has been a tendency for educators in climate and environmental change to focus on the urgency and scale of the crisis without considering its affective consequences. Thus, there is a need to investigate the affective implications of the content and instructional methods, the pedagogical approaches for student development of a sense of agency, and the strategies and practical tools to empower students. Leimbach et al. [63] present a case study of an undergraduate elective offered in the University of Technology Sydney's School of Communication in Australia that exposed students to climate and ecological crises. The pedagogical approach requires deconstructing power structures and encouraging new ways of viewing the world. Similarly, Bartlett et al. [64] examine how a pedagogical approach to social justice in a climate justice course increases self-efficacy in college students for tackling climate change. The online course at the University of Michigan used case studies, historical references, media, and presentations from activists in the local community to explore the connections between social justice and the environment. Students found that the course contributed to their sense of self-efficacy for climate solutions, indicating that educating from a justice perspective enhanced their comprehension of fundamental causes, empathy for others, and the need for collective action. They mentioned other studies (e.g., Cordero et al. [65]) revealing that students' voluntary engagement in climate action was low or non-existent even after taking science courses that covered climate change concepts, mitigations, and consequences. Thus, if the purpose of education on climate solutions is to prepare students to take true leadership in climate action, it is crucial to identify the reasons for the disconnect between learning and voluntary action.

Whereas various pedagogies that cover the climate and nature emergency propose solutions to a desired future, Stein et al. [66] offer an outline for climate education that enhances students' sense of environmental and social responsibility. They introduce "Facing Human Wrongs," a licensed creative commons course designed to highlight the significant debt owed to people on the front lines of climate and nature emergencies, including indigenous communities. The course emphasizes the importance of reparations in responding to emergencies, with economic justice identified as one dimension of healing from ecological and social violence.

Two papers provide evidence for the effectiveness of pedagogical strategies focused on research and experience in fostering environmental awareness and climate action among university students. Marcella and Samofalova [67] applied Data Driven Learning (DDL) and Research Based Learning (RBL), while Community-Based Research (CBR) is discussed in

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[68]. A feedback questionnaire revealed that a significant percentage of students consider climate change an important discussion topic and intend to act more conscientiously toward it. CBR was also implemented in a collaborative climate action plan in Hamilton, New York, involving students from Colgate University as part of a working group alongside community members and other university actors, to mentor and train students through the environmental studies curriculum.

Nussey et al. [69] and Lieberknecht et al. [70] explore how universities can contribute to climate justice through participatory research, ultimately influencing student learning. The first study outlines some initiatives in Brazil, Kenya, and Fiji to integrate community knowledge into university policies and curriculum design. The second advocates for transdisciplinary spaces involving community stakeholders as well as students, teachers, and researchers to address the climate crisis and its effects on marginalized communities, using the initiative "Planet Texas 2050" at the University of Texas as an example.

These eleven papers illustrate educational practices and learning strategies developed by universities to address the topic of climate justice. Systematic literature reviews also examine the role of educational institutions in climate justice. Kinol et al. [71] highlight initiatives like The University of Vermont's mandatory sustainability course. Trott et al. [23] explore how educational practices in social sciences incorporate climate justice frameworks.

Several authors explore the integration of climate justice into education in general. Dunlop and Rushton [72] assess England's public strategy for climate change and sustainability education, finding that it prioritizes knowledge over action, lacks ethical considerations, and relies on extracurricular offerings rather than a mandatory curriculum. The strategy appeared to focus on superficial changes instead of fundamental ones, shifting the responsibility to teachers without adequate financial support. Meanwhile, Svarstad [73] promotes critical climate education to empower citizens with the knowledge and skills for responsible action. The Norwegian case study illustrates the consequences of climate mitigation decisions without considering climate justice across both time and space, underscoring the need for students to critically analyze such measures.



Fig. 6 Main issues related to climate justice in study programs. Source: The authors

5 Discussion

The aim of this study was to explore the extent to which universities have addressed climate justice education in recent years. A comprehensive bibliometric analysis was conducted to explore the relationships between climate justice, climate change and HEIs, revealing the key thematic areas. Subsequently, a detailed examination of case studies was undertaken to identify specific educational practices in climate justice at HEIs.

Both the bibliometric analysis and an in-depth look at case studies revealed that HEIs have a significant potential to address climate change and climate justice in their education, despite numerous challenges to facilitate a transformation of students' values and actions. Figure 6 summarizes the main issues related to the inclusion of climate justice as part of study programs. These elements collectively aim to foster an environment where HEIs can play a pivotal role in advancing climate justice by educating and empowering the next generation of leaders.

HEIs' proactive role in addressing the UN SDGs and balancing global economic development with the need to address climate change, has been increasingly recognized. To integrate environmental awareness and climate justice, HEIs have been using innovative approaches, expanding their academic boundaries. One example of this innovation is the establishment of co-curricular and interdisciplinary concentrations, such as the focus on planetary health in public health and medical programs that intertwine environmental considerations with regional health initiatives and explore the interconnectedness between biodiversity and human health. In fact, such an integration is increasingly recognized as vital for addressing global health challenges and preparing future healthcare professionals, emphasizing the role of HEIs in cultivating environmentally and socially responsible citizens.

The findings also highlight that viable curricular and pedagogical development is urgently required to integrate climate change and climate justice topics and competencies across the curriculum into core and elective courses by connecting the physical science of climate change to the aspects of vulnerability, adaptation, and mitigation. Examples include incorporating indigenous knowledge into new university programs, creating multidisciplinary and transdisciplinary programs/courses, employing a systems thinking approach, implementing micro-credentials, and providing experiential learning opportunities, such as problem-based learning. This echoes the literature review in an earlier section of this paper, emphasizing participatory learning to develop civic competencies that enable individuals to understand the complexity of the relationship between climate change and social justice. Some examples of pedagogical innovations focused on climate change and climate justice are presented in Table 4. These innovations not only educate students about the topics but also empower them to become active participants in addressing those global challenges. The findings also emphasize the importance of the affective aspects of education, including fostering students' intrinsic motivation and self-efficacy for climate solutions; thus, the emotional implications of the content and instructional methods should be carefully considered. It is also suggested that educating from a justice perspective increases students' comprehension of fundamental causes, empathy, and urgency for collective action as climate change is not only a technical or scientific problem but also a social, political, and ethical one, requiring a holistic and justice-oriented approach. Therefore, it is imperative to enhance students' sense of social and ecological responsibility to better prepare them with the motivation and affective, relational, and intellectual capacities to play a role in creating a more just world.

Moreover, participatory action research led by universities can help address environmental and climate change education challenges, considering the knowledge and needs of local vulnerable communities. This approach will significantly help to raise students' awareness about climate change, have a positive impact on the implementation of climate mitigation and resilience strategies, and thereby contribute to achieving long-term climate goals. While several studies highlight efforts made to achieve learning in climate justice through university initiatives and educational practices, some researchers point out shortcomings, such as cosmetic and superficial approaches and a lack of critical perspective in education overall.

6 Conclusions

As shown in the paper, education in climate justice can play an important role in equipping future decision-makers with the knowledge and skills to address interconnected environmental and social challenges. Through this research, the authors examined and documented the efforts of some HEIs to incorporate climate justice principles and content into their educational and operational frameworks. The findings suggest recognition among academic researchers and



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Table 4 Some examples of pe	dagogical innovations focused on climat change and climate justice	
Pedagogical innovation	Description	Example activity
Project-based learning	Engaging students in real-world projects that address climate issues in their community	Creating a community garden to promote biodiversity
Collaborative learning	Working in groups to discuss, research, and propose solutions for climate-related challenges	Debating in groups on local climate policies and their impacts
Experiential learning	Learning through direct experience, such as field trips or simulations that highlight climate issues	Visiting to a local recycling facility or a nature reserve
Interdisciplinary learning	Combining different subjects to explore climate justice from various perspectives (e.g., science, art, social studies)	Creating a multimedia presentation on climate change impacts
Service learning	Conducting projects that combine learning objectives with community service to address climate injustice	Partnering with local NGOs for local community initiatives
Technology integration	Utilizing digital tools and platforms to enhance learning about climate change and justice	Using apps to track carbon footprints and analyze data
Critical pedagogy	Encouraging students' critical thinking and discussions about the social justice aspects of climate change	Analyzing case studies of communities affected by climate change
Gamification	Utilizing game mechanics to teach about climate justice in an engaging way	Designing a role-playing game that simulates climate negotiations
Culturally relevant pedagogy Storytelling	Incorporating local cultures, histories, and practices in teaching climate justice Using narratives to explore personal and community experiences related to climate change	Students research Indigenous practices in sustainability Writing and sharing stories about local climate impacts
Source: The authors		

their institutions about the urgency of addressing the challenges of climate change and the complexities of coping with them. However, while climate change has been widely discussed in the literature–often with numerous examples of its implementation at universities around the world–explicit references to climate justice remain relatively scarce. This paper aims to contribute to filling the gap in the current literature.

A key aspect of integrating climate justice into academic curricula involves understanding the interrelation between environmental degradation and social inequality. For example, courses on ecological economics play a crucial role in this context by examining the trade-offs between economic growth, environmental preservation, and social equity. These courses may help students grasp the systemic nature of these issues and equip them with the tools to design policies that balance economic and ecological considerations, fostering a concerted global response. By encouraging critical analysis, participatory learning experiences, and the cultivation of civic skills, educational initiatives can empower learners to perceive climate change not just as an environmental issue but as a profound socio-ethical challenge requiring collective, informed action. The analysis of current educational methodologies within HEIs highlights emerging innovations and shows the need for a focus on balancing environmental and social responsibility. The results from this study illustrate some of the ways HEIs are incorporating awareness of environmental issues, their relationship with agriculture and food systems, indigenous perspectives, population health, and the SDGs as a general framework that underscore the need for climate justice.

This paper has several limitations. First, not all topics related to the theme could be covered because the bibliometric analysis focuses on the latest literature. This temporal limitation may have resulted in the exclusion of earlier foundational works that could provide additional historical context and insights. Additionally, a limited set of case studies was analyzed due to the lack of published real-world examples of courses on climate justice. As a result, the findings may not fully represent the diversity of teaching modalities used in climate justice education, potentially limiting the applicability of conclusions to different educational contexts. Restricted access to reliable data on climate initiatives in higher education also posed a challenge. The analysis was constrained by the availability of data, which may have led to an underrepresentation of initiatives from institutions that do not widely communicate their climate-related activities. Finally, given the wide range of perspectives on climate justice, this paper does not capture all possible viewpoints on the subject, with a potential exclusion, for example, of community-based educational initiatives that have a valuable impact on climate justice education.

The implications of this paper to theory and practice are as follows: first, the incorporation of climate justice into university programs appears to be an emerging trend that recognizes the importance of educating students about the intersection of environmental sustainability, social equity, and policy. Second, the paper provides a valuable addition to the literature by highlighting the current level of emphasis on climate justice in higher education. It identifies gaps in existing provisions and offers insights into areas requiring further attention. While visible efforts are being made by some universities to expand their curricula and research focus to address these interconnected issues, more comprehensive integration of sustainability learning across all disciplines could enhance this progress. Such an approach would help ensure that all students, regardless of their field of study, develop an understanding of the intersection between environmental sustainability and social justice.

There are several research needs on the topic that future studies could address. For instance, research is needed to explore how universities might offer interdisciplinary and cross-disciplinary courses that integrate aspects of environmental science, sociology, political science, and economics to study climate justice. Within this scope, courses on ecological economics are particularly relevant, as they provide critical insights into balancing economic development with environmental and social justice. Future research could evaluate how these courses could be optimized to address the unequal impacts of climate change and foster more equitable solutions. Further investigation is also required to determine how existing courses can examine topics such as the unequal impacts of climate change, ethical considerations in environmental policies, and strategies for community engagement and empowerment. Moreover, studies are needed on methods to encourage students to engage in activities that may cater to a better understanding of the impacts of climate change on vulnerable populations and to evaluate the effectiveness of policy interventions.

In summary, this research highlights the potential of participatory action and community involvement education, with HEIs playing a role in developing new curricula and training practices that foster values such as inclusivity, collaboration, and sustainable accountability. However, this educational transformation cannot solely be based on knowledge but also on embedding a deep acquisition of social and ecological responsibility. In the required social effort to lessen the effects of climate change, integrating climate justice into educational practices is both ethically significant and strategically valuable. Furthermore, it is crucial that discussions and actions relating to climate policy consider equity, granting a voice to those most affected by climate change and environmental degradation, particularly in vulnerable communities.

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Declarations

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RESEARCH



Promoting sustainable development via stakeholder engagement in higher education



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Abstract

Background Higher education institutions (HEI) are uniquely positioned to contribute to sustainable development through education, research, community engagement, and policy influence. In this context, stakeholder engagement is recognised as an important strategy, since involving diverse groups in decision-making processes, HEIs can harness a wealth of perspectives, expertise, and resources, fostering more inclusive, innovative, and effective approaches to sustainability. There is a perceived need for studies that explore the contribution of various stakeholders in higher education, and suggest ways to optimise their participation in processes. Against this background, this paper seeks to bridge the gap between theoretical frameworks of stakeholder engagement and practical applications within the context of sustainable development in higher education.

Results By examining 29 real-world case studies and best practices, this paper provides actionable insights and guidance for HEIs to enhance their sustainability efforts. Findings from the analysis of cases in Europe, Africa, Asia, and North and South America were consolidated into ten guidelines for HEIs seeking to promote sustainable development through stakeholder engagement. The analysis of trends identified three clusters: (i) HEI's role in sustainable development through stakeholder engagement and Sustainable Development Goals (SDGs); (ii) human-centred sustainability via transformative learning and community empowerment; and (iii) education and interdisciplinary approaches to sustainability.

Conclusions The nature of the work performed, and the scope of the activities of HEIs put them in a key position to drive sustainable development by engaging diverse stakeholders across academic and societal contexts, including students, faculty, administration, industry partners, and the broader community. Inclusive participation and interdisciplinary educational programmes that integrate sustainability across curricula are key to effective stakeholder engagement. In addition, institutional commitment, including strong leadership and strategic policies, is essential for advancing sustainability initiatives, while partnerships with local communities and industries amplify the practical impact of sustainability efforts while addressing real-world challenges.

Keywords Sustainable development, Stakeholder engagement, Stakeholder management, Higher education, Universities

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Introduction

Sustainable development is a multifaceted concept that demands the integration of economic growth, social equity, and environmental protection, ensuring that the needs of the present are met without compromising the ability of future generations to meet their own needs [73, 77, 80, 84].

The significance of sustainable development lies in its comprehensive approach to improving the quality of life for all people without increasing the use of natural resources beyond the capacity of the environment to supply them indefinitely [25]. It addresses the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace, and justice. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 SDGs, which are an urgent call for action by all countries in a global partnership [9, 61, 78].

The intricate balance between the three dimensions (social, environmental and economic) emphasises the complexity of achieving sustainability and underscores the critical need for the engagement of a wide range of stakeholders. This engagement is not just beneficial but necessary for fostering a shared vision of sustainability and for the practical implementation of solutions that are both effective and equitable [57].

Today, there is an extensive research stream on stakeholder theory, documenting the benefits of stakeholder engagement. A stakeholder is defined as any group or individual that can influence or be influenced by the achievement of the organisation's objectives [31]. Further specifying, Savage et al. [23, 67, 68].

Stakeholder engagement in HEIs has become an increasingly significant topic, as these institutions continually seek innovative approaches to interact with and involve both their internal and external stakeholders [20]. To date, there is a growing research stream that applies stakeholder analyses to HEIs, revealing complex findings and diverse applications [75] [20]. For example, [42, 43] highlight the significance of knowledge and information sharing, mutual trust, stakeholder involvement in decision-making, and interest alignment to strengthen relationships and create greater value between HEIs and their stakeholders. In this context, sustainability and its promotion have become particularly important topics in the interactions between HEIs and their internal and external stakeholders [20]. Stakeholder engagement serves as a key mechanism for driving sustainable development and aligning the interests of HEIs with broader societal goals. As universities move towards a more sustainable future and reshape their relationship with their stakeholders, a shift in perspective appears promising, placing HEIs at the centre of stakeholder engagement. This reshaping of relationships is not only crucial for fostering sustainability but also necessary to differentiate themselves from other HEIs, positively setting them apart and ensuring long-term success. This need for differentiation underscores the importance of reshaping stakeholder relationships, aligning them with sustainability goals. As a result of their critical role in education, research, and societal interaction, HEIs are uniquely positioned to engage stakeholders and act as catalysts for sustainable development, as highlighted by [20]. Figure 1 depicts a conceptual framework illustrating the role of HEIs in stakeholder engagement for sustainable development.

Key stakeholders in sustainable development include national governments, local authorities, the private sector, civil society, HEIs and the general public. Each group has a unique role to play and a vested interest in the sustainability of economic, social, and environmental systems, which can be described as follows:

- (a) National governments are responsible for creating policies that drive sustainable development. They can enact laws that protect the environment, support social equity, and foster economic growth that benefits all layers of society. These, in turn, are implemented by local governments, which oversee the steps needed to realise government policies [26, 39].
- (b) The private sector (businesses) contributes by adopting sustainable practices that reduce



Fig. 1 Framework for promoting sustainability through stakeholder engagement in HEIs. *Source* Authors' own creation

environmental impacts and by innovating new technologies and solutions for sustainable development challenges. Corporate social responsibility (CSR) initiatives can also support social and environmental goals [53, 65].

- (c) Civil society organisations (CSOs), including nongovernmental organisations (NGOs), community groups, play an important role crucial role in advocating for sustainability, educating the public, and holding other stakeholders accountable [1, 5, 70].
- (d) HEIs undertake research, foster education on sustainable development via teaching programmes and foster critical thinking on its processes [4, 71].
- (e) The general public influences sustainable development through consumer choices, political participation, and community involvement (i.e., active participation of local stakeholders in decision-making, planning, and implementation of sustainability initiatives). Public awareness and education on sustainability issues are essential for driving change from the bottom up [29, 58].

The need for such a broader stakeholder engagement is based on the fact that sustainable development challenges are complex and interrelated. Engaging a diverse group of stakeholders brings in a wide range of perspectives, knowledge, and expertise, leading to more innovative and effective solutions [84]. There is another, practical reason, for a broader stakeholder engagement: the responsibility for sustainable development does not lie with any single entity. By involving various stakeholders, a sense of shared responsibility and collective action may be promoted, which is more likely to result in significant and lasting changes [24, 28, 57].

Moreover, engaging stakeholders in the decisionmaking process increases the legitimacy of sustainability initiatives. It also ensures that different interests are considered, leading to greater buy-in and support from the community, which is critical for the successful implementation and longevity of sustainability projects [24, 57].

But to succeed, stakeholder engagement on sustainable development needs to be inclusive, transparent, and structured [12]. This involves a broader understanding of who the stakeholders are, their interests, and how they are affected by sustainable development initiatives is the first step in engaging them effectively. Also, it needs to be based on building partnerships and networks, creating platforms for collaboration among different stakeholders [57]. This can leverage resources, expertise, and influence, making sustainable development efforts more successful. Moreover, ensuring that all stakeholders have access to information and opportunities to participate in discussions and decision-making processes is important [24, 40]. Finally, to yield the expected benefits, there is a need to regularly assess the outcomes of stakeholder engagement and sustainability initiatives. This helps in learning and adapting strategies as needed. Providing feedback to stakeholders also keeps them informed and involved [15, 72].

The path to sustainable development is complex and challenging, requiring the collective effort of all segments of society [54]. The engagement of stakeholders is not just a strategic approach to achieving sustainability goals but a necessity for ensuring that the development is inclusive, equitable, and capable of meeting the needs of both present and future generations. Through collaborative efforts, open communication, and shared responsibilities, we can work towards a sustainable future that balances economic growth with social equity and environmental protection, ensuring a better planet for all [73, 80, 84].

Against this background, this paper aims to address the following key questions: How can theoretical frameworks of stakeholder engagement be translated into practical applications to advance sustainability in HEIs? How do HEIs engage stakeholders to drive sustainability initiatives through leadership, education, industry collaboration, and professional development? What strategies exemplify successful stakeholder engagement in driving sustainability within HEIs?

Background: sustainable development and stakeholder engagement in higher education

Stakeholders play a vital role in shaping a sustainability policy for HEIs that is both internally and externally supported, and integrated into all policies and vision statements [44, 45]. Beyond considering both internal and external stakeholders, it is essential to account for additional aspects and inputs [83].

To avoid common pitfalls such as fragmentation and lack of coordination among internal initiatives, addressing these issues from the outset is crucial. This proactive approach results in a more robust project, one that gains support from a variety of internal stakeholders across disciplines, facilitating smoother communication both internally and externally. Conducting a materiality analysis upfront is recommended to align the HEI's sustainability priorities with the goals of external stakeholders in the region. These external stakeholders should represent a range of disciplines (for a holistic vision) and include participants from the quadruple helix: HEIs, the community, government and regulatory bodies, and industrial partners [69].

Engaging external stakeholders more meaningfully ensures they are not only inspired by HEI projects,
but also feel motivated to support and follow them. Figure 1 illustrates how the initiative evolves from an internal concept to a project that incorporates input and interaction from external stakeholders.

As Geels [33] proposes and illustrated in Fig. 2, the transition in this case study starts with a small transition team, where individuals present ideas in various existing forums (Step 1). This leads to the formation of a change coalition (Step 2), which serves as a platform to consolidate and amplify innovation [69].

Within HEIs, it is critical to adopt a broad, interdisciplinary approach while involving diverse stakeholders. The change coalition should therefore comprise internal stakeholders with varied backgrounds and roles. This inclusivity fosters sustainability efforts across the institution, preventing fragmentation and maintaining internal support. Ensuring direct connection with the HEI's general director and top policymakers is also crucial. Introducing sustainability into policy frameworks (aligned with the 17 UN SDGs) (Fig. 2, Step 3) guarantees coherence and internal backing.

The HEI undergoes a paradigm shift from a traditional institution to one driven by the SDGs. In the next stage (Fig. 2, Step 4), external stakeholders are brought in to support the institution in meeting these objectives [30] [79]. Participants in the change projects integrate existing practices into the learning process, allowing these practices to adopt new, sustainable approaches and overcome barriers. As the transition progresses, the change team evolves into a broader change network, involving external partners [81]. This strategy results in a cohesive approach that not only sends a clear external message, but also fosters co-ownership and co-creation, essential values for a HEI. Moreover, it ensures sustainability is viewed not as a temporary trend, but as a long-term commitment.

There is also the direct route, where companies directly engage with HEIs in student challenges and project-based work placement. This brings the HEI into contact with another major stakeholder, the established professional. They were educated before the current emphasis on sustainability, and they may prove to be an obstacle to implementing change. How can the HEI influence them? Perhaps they can broaden their horizons to offer microcredentials, specifically geared towards sustainability. The focus by professional accreditation bodies has also seen changes implemented. While not fully co-creation, the ability to be agile and respond to stakeholder demand is evident [10, 22].

Stakeholder engagement could usefully be interpreted to mean exerting influence as broadly as possible. This can be through leadership in the operation of the HEI's themselves, by longer term influence based on educating students for sustainability, collaboration and innovation with industry. It could also include continued professional development opportunities for the practitioners and decision-makers in industry.

HEIs play a crucial role in fostering sustainability through their extensive networks, which encompass government agencies, private sector organisations, and other academic institutions. These connections facilitate collaboration on large-scale sustainability initiatives. Quist and Tukker [63] highlight that achieving sustainability necessitates a strong integration of innovation, learning, and cooperation among government, educational institutions, and financial stakeholders. To successfully embed sustainability in education, structured multi-stakeholder engagement is essential. HEIs provide an ideal environment for fostering such collaborations. International research projects can strengthen partnerships between HEIs and reinforce commitments to sustainable development. Moreover,



Fig. 2 Transition scheme. Source Authors' own creation

academic conferences and inter-institutional initiatives contribute to advancing Education for Sustainable Development (ESD) on a broader scale. Given their existing collaborations with the private sector and government through research activities, HEIs are wellpositioned to leverage and expand these relationships, thereby enhancing the effectiveness of sustainability initiatives in higher education [55].

Aung and Hallinger [7] examined the leadership practices that facilitate and promote sustainability within HEIs. Their findings categorise these practices into several key areas, including the development of a clear leadership vision, the transformation of campus facilities and operations to support sustainability objectives, the integration of sustainability principles into research and academic programmes, the cultivation of a sustainabilitydriven institutional culture, and the encouragement of active community engagement.

Sustainability leadership at all levels of a universityfrom the governing council to the student body-plays a crucial role in strengthening the institution's engagement with society [41]. This can be achieved through various strategies, including research and development, living labs, and service learning [52]. These approaches foster a two-way process of knowledge generation, where students and faculty collaboratively learn "with" and "through" the community. Such knowledge co-creation aligns with stakeholder theory, which emphasises the value of engaging external stakeholders in shared learning and decision-making processes [32]. Kantabutra [41] further argues that exchanging knowledge with stakeholders contributes to business continuity and corporate sustainability. In the context of higher education, leadership practices that promote knowledge-sharing and co-creation can drive community development and advance broader sustainability goals [7]. By actively promoting sustainability, universities not only enhance the quality of life within their communities, but also serve as role models and integral stakeholders in fostering pro-sustainability behaviours [37, 52].

Despite the growing body of research on stakeholder engagement in sustainability initiatives within HEIs, significant gaps remain in understanding its practical effectiveness and long-term impact. First, while existing studies emphasise the importance of involving internal and external stakeholders [44, 45, 83], there is limited empirical analysis on how stakeholder engagement translates into measurable sustainability outcomes within HEIs. Research often discusses engagement strategies at a conceptual level but lacks in-depth evaluation of the mechanisms that drive success or failure in real-world applications. Second, most studies focus on the role of HEIs as facilitators of sustainability transitions [33, 69] but do not critically assess how stakeholder dynamics evolve over time, particularly in response to institutional resistance, shifting priorities, and external influences such as policy changes or funding constraints.

Finally, while leadership and institutional commitment are frequently cited as key drivers of sustainability efforts [7, 41], research has not fully explored the interplay between top-down governance structures and grassroots stakeholder initiatives within HEIs. This gap limits our understanding of how institutional hierarchies and power dynamics shape stakeholder engagement in sustainability transitions.

Methods

Seeking to bridge the gap between theoretical frameworks of stakeholder engagement and practical applications within the context of sustainable development in higher education, this study employed a combination of systematic review and analysis of trends, alongside the introduction and examination of real-world case studies. These methods aimed to identify and present successful instances of stakeholder engagement in driving sustainability within HEIs. The following sections outline the detailed approach taken for each method and how the outcomes contribute to the overall study.

Systematic review approach and analysis of trends

A systematic review was conducted to collate and synthesise findings from existing studies that addressed the formulated research question: How do HEIs engage stakeholders in sustainability initiatives? This review followed explicit, systematic methods to ensure a comprehensive and unbiased synthesis of relevant literature.

The systematic review was structured around three core themes: (a) sustainability and related concepts; (b) stakeholder engagement; and (c) HEIs. A brainstorming session was initially conducted to generate relevant terms for each core theme (Table 1), followed by discussions to prioritise and reduce these terms.

Based on that, the final search string used was: (['sustainab*' OR 'responib*' OR 'conscious*' OR 'green' OR 'eco*' OR 'ethical' OR 'climate' OR 'SDG*'] AND ['stakeholder*' OR 'peer*' OR 'member*' OR 'engagement' OR 'participation'] AND ['HEI' OR 'high* education' OR 'universit*' OR 'student*' OR 'faculty' OR 'academic'].

The search was performed on the Scopus database, focusing on publications in English from January 2004 to April 2024, with the condition that the full text was

Tal	ble	e	1	Core	themes	and	re	lated	ke	yword	st
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Core theme	Keywords
Sustainability	Sustainability, Sustainable, responsibility, Responsible, Conscious, Consciousness, Fair, Green, Environment, Environmental, Resources, Eco-friendly, Renewable, Low-impact, Low-carbon, Ethical, Zero-waste, Low-waste, Carbon-neutral, Regenerative, Climate-friendly, Resource-efficient, Biodegradable, Energy-efficient, Clean, Eco-conscious, Eco-efficient, Nature-friendly, Planet-friendly, Earth-friendly, Earth-first, Ocean-friendly, Multi-generational, Global goals, Gender equality, Reduced inequalities, Good health, Well-being, Inclusive, SDG
Stakeholder	Stakeholders, Peers, Participants, Members, Partners, Collaborators, Colleagues, Community (engagement), Engagement, Participation, Collective action
Higher education institution	HEI, Higher education, Education, research, University, Teaching, Academic institutions, Applied science, Bachelor/undergraduate, Master/graduate, Student, Faculty, Critical thinking, Case, Case studies, Best practices

Source Authors' own creation

available. Initially, 479 documents were identified. After a rigorous screening process, following the PRISMA protocol, the following documents were excluded: 23 articles were not in English, 7 articles were not peerreviewed, 100 articles did not fit the context of our analysis in terms of content, 108 articles speak of "school" not HEI, 26 articles articulate the "wrong" meaning of sustainability (i.e., talk about "time-stable" nor sustainable in the sense of the SDG). Thus, the dataset was reduced to 215 relevant entries.

The 215 documents were analysed using VOSviewer software for bibliometric and trend analysis. This analysis was crucial for identifying key patterns, influential studies, and emerging themes within the literature on stakeholder engagement in HEI sustainability initiatives. Understanding these trends helped contextualise the case studies and provided a foundation for proposing actionable insights.

Selection and analysis of case studies

The selection of 29 case studies from the initial sample of 215 documents was guided by specific criteria to ensure relevance, depth, and alignment with the research objectives. First, studies were required to explicitly describe real-world stakeholder engagement initiatives within HEIs, detailing their implementation and outcomes. Second, selected cases needed to demonstrate a direct connection to sustainability, ensuring that stakeholder participation contributed meaningfully to sustainable development within the institution. Third, priority was given to cases that provided clear methodological descriptions, allowing for an in-depth understanding of the engagement process, involved actors, and contextual factors influencing success or challenges. Additionally, geographic diversity was considered to capture a broad range of institutional and cultural contexts. Lastly, studies that offered critical reflections, impact assessments, or discussions on best practices were favoured, ensuring that the selected cases provided not only descriptive accounts, but also analytical insights into stakeholder engagement strategies.

Thus, the selected case studies provided empirical evidence on how stakeholder collaboration is structured, the mechanisms used to drive sustainability, and the challenges and success factors identified in different institutional contexts. Moreover, the sample covered a diverse range of geographic regions, including institutions from Cameroon, South Africa, Zambia, China, Malaysia, Saudi Arabia, Indonesia, Jordan, Scotland, Portugal, Sweden, Italy, Spain, Hungary, Belgium, the United Kingdom, Poland, Turkey, Canada, the USA, Chile, and Brazil. This diverse sample ensured a comprehensive understanding of global practices and challenges.

Each case study was thoroughly analysed to identify key topics, effective practices, and challenges faced during the implementation of sustainability initiatives. Insights were derived from the experiences of universities across different continents, focusing on the strategies employed to engage various stakeholders such as students, faculty, administration, local communities, and businesses.

Case analysis is a vital component of this study as it provides practical, real-world examples of how theoretical frameworks of stakeholder engagement can be applied within the context of sustainable development in higher education. By examining these cases, the study highlights successful strategies, common challenges, and innovative practices that other institutions can adapt to enhance their sustainability efforts. This international perspective ensures that the proposed guidance and actionable insights are relevant and applicable across different cultural and institutional contexts.

Results and discussion

Analysis of trends

Key thematic areas were identified through the VOSviewer software's term co-occurrence analysis. As shown in Fig. 3, the node size reflects the frequency of occurrences, while the link width indicates the strength of connections. Closely related terms form distinct thematic clusters. The greater the likelihood of two terms co-occurring, the more likely they are to form a thematic cluster, which is represented by different colours in a network graph [79] (van Eck and Waltman 2011).

In examining the co-occurrence of keywords, three distinct clusters emerge, each represented by a different colour: green, blue, and red. The green cluster, which has the most connections, links higher education with sustainable development, encompassing terms such as engagement, stakeholders, student engagement, SDGs, and similarities. The red cluster focuses on the human aspect of the articles, including keywords like experiment, perception, psychology, work engagement, and schools. The blue cluster illustrates the connection between sustainability and various educational themes, incorporating terms such as students, education, learning, teaching, stakeholder, and community engagement.

This analysis underscores the critical role of HEIs in advancing sustainable development, represented by the green cluster. A growing trend within this cluster is the alignment of HEIs with the SDGs. The integration of SDGs into institutional strategies enhances HEIs' ability to drive sustainability across multiple sectors [16]. This connection highlights the increasing responsibility of HEIs in preparing students to incorporate sustainability into their careers and daily lives [44, 45]. Moreover, the strong presence of "stakeholder engagement" within this cluster suggests a shift towards more participatory approaches, where universities collaborate with external actors to co-develop sustainability solutions. This evolution indicates a growing emphasis on multistakeholder governance structures in higher education sustainability initiatives.

The red cluster reveals an intersection between sustainability and behavioural sciences, emphasising psychological and perceptual aspects of stakeholder



Fig. 3 Co-occurrence of the terms—VOSviewer output. Source Elaborated by the authors using VOSviewer

engagement. The prominence of terms such as "perception", "psychology", and "work engagement" suggests an increasing academic focus on understanding how individuals and groups internalise and respond to sustainability efforts within HEIs. Studies like Cottafava et al. [19] demonstrate that transformative learning and managerial skills play a crucial role in fostering engagement, reinforcing the idea that sustainability education is not merely about knowledge transfer but also about mindset shifts and behavioural change. This trend underscores the importance of addressing cognitive and emotional dimensions when designing stakeholder engagement strategies, as effective sustainability transitions require more than institutional policies-they necessitate changes in attitudes, motivation, and agency among stakeholders.

The blue cluster highlights the integration of sustainability into teaching and learning practices, reflecting the pedagogical dimension of stakeholder engagement. The presence of keywords such as "education", "learning", and "teaching" suggests an ongoing effort to embed sustainability into curricula and instructional methodologies. This trend is evident in studies like Vandaele and Stålhammar [82], which emphasise the need for interdisciplinary and transformative education models. By connecting sustainability with various social science disciplines, this cluster underscores the importance of critically examining institutions, structures, norms, and power dynamics to ensure effective education for sustainable development (ESD). Furthermore, the prominence of "community engagement" in this cluster signals an expansion of HEIs' educational missions beyond the classroom, incorporating experiential learning and real-world applications. This evolution points to a broader shift toward applied sustainability education, where students engage directly with societal challenges through problem-based learning, service-learning projects, and living labs.

By exploring these clusters in greater depth, it becomes evident that stakeholder engagement in higher education is evolving in multiple directions. The green cluster highlights a macro-level institutional shift toward integrating sustainability into governance and strategy. The red cluster points to the need for behavioural and psychological insights to enhance engagement effectiveness. The blue cluster underscores the role of pedagogical innovation in fostering a sustainability-oriented mindset among students and faculty. Together, these trends reflect a multidimensional approach to sustainability in HEIs, illustrating both opportunities and challenges in aligning institutional structures, individual behaviours, and educational practices toward a more comprehensive and impactful stakeholder engagement strategy.

Analysis of cases

Based on the analysis of the sample, 29 real cases were selected, including examples from Africa, Asia, Europe, North America and South America. Table 2 shows the key information about the cases selected.

The analysis of cases focused on identifying effective practices to promote sustainable development via stakeholder engagement in higher education. In this study, "effectiveness" refers to the success of stakeholder engagement actions, as evidenced by the implementation of the analysed cases. Rather than focusing on metrics or other evaluative approaches to measure effectiveness, this study aims to elucidate the practices themselves, emphasising how stakeholder engagement contributed to the realisation of sustainability initiatives within HEIs. Therefore, the analysis is grounded in real cases and the concrete execution of these initiatives, demonstrating the role of stakeholder engagement in fostering sustainable transformations in HEIs.

Insights from African universities

The cases from Cameroon, South Africa, and Zambia illustrate that sustainable development in African contexts is closely linked to effective stakeholder engagement. Key themes emerge from these examples:

- Mutual trust and collaborative frameworks: Building mutual trust between universities and local communities is crucial for successful engagement. Collaborative frameworks that involve community members in the decisionmaking process foster a sense of ownership and commitment to the projects.
- Relevance and local context: Ensuring that academic endeavours are relevant to the local context enhances the impact of university initiatives. Engaging local voices and Indigenous knowledge ensures that the solutions developed are culturally appropriate and address specific community needs.
- **Capacity building through co-learning**: The colearning approach, as seen in the South African case, demonstrates that when universities and communities learn together, it leads to more effective capacity building and sustainable outcomes. This method promotes shared knowledge creation and application, which is critical for innovation and development.

Table 2 Cases of HEIs pror.	noting SD via stakeholder engagement			
Continent	Case(s)	Country	Key topic	References
Africa	African universities	Cameroon	Local voices into the university's mission to foster sustainable development	Mbah [50]
	University of Johannesburg	South Africa	Co-learning approach to bridge the knowledge gap between universities and disadvantaged communities	Habiyaremye [36]
	University of Zambia	Zambia	Integration of Indigenous knowledge into the university's community engagement strategies	Mbah et al. [51]
Asia	Ningbo University and University of Nottingham Ningbo China	 China 	Differences in sustainable development practices between culturally different universities	Dawodu et al. [21]
	Five Malaysian private institutions	Malaysia	Role of student engagement in promoting green entrepreneurship	Chatterjee et al. [17]
	Saudi higher education institutions	Saudi Arabia	Sustainability practices in HEIs from the perspective of faculty members	Al Ali and Aboud [2]
	Thai universities	Indonesia	Stakeholder perceptions between Green Campus and Non-Green Campus universities	Tiyarattanachai and Hollmann [76]
	University of Jordan	Jordan	Factors influencing student participation in the Green- Smart Campus initiative	Al-Dmour [3]

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Table 2 (continued)				
Continent	Case(s)	Country	Key topic	References
Europe	University of Córdoba	Spain	Education for Sustainable Development and environmental education, awareness, and training in the university environment	Gomera et al. [34]
	Eight universities belonging to the Catalan Association of Public Universities	Spain	Economic value and the social value created for all the organisation's stakeholders through a participatory and systematic process	Ayuso et al. [8]
	University of West of Scotland Paisley	Scotland	HEIs' levels of awareness and disclosure of sustainable practices	Raji and Hassan [64]
	Seven Portuguese public universities	Portugal	HEIs contributions to better development and regional transformation	Pedro et al. [60]
	Technical university	Sweden	Implementation of sustainable development in educational programmes at a technical university	Högfeldt et al. [38]
	University of Molise	Italy	Stakeholders' perception about the university role in promoting a regional development	Forleo and Palmieri [27]
	University of Northampton	X X	Efffcacy of student engagement with sustainability projects	Cleverdon et al. [18]
	University of Salamanca	Spain	Climate emergency declaration (CED) in HEIs	Reyes-Carrasco et al. [66]
	University of Szeged	Hungary	Role of social justice orientated university community engagement	Málovics et al. [49]

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Continent	Case(s)	Country	Key topic	References
	Vrije Universiteit Brussels	Belgium	Promotion of sustainable behaviour of university members	Macharis and Kerret [48]
	University of Bristol	З Л	HEIs involvement in citywide sustainability initiatives	Bigg et al. [11]
	Wrocław University of Science and Technology	Poland	Incorporation of sustainability concepts in employee and student environment	Brdulak and Stec [13]
Europe/Asia (transcontinental)	Yildiz Technical University	Turkey	Association between stakeholders' materiality and the SDGs	Aras et al. [6]
North America	Stetson University in Florida	USA	Balancing financial and sustainability demands in construction projects in HEIs settings	Subramanian and Demoss [74]
	University of Wyoming	USA	Role of civic engagement in fostering sustainability among students	Press et al. [62]
	University of British Columbia (UBC)	Canada	Formation and implementation of the Sustainable Development Policy in HE	Moore [56]
	University of Toronto	Canada	Student engagement and sustainability integration into the university's course management system	Brugmann et al. [14]
	University of Calgary	Canada	SDG Alliance at the HEIs, a student-led initiative that empowers students to engage with the SDGs	Lee et al. [46, 47]

Table 2 (continued)				
Continent	Case(s)	Country	Key topic	References
	University of Georgia	USA	Participation of students in sustainability programmes	Lee et al. [46, 47]
South America	Universidad del Desarrollo	 Ahile 	Role of entrepreneurial university ecosystems in achieving the SDGs	Guerrero and Lira [35]
	Centro Universitario Municipal de Franca, Uni-FACEF	Brazil	Stakeholder networks' roles in achieving the SDGs	Paucar-Caceres et al. [59]

Source Authors' own creation

• **Community-centric engagement**: Universities must prioritise community-centric engagement by actively involving local stakeholders in research and development projects. This approach not only benefits the communities, but also enriches the academic institutions with practical insights and diverse perspectives.

Insights from Asian universities

The cases from China, Malaysia, Saudi Arabia, Indonesia, and Jordan demonstrate that sustainable development in Asian universities is closely linked to effective stakeholder engagement. Several key themes emerge:

- **Comparative and context-specific approaches**: Understanding the unique strengths and challenges of different university models, as seen in the Chinese case, allows for more effective ESD implementation tailored to specific contexts.
- Youth and student engagement: Engaging students in sustainability efforts, as evidenced by the Malaysian and Jordanian cases, is crucial for fostering a culture of sustainability and innovation. Universities that support and motivate students can significantly enhance their contribution to sustainable development.
- Faculty insights and strategic vision: Leveraging faculty perspectives, as highlighted in the Saudi Arabian case, can identify gaps and opportunities for improvement in sustainability practices. A strategic vision and dedicated committees are essential for advancing sustainability in higher education.
- **Benchmarking and best practices**: Adopting recognised sustainability frameworks, such as the UI GreenMetric, can drive significant improvements in campus sustainability and stakeholder satisfaction, as shown in the Indonesian case.

Insights from European universities

European universities are actively engaging in a wide range of sustainability initiatives, emphasising the importance of stakeholder involvement, transparent communication, and strategic planning. Key insights from these studies include:

• **Engaging all stakeholders**: Effective sustainability practices require active participation from all stakeholders, including students, staff, and external community members. Programmes like the Trébol Programme and the climate emergency declaration at

the University of Salamanca demonstrate the impact of inclusive, participatory approaches.

- Integrated thinking: Universities need to adopt integrated thinking to align sustainability goals with broader institutional strategies. This involves comprehensive frameworks for measuring, reporting, and communicating sustainability efforts, as seen in the ISV analysis in Catalonia and the proposed frameworks in Turkey.
- Educational integration: Sustainability must be embedded into educational curricula and research agendas. Initiatives in Sweden and Portugal highlight the importance of involving academics and students in sustainability efforts, promoting long-term commitment and innovation.
- **Regional development**: Universities can significantly impact regional sustainability through partnerships and community engagement. Studies from Italy and Portugal illustrate how universities can drive regional transformation by integrating sustainable practices into their operations and collaborations.
- Challenges and barriers: Despite progress, universities face challenges in fully implementing sustainability initiatives. Common barriers include limited resources, lack of comprehensive frameworks, and varying stakeholder priorities. Addressing these challenges requires coordinated efforts and strategic investments.
- **Innovative approaches**: Unique methodologies and innovative approaches, such as the positive sustainability framework at Vrije Universiteit Brussels and the AHP/ANP framework in Turkey, provide valuable models for other institutions seeking to enhance their sustainability efforts.

Insights from North and South American universities

North and South American universities are engaging in diverse sustainability initiatives, emphasising stakeholder involvement, policy integration, and innovative approaches. Key insights from these case studies include:

- **Stakeholder engagement**: Effective sustainability initiatives require addressing the diverse needs and expectations of stakeholders, as illustrated by the Stetson University case and the stakeholder networks at Uni-FACEF. Engaging students, faculty, and the community is crucial for the success of these initiatives.
- Educational integration: Embedding sustainability into educational programmes and research agendas is essential. Universities like UBC and the

University of Toronto demonstrate the importance of comprehensive policies and inventories to integrate sustainability into academic and extracurricular activities.

- **Inclusive participation**: Ensuring diverse representation in sustainability programmes is vital. Studies from the University of Georgia highlight the need for inclusive strategies to engage students from various backgrounds, promoting equity and diverse perspectives in sustainability efforts.
- **Student leadership**: Supporting student-led initiatives can significantly enhance sustainability engagement. The University of Calgary's SDGA showcases how empowering student leaders can foster a deeper commitment to the SDGs and drive grassroots change within institutions.
- Innovative methodologies: Utilising innovative approaches, such as soft systems methodology at Uni-FACEF, can help manage the complexity of sustainability initiatives and enhance stakeholder collaboration. These methodologies provide valuable frameworks for other institutions seeking to improve their sustainability efforts.
- **Regional development**: Universities can drive regional sustainability through community engagement and entrepreneurial ecosystems. The Universidad del Desarrollo case highlights how universities can contribute to sustainable development by addressing local and global challenges through their core activities.

The 29 case studies from universities across various continents analysed reveal common patterns advancing sustainability through stakeholder in engagement. A fundamental aspect is the integration of all stakeholders-both internal, including students, faculty, and administrative staff, and external, encompassing local communities, industries, policymakers, and non-governmental organisations. The successful implementation of sustainability initiatives depends on addressing the diverse needs, expectations, and priorities of these stakeholders, fostering a shared vision and long-term commitment. Mutual trust, collaboration, and continuous dialogue are crucial in ensuring that sustainability projects remain relevant, impactful, and culturally appropriate across different regional contexts.

A particularly noteworthy finding is the pivotal role of students and youth in driving sustainability and innovation. Their engagement is not merely a byproduct of institutional efforts but a critical force shaping the future of sustainability in higher education. Universities that embed sustainability within their curricula not only strengthen student motivation but also create a long-term cultural shift toward sustainability-conscious professionals. Furthermore, integrating sustainability into research agendas serves as a key driver for faculty involvement, encouraging interdisciplinary approaches that address complex sustainability challenges.

Beyond curricular integration, universities play a strategic role in building bridges between academic knowledge and real-world applications. Sustainability efforts gain greater traction when academic institutions align their research and outreach activities with the specific socio-economic and environmental needs of their local and regional communities. Collaborative that promote co-learning frameworks between universities and external stakeholders have proven particularly effective, as they foster mutual understanding and knowledge exchange. This participatory model, based on equity and shared decision-making, enhances the practical applicability of sustainability initiatives and reinforces their long-term impact.

Institutional leadership emerges as a decisive factor in the success of sustainability initiatives. Universities with clear strategic visions and dedicated sustainability commitments are more likely to develop cohesive policies that integrate sustainability across governance structures, research priorities, and operational practices. The effectiveness of these efforts is further amplified by the adoption of innovative methodologies, such as sustainability benchmarking, stakeholder networks, and participatory governance models. These tools enable institutions to assess progress, identify best practices, and adapt strategies to their specific contexts.

Despite the diversity of regional and institutional settings, these findings underscore the universal importance of inclusive participation, community-centric engagement, and capacity building. The integration of sustainability into higher education requires a multidimensional, collaborative approach that leverages the strengths of various stakeholders. By fostering interdisciplinary learning, encouraging co-creation with communities, and embracing adaptive and innovative frameworks, universities can play a transformative role in advancing global sustainability. The key insights derived from these case studies are translated into concrete operational guidelines in the following section.

Actionable insights and guidance for HEIs

Based on the insights from real cases from around the world, ten guidelines were formulated for HEIs seeking to promote sustainable development through stakeholder engagement (Table 3).

The guidelines proposed in the research paper serve as actionable insights for HEIs by offering a structured

Table 3	Guidelines	for HEls seekin	g to	promote SD	through	n stakehold	er engagement

Guidelines	Actions
1. Embed community perspectives	Integrate local community insights and needs into the university's knowledge creation and dissemination processes to ensure development efforts are relevant and effective
2. Foster mutual trust and commitment	Build and maintain mutual trust and shared commitment among all stakeholders, including national governments, private sector, civil society organisations, and citizens, to optimise collaborative efforts
3. Culturally relevant approaches	Address socio-economic, political, and environmental issues in ways that are culturally sensitive and relevant to ensure sustainability initiatives are well-received and impactful
4. Support student and staff engagement	Actively support and motivate students and staff by providing resources, leadership opportunities, and recognition to translate their engagement into tangible, sustainable actions
5. Establish dedicated sustainability committees	Form dedicated committees focused on sustainability initiatives and adopt best practices from successful institutions to drive continuous improvement and stakeholder satisfaction
6. Enhance communication and transparency	Develop methods to measure and communicate the social value created by the university, increasing accountability and transparency with stakeholders through integrated thinking and reporting
7. Integrate sustainability into education	Develop comprehensive sustainability curricula and community-engaged learning opportunities, fostering sustainable skills and competencies among students and staff
8. Construct efficient participatory mechanisms	Implement efficient participatory mechanisms using bottom-up approaches to ensure inclusive and effective community involvement in sustainability initiatives
9. Balance financial and sustainability goals	Carefully manage the trade-offs between financial considerations and sustainability objectives in university projects, preparing for potential unexpected impacts and challenges
10. Adopt inclusive and systemic approaches	Use systemic approaches to clarify stakeholder roles and formalise action networks, ensuring inclusive recruitment and diverse representation in campus sustainability efforts

Source Authors' own creation

approach to effectively engage diverse stakeholders in their sustainability initiatives. These guidelines provide concrete strategies for involving students, faculty, administration, local communities, governments, private sector, and civil society in decision-making processes, ensuring a comprehensive representation of perspectives and expertise.

By examining real-world case studies and best practices, the paper translates theoretical frameworks into practical applications, enabling institutions to implement inclusive and innovative sustainability efforts. This approach not only enhances the relevance and impact of sustainability projects, but also fosters a sense of shared responsibility and collaboration among all involved parties, ultimately driving more effective and sustainable outcomes. By leveraging these guidelines, HEIs can harness the collective power of their stakeholders, leading to more robust and resilient sustainable development practices.

Whereas stakeholder engagement in higher education is important for promoting sustainable development, there are several challenges can impede effective collaboration. One major challenge is the lack of awareness or understanding of the importance of stakeholder engagement among faculty, students, and administration. Many stakeholders may not recognise how their involvement can contribute to sustainable development objectives, which can lead to apathy or reluctance to participate. To address this, institutions should implement educational programs that emphasise the value of stakeholder engagement and its benefits for both the institution and the community.

Another significant challenge is the power imbalance among stakeholders, where certain groups may dominate discussions or decision-making processes. For instance, faculty members may inadvertently overshadow student voices or external partners, leading to a narrow perspective on sustainability initiatives. Mitigation measures include establishing inclusive decision-making frameworks that ensure all stakeholders have an equal opportunity to contribute. Institutions can create committees that represent diverse groups and facilitate open dialogues to promote equal representation and encourage varied viewpoints.

Additionally, logistical issues such as time constraints and competing priorities often hinder stakeholder participation. Faculty and administrators may struggle to balance their academic responsibilities with engagement efforts, resulting in minimal involvement. To counter this, institutions could schedule regular engagement activities during designated times to accommodate stakeholders' availability. Incorporating stakeholder engagement into course requirements or institutional objectives can help align priorities and encourage participation without overburdening individuals.

Lastly, inadequate communication channels can lead to misunderstandings and disengagement. Stakeholders may struggle to access information or may not feel informed about ongoing initiatives. Implementing cannot communication strategies, such as newsletters, workshops, and social media platforms, can enhance transparency and keep all parties informed. By addressing these challenges through targeted actions, HEIs can foster more effective stakeholder engagement and advance SDGs.

Conclusions

This paper has investigated the integration of sustainable development principles into higher education through stakeholder engagement. It fills in a gap in respect of research on theoretical frameworks of stakeholder engagement on the one hand, and practical applications on the other, within the context of sustainable development in higher education. It also examined a set of real-world case studies, presenting some examples of best practices.

The conclusions from this paper have been derived through a robust methodology that includes qualitative analysis of case studies, stakeholder interviews, and surveys conducted across various institutions. By examining multiple perspectives, the research highlights how diverse stakeholder involvement—encompassing students, faculty, industry partners, and community members—significantly contributes to integrating sustainability into educational frameworks and practices.

The study provides strong evidence that collaborative engagement fosters innovation, enhances student learning experiences, and cultivates a culture of sustainability within HEIs. Thus, it can be concluded that meaningful stakeholder engagement is vital for achieving SDGs in academic settings.

The first conclusion which can be derived from the paper is related to the fact that the nature of the work performed, and the scope of the activities of HEIs put them in a key position, in fostering sustainable development by engaging various stakeholders, including students, faculty, administration, industry partners, and the broader community.

Also, the experiences from the paper indicate that successful stakeholder engagement requires a holistic approach that encompasses a set of important elements. The first one is inclusive participation. Engaging a diverse range of stakeholders ensures that multiple perspectives are considered, leading to more comprehensive and effective sustainability initiatives. HEIs should create platforms that facilitate dialogue and collaboration among all relevant parties. A second element is linked with educational programmes. Much can be gained by incorporating sustainability into the curriculum across disciplines. It not only helps to raise awareness, but may also equip students with the knowledge and skills needed to address sustainability challenges. Ideally, study programmes should be designed to be interdisciplinary, reflecting the interconnected nature of sustainable development issues.

A third element is related with institutional commitment. Strong leadership and institutional commitment to sustainability are very helpful in facilitating the implementation of ideas. This includes establishing clear policies, dedicated sustainability offices, and integrating sustainability into the strategic goals of the institution.

Finally, building strong partnerships with local communities and industries can enhance the impact of sustainability efforts. Such collaborations can provide practical experiences for students and address real-world sustainability challenges.

There are some key theoretical and empirical gaps that the paper has addressed. For instance, the gap on research that highlights the diversity of effective engagement with diverse stakeholders, including students, faculty, administrators, and external partners, which is essential for integrating sustainable development into higher education curricula and practices. The study has also shown that the advantages of collaborative approaches, which may foster innovation, enhance learning experiences, and create a culture of sustainability within institutions. A second gap is seen in respect of the need for use of experiential learning opportunities, such as project-based initiatives and community partnerships, significantly improve stakeholder involvement.

In terms of key findings, a set of key ones are:

- (a) Inclusivity ensures diverse perspectives are considered, leading to more innovative and holistic sustainability solutions.
- (b) Co-creation of sustainability strategies and policies increases stakeholder ownership, commitment, and long-term support for initiatives.
- (c) Feedback mechanisms and regular reporting on progress help maintain accountability and adapt strategies based on stakeholder input.

These findings underscore the importance of inclusivity, collaboration, and communication in fostering effective stakeholder engagement for sustainable development in higher education.

This research underscores the value and role of stakeholder engagement in advancing sustainable development within higher education. In respect of the research question "How do HEIs engage stakeholders in sustainability initiatives?", the answer is two-fold. Firstly, by actively involving diverse groups—such as students, faculty, industry partners, and local communities—institutions can cultivate a more inclusive and innovative approach to sustainability challenges. The findings reveal that meaningful collaborations not only enhance educational outcomes but also foster a culture of sustainability across campuses. Secondly, HEIs need to prioritise developing structured frameworks for stakeholder engagement, ensuring that all voices are heard and valued, ultimately driving effective sustainable development strategies that benefit both the institution and the wider community.

It is also important to note what cannot be concluded from this study. While the findings illustrate the benefits of engagement, they do not establish a direct causal relationship between specific engagement strategies and sustainability outcomes. The research is qualitative in nature, lacking quantifiable measures of success or comparative analyses across differing engagement models. Therefore, further research is necessary to identify best practices, determine the effectiveness of various engagement strategies, and quantitatively assess their impact on sustainable development initiatives within higher education.

The contributions of this paper to theory and practice are twofold. The first is the fact that it has identified the thematic focus on the topic currently being given by the literature, and this is helpful in pointing out some areas where improvements are needed. For example, there is a need for studies on the effectiveness of Stakeholder Engagement initiatives. Secondly, the examples from various geographical regions show that the theme is emerging, and its relevance is becoming increasingly acknowledged.

This study addresses a perceived knowledge gap concerning the theoretical frameworks and empirical evidence around effective stakeholder engagement within HEIs. While the importance of stakeholder involvement in advancing sustainable development is recognised, there is a lack of comprehensive studies that illustrate successful models and practices. The paper seeks to bridge this gap by presenting theoretical insights, and data demonstrating how active engagement with diverse stakeholders-such as students, faculty, industry partners, and community members-can facilitate the integration of sustainable development principles within educational frameworks. From the experiences gathered, we can list a set of 5 elements which are needed to make stakeholder involvement on sustainability in higher education effective:

• Inclusive engagement: Identify and involve a diverse range of stakeholders, including students, faculty, staff, administrators, alumni, local communities, industry partners, and government bodies. Ensure representation from underrepresented groups to foster equity and inclusivity in decision-making processes.

- Clear communication and transparency: Establish open and consistent communication channels to share goals, progress, and challenges related to sustainability initiatives. Use accessible language and multiple platforms (e.g., meetings, newsletters, social media) to keep stakeholders informed and engaged.
- Collaborative decision-making: Involve stakeholders in co-creating sustainability strategies, policies, and actions to ensure their needs and perspectives are reflected. Use participatory approaches like workshops, focus groups, and advisory committees to foster ownership and commitment.
- Capacity building and education: Provide training, resources, and workshops to empower stakeholders with the knowledge and skills needed to contribute effectively to sustainability efforts. Integrate sustainability into curricula, research, and campus operations to embed it into the institutional culture.
- Accountability and feedback mechanisms: Establish measurable goals and regularly monitor progress to demonstrate the impact of stakeholder contributions. Create feedback loops to gather input, address concerns, and adapt strategies based on stakeholder insights.

By incorporating these elements, HEIs can build strong, collaborative partnerships that drive meaningful and lasting sustainability outcomes.

In terms of the future, HEIs cannot and should not rely on past achievements in respect of engaging internal and external stakeholders. Rather, they need to adopt a culture of continuous improvement, regularly assessing and refining their sustainability initiatives. In this context, feedback from stakeholders is essential, to ensure that the efforts remain relevant and effective.

The limitations of this paper include its focus on three core themes—sustainability, stakeholders, and HEIs resulting in a limited review of 215 documents, which may not capture the full breadth of relevant literature. Additionally, the case studies are based on a small sample of 29 universities, which, while exemplary, may not fully represent the diversity of HEIs worldwide, particularly those in less-resourced regions. The study also does not explore in-depth the specific challenges or barriers faced by universities in implementing stakeholder engagement practices, which could offer valuable insights for overcoming obstacles in real-world applications. Furthermore, the paper does not address the effectiveness of stakeholder engagement initiatives, an area that warrants further investigation. Overall, this paper defends the view that stakeholder engagement is not just a beneficial practice but a fundamental requirement for driving sustainable development in higher education. By adopting a comprehensive approach that involves all stakeholders, HEIs can lead the way in creating a sustainable future. Our findings suggest that, while challenges exist, the potential benefits far outweigh the difficulties, making the pursuit of a greater engagement of all stakeholders in implementing sustainability in higher education both a noble and necessary endeavour.

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Author contributions

WLF conceived and coordinated the project, designed the methodology, amended the manuscript in several steps, and was a major contributor in writing the manuscript. TFACS contributed in the coordination of the project, amended the manuscript in several steps, and was a major contributor in the selection and analysis of the cases and in writing the manuscript. RA contributed in the coordination of the project, amended the manuscript in several steps, and was a major contributor in the selection and analysis of the cases and in writing the manuscript. BGR performed the analysis of trends and contributed to bibliometrics analysis, and contributed in writing the manuscript. ISR contributed to search, selection and definition of the sample for systematic review and analysis of cases, and contributed in writing the manuscript. SHB contributed to search, selection and definition of the sample for systematic review and analysis of cases, and contributed in writing the manuscript. DF contributed to develop the conceptual framework, analysis of cases, and in writing the manuscript. TT contributed to develop the conceptual framework, analysis of cases, and in writing the manuscript. LLB commented on and edited the first draft, and contributed in the interpretation of data. All authors read and approved the final manuscript .

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

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Research

Assessing the impacts of sustainability teaching at higher education institutions

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Abstract

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

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

Keywords Sustainability teaching \cdot Sustainable development \cdot Higher education \cdot Curricula \cdot Universities \cdot Higher education institutions

1 Introduction

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

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

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

2 Literature review

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

2.1 A brief history of sustainability in HEIs

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



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

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

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

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

2.2 Sustainability teaching: its needs and challenges

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

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



Table	1 Some milestones in the evolution of sustainability teaching in higher educ.	ation	
Year	Development	Influence	Reference
1713	Hans Carl von Carlowitz coins the concept of sustainability: Nachhaltigkeit	Devises notion: "conservation and replanting of timber that there can be a continuous, ongoing and sustainable use"	Schmithüsen [8]
1970	April 22, Celebration of First Earth Day in the US	Helped Establish modern environmental movement in the US	Hughes and Thomson [9]
1977	Tbilisi Declaration from the 1977 United Nations (UN) Conference on Environmental Education	Instrumental in broadening ecological education to include cultural aspects and stewardship	Gillett [10]
1987	Publication of Our Common Future	Agreement on a widely used definition of SD	Brundtland [11]
1990	Talloires Déclaration	Highlights the central sustainability role of HEIs through research, teach- ing, policy generation, etc	Adlong [12]
1991	The graduate curriculum in sustainability in the U.S. (MS3), enrolled its first students at Slippery Rock University of Pennsylvania	Pioneer program (first graduate curriculum) to prepare leaders in SD in the U.S	Anderson [13] Borsari [14]
1993	US Nonprofit Second Nature is founded	Founded to mobilise a diverse array of HEIs to act on bold climate com- mitments, scale campus climate initiatives, and create innovative climate solutions	Second Nature Inc. [15]
1996	Environmental Association for Universities and Colleges (EAUC)	Initiated to enhance the visibility of environmental management and improve facilities for better environmental performance in further and HEIs	Soini, Jurgilevich [16] EAUC [17]
		Exists to lead and empower the post-16 education sector to make sustain- ability 'just good business'	
1998	US Green Building Council creates the LEED green building rating	By including LEED-certified green buildings, colleges and HEIs work towards more sustainable solutions	Worden, Hazer [18]
2000	Establishment of the International Journal of Sustainability in Higher Education	Establishment of an outlet for international scholarly research on Sustain- ability in Higher Education	IJSHE [19]
2005	Launch of the Association for the Advancement of Sustainability in Higher Education	The first professional higher education association dedicated to the cam- pus sustainability community in North America	Fien [20] AASHE [21]
2006	Launch of American College & University Presidents' Climate Commitment	Created a network of US HEI committed to reducing greenhouse gas emissions and spurring research in sustainability	Dyer and Dyer [22]
2006	Arizona State University creates a School of Sustainability	Establishes the first sustainability degree program in the US. Hundreds follow	Redman [23]
2007	Development of United Nations Principles for Responsible Management (UN PRME)	Legitimate Business School Faculty Teaching and Research in partnership with UN Compact, Focused on business school education	Alcaraz, Marcinkowska [24] Godemann, Haertle [25]
2015	Launch of UN Agenda 2030 and establishment of SDGs	Provides a framework for scholarly contributions to sustainability	Caballero [26] Hujo [27]
2020	Establishment of the European School of Sustainability Science & Research (ESSSR)	Coordinates initiatives in sustainability science education and research across Europe	Filho, Sierra [28]
2021	Quality Assurance Agency [QAA) and Advance HE Education for SD Guid- ance	Jointly published in 2014 and updated in 2021 by QAA and Advance HE, this guidance provides a framework to help UK HEI staff incorporate ESD within their curricula. Advance HE has emphasized the critical role of leadership and innovation in embedding ESD across HEIs, as outlined in its foundational frameworks	Martin, Jucker [29] Sterling [30] Fiselier and Longhurst [31] Advance HE [32]

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2.3 Distinctive practices in sustainability teaching

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

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

3 Methods

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

3.1 Bibliometric analysis

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

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

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

3.2 Case studies

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



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



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

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

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

3.3 Survey

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



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



Table	2 (continued)				
Case	Region	Objective	Key findings	Implications	Reference
6	Japan	Promoting interdisciplinarity via sus- tainability	Integrating sustainability issues in non-environmental courses such as general education to enhance inter- disciplinarily teaching and learning	Students' and instructors' communica- tion opportunities were broadened. Instructors were able to develop a keener understanding of sustainabil- ity and interdisciplinary education	Liu, Watabe [81]
10	Netherlands	Developing higher education students' sustainability competencies	Exploring the impact of transformative, interdisciplinary and intercultural learning to advance sustainability learning	Structural support is critical to effectively integrate sustainability in higher education teaching and curriculum	Sommier, Wang [82]
1	Europe and North America	Evaluate the curricula of programs granting degrees in sustainability	Core sustainability courses constituted most of the curricula, with bachelor's programs generally being more flex- ible than master's programs	Shared foundation courses across programs are essential for the devel- opment of sustainability as a mature scientific discipline	O'Byrne, Dripps [83]
12	Spain	Assess university faculty's practice, concerns, and the need to embed sustainability educa- tion	Project-based learning is the predomi- nant approach for ST, even though its application is hindered by a lack of faculty training	Establishing sustainability as a crucial area of study in a university requires adequate ST materials, study cur- ricula, and institutional backing	Busquets, Segalas [84]
13	Australia	Investigate teaching methods and pedagogical strategies employed by university faculty in teaching educa- tion for sustainability	Low adoption of the pedagogies and teaching methods advocated for education for sustainability	The extent to which innovative peda- gogical approaches are integrated into education for sustainability can provide valuable insights for shaping its future direction	Christie, Miller [85]
14	Europe and Latin America	Explores faculty experience in imple- menting sustainability principles and curriculum greening in higher education	The process of conducting action- oriented research, collaborative efforts and the integration of diverse fields of knowledge faced operational challenges	Effective sustainability education necessitates the collaboration of all domains of knowledge to conserve and enhance the environment	de Ciurana and Filho [86]
15	Global Study	Review strategies change agents employ to strengthen their efforts in implementing education for sustain- ability	Sustainability education is a multifac- eted undertaking, with both chal- lenges and achievements in trying to broaden the curriculum	Considering the institutional culture is a crucial aspect of initiatives aimed at transforming the curriculum for education for sustainability	Higgins and Thomas [87]
16	Europe	Compare how three European HEIs incorporate education for sustain- able development (ESD) into their academic curricula	Integrating ESD into all academic programs through a thorough revi- sion of the curriculum is an arduous undertaking	Incorporating ESD into academic curricula requires robust, enduring strategies and involvement from university management and various groups within the institution	Holmberg, Svanström [88]
11	Australia	Evaluate the potential of a constructiv- ist-informed pedagogical approach to facilitate authentic transformative learning in sustainability education	Sustainability education curricula encompass a few interdisciplinary approaches and pedagogical prac- tices to promote critical and reflective thinking in students	Education for sustainability requires individuals who can effectively engage with the intricacies of envi- ronmental issues and think critically about them	Howlett, Ferreira [89]

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Table	2 (continued)				
Case	Region	Objective	Key findings	Implications	Reference
18	Global	Examine the utilisation of a systems theory approach in researching and teaching sustainability at the university level	Having a practical and effective approach is essential to achieving sustainability across environmental, socio-cultural, economic, technical, and personal domains	HEIs should create sustainability content that is rooted in values and applicable to various disciplines, with a particular emphasis on carefully evaluating both human and technical aspects when addressing sustainabil- ity challenges	Pappas [90]
19	Canada and England	Investigate whether education for ESD keep pace with the rapid progress of sustainability values in business, com- munity, and government	Found a lack of structural changes required to develop transdisciplinary curricula, incorporate fieldwork and real environmental problems for student-centred instruction, and promote diversity in education	HEIs as key components of the formal delivery of sustainability education must provide effective environmental and sustainability learning	Pearson, Honeywood [91]
20	Saudi Arabia	Study the evaluation of sustainability education curriculum and research from the perspective of students	Few courses and student projects across different disciplines prioritise sustainability as a key component of their content or objectives	Incorporating sustainability into the curriculum can equip students with the necessary knowledge, skills, and attitudes to tackle sustainability chal- lenges in their personal and profes- sional lives	Abubakar, Al-Shihri [92]

Source: prepared by the authors based on the study findings

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

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

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

4 Results and discussion

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

4.1 Bibliometric analysis

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

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

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





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

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

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

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



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

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

4.2 Case studies analysis

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

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

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

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

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

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

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

4.3 Survey results

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

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

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



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



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

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

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

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

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



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

Table 3 Approaches of integrating sustainability into teaching (n = 112)	Variable	n (%)
	Case-studies	86 (76.8)
	Research	71 (63.4)
	Project-based instruction	69 (61.6)
	Guest Lectures	53 (47.3)
	Local sustainability event reports by students	33 (29.5)
	Service-learning activities	26 (23.2)
	Fostering students' engagement and leadership in campus government	26 (23.2)
	Hands-on activities through lab exercises	22 (19.6)
	Various forms of art expression (poetry, music, photography, painting, etc.)	12 (10.7)
	Letter writing to local newspaper editors	4 (3.6)

Table 4Self-reported effectsof sustainability teaching,as perceived by students $(n = 112)$	Variable	
	Enhancing interest to want to learn more about sustainability	97 (86.6)
	Increased aspirations to 'make a difference' in making their communities more sustainable	87 (77.7)
	Take personal action to change their own life-style towards sustainability	72 (64.3)
	Pursue professional careers in sustainability	67 (59.8)
	Source propared by the authors based on the study findings	

Source: prepared by the authors based on the study findings

Table 5	Estimated students	'attitudinal change whe	n these are taught about s	ustainability teaching (<i>n</i> = 112)
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Variable	n (%)
Students' interest in sustainability has increased	93 (83.0)
Students' aspirations to pursue more knowledge in sustainability	80 (71.4)
Students' desire to pursue careers in sustainability has increased	66 (58.9)
Students' groups/committees engaged in making their campus and community more sustainable have become well-established	33 (29.5)
Students' groups/committees engaged in making their campus and communities have been formed	27 (24.1)

Source: prepared by the authors based on the study findings

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

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

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

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



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





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



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

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

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



5 Conclusion and recommendations

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

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

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

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

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



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

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

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Declarations

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

Consent for publication Were obtained from all participants.

Competing interests The authors declare no competing interests.

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⁵ Available at: https://www.haw-hamburg.de/ftz-nk/programme/european-north-american-sustainability-research-consortium/.



¹ Available at: https://www.haw-hamburg.de/en/ftz-nk/.

² Available at: https://esssr.eu/.

³ Available at: https://www.mmu.ac.uk/research/research-centres/ecology-environment/groups/zero-carbon-sustainable-futures/UK-CSR.

⁴ Available at: https://www.haw-hamburg.de/en/ftz-nk/programmes/iusdrp/.
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Promoting climate action through youth empowerment and environmental education: Insights from Mohamed Bin Zayed University for Humanities

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Abstract: Climate change is a pressing global challenge that requires immediate action. To address this issue effectively, it is essential to engage and empower the younger generation who will shape the future. This abstract presents the experience of Mohamed Bin Zayed University for Humanities (MBZUH) in UAE in promoting climate action through youth empowerment and environmental education.MBZUH has recognized the significance of incorporating environmental education into its curriculum to foster a generation of environmentally conscious individuals. Through a multidimensional approach, the university has developed innovative strategies to empower students, enabling them to become active participants in addressing climate change. These strategies encompass both formal and informal education, leveraging various platforms and partnerships to create a comprehensive learning environment. This study delves into the initiatives undertaken by MBZUH to empower youth in climate action. It explores the incorporation of environmental education across disciplines, integrating sustainability principles into existing courses, and offering specialized programs focused on environmental science and climate studies. Additionally, it highlights the university's efforts in promoting hands-on learning experiences, such as field trips, research projects, and community engagement, to deepen students' understanding of climate issues and inspire practical action.Furthermore, the study examines the role of MBZUH's collaboration with local and international organizations, governmental bodies, and the wider community in fostering youth empowerment and climate action. It showcases successful partnerships that have resulted in impactful initiatives, including awareness campaigns, capacity-building workshops, and youth-led environmental projects.By sharing the experience of MBZUH, this study aims to provide valuable insights and best practices for promoting climate action through youth empowerment and environmental education. It underscores the importance of empowering the next generation with the knowledge, skills, and motivation to become effective agents of change in addressing climate challenges.

Keywords: Climate action; Youth empowerment; Environmental Education (EE); Mohamed Bin Zayed University for Humanities (MBZUH); Sustainability; Interdisciplinary learning; community engagement

1. Introduction

Climate change presents a concern for our society at present due to activities, like burning fossil fuels and cutting down forests, which have released large amounts of greenhouse gases into the atmosphere. Causing notable disturbances, to the Earth's climate patterns already affecting ecosystems and economies and overall well-being of life.

Climate change is clearly showing its impact through frequent and intense heatwaves, droughts and wildfires. Unpredictable changes in rainfall patterns lead to floods and severe storms while rising sea levels pose a threat to areas and island nations. In addition to these effects climate change exacerbates issues, like food and water scarcity, population displacement and the decline of biodiversity (Wells, 2019).

Dealing with these issues demands efforts that engage a wide range of stakeholders. Governments and individuals alike must now consider switching to eco options as a necessity rather, than just an option. Yet this duty cannot be shouldered by policymakers or experts. Climate initiatives should encompass all facets of society with the youth holding a position, in driving change (Klein, 2014).

The youth have a role in combating climate change because they make up a large part of the world's population and have the innovative spirit to drive change forward effectively and have a lot at stake in today's decisions since they will bear the consequences of climate actions, in the long run Their progressive mindset positions them as influential supporters of creating a sustainable and just tomorrow (Global Sustainable Development Report, 2019).

People's movements like Fridays for Future and the Sunrise Movement have proven the capabilities of youth to the global community already. These campaigns have engaged millions of individuals. Increased awareness regarding environmental concerns while ensuring leaders are responsible for their choices. By participating in movements young individuals have shown that they are not merely bystanders in the climate dilemma but rather catalysts, for transformation.

Environmental education is crucial, for unlocking the potential of young people by providing them with the necessary tools and knowledge to comprehend climate issues and develop solutions effectively.

This study delves into the impact of empowering individuals and promoting environmental awareness on advancing climate initiatives at Mohamed Bin Zayed University for Humanities by sharing real life instances of achievements and obstacles faced along with potential prospects ahead. The intention behind presenting these case studies is to demonstrate the role of involving youth in fostering a greener tomorrow and encouraging broader participation in the global campaign, against climate crisis.

2. The importance of the youth in climate action

The engagement of people in addressing climate issues is crucial for several reasons that stand out prominently in this context; Firstly, and most importantly; the demographic significance of the youth population globally cannot be overstated. As per the United Nations data on demographics reveal that there are over 1.8 billion young individuals aged between 15 to 24 years old representing about one fourth of the world's total population statistics (World Youth Report, 2017). This substantial demographic presence empowers the youth to influence both future directions, in climate action initiatives.

In addition to that point mentioned earlier on climate change activism by people has been quite impactful in driving change forward rapidly and effectively. Notably initiatives like Fridays for Future led by Swedish activist Greta Thunberg and the Sunrise Movement in the United States have drawn interest and brought together millions of youths worldwide. By organizing protests strikes and advocacy efforts these youth led movements have played a role in increasing awareness about climate change issues, at both local and global levels. They have successfully leveraged social media channels and community-based efforts to amplify their messages and advocate for action, on climate change (Hadden, 2020). Youth driven climate movements go beyond creating awareness. They have significantly shaped policy debates and decisions by pushing for swift and bold action on climate change issues They have pushed governments and decision makers to focus on climate concerns by demanding urgent and ambitious steps, towards sustainable and eco-friendly economies (Van der 2021).

The energy and originality of people offer a new outlook on climate action and the challenges it brings about due to climate change issues Their optimism and creative thinking pave the way for fresh strategies and solutions to tackle these intricate problems By leveraging the vigor and zeal of the youth we are able to unleash their capacity as drivers of change and promoters of sustainable progress involving young individuals, in climate initiatives not only gives them a sense of empowerment but also enriches society by utilizing their distinct talents thoughts and viewpoints (Rode, 2020)

3. Environmental education: What is it and why is it important?

Teaching about the environment is essential for encouraging action, on climate change and empowering people to get involved in tackling environmental issues head here we'll delve into what environmental education means and aims to achieve and how it helps shape sustainable behaviors and mindsets in the younger generation.

Environmental education is described as an encompassing and multidisciplinary method of learning that emphasizes raising awareness and understanding of the environments connections to social and economic systems as well, as ecological systems (UNESCO, 2017).

Environmental education has goals that involve multiple important aspects to consider. Initially the main objective is to increase consciousness and deepen comprehension of environmental concerns like climate change decline in biodiversity and pollution. It emphasizes the link between human behaviors and the environment. Moreover, this kind of education aims to enhance awareness and understanding by offering details on environmental processes, ecosystems and the outcomes of human activities. Empowering individuals, with knowledge enables them to make well informed choices and undertake responsible actions.

Moreover, environmental education aims to cultivate beliefs and mindsets that encourage caring for the environment with a reverence for nature and a commitment to sustainable progress It aims to nurture a strong admiration for the beauty of the outdoors and a sincere urge to safeguard and preserve it Ultimately one of its key goals is to equip individuals, with the abilities and expertise needed to tackle environmental issues efficiently. These abilities include analysis skills for problem solving and effective communication for collaborating in efforts, towards impactful climate initiatives and sustainable environmental strategies (Kollmust, 2002).

Education has an impact on shaping sustainable behaviors and mindsets, in young people specifically when it comes to integrating environmental education into various learning settings—both formal and informal—leading to several important results.

Environmental education plays a role in raising awareness, about environmental issues and promoting sustainable behaviors among individuals.

Furthermore, teaching about the environment emphasizes the importance of considering how different aspects such, as society, economy and nature are all

connected. This broad view helps people understand and tackle the underlying issues causing challenges instead of just dealing with their surface effects.

Additionally teaching about the environment promotes thinking and solving problems. It provides people, young people with important abilities to analyze complicated environmental problems consider different viewpoints and suggest creative answers. This ability to assess information critically help them handle issues effectively and decide wisely.

Lastly teaching about the environment promotes being a citizen of the Earth. It gives people the power to get involved in environmental problems both locally and globally making them supporters of making things better. They are more likely to take part in community projects and help with making development that can be continued without harming the environment showcasing well informed care, for nature (Tilbury, 2011).

Engaging people with environmental knowledge and critical thinking skills plays a crucial role in driving effective climate action forward. Teachings about the environment serve as a driver, in reaching this objective by giving youths a diverse toolkit to tackle the urgent issues related to climate change. First and foremost, it provides them with an understanding of climate change. Its root causes and farreaching consequences. This raises awareness. Cultivates a sense of duty to address these pressing matters. Furthermore, environmental education fosters problem solving abilities by nurturing thinking and fostering innovative approaches to address and adapt to climate change - crucial skills for addressing the intricate and ever-changing environmental issues at hand. Additionally, it promotes involvement by equipping individuals with the information and resources needed to actively participate in climate related activities; this includes supporting sustainable development projects; engaging in advocacy campaigns; and playing a significant role, in decision making procedures. In the end teaching about the environment could lead to lasting changes in behavior by instilling values and knowledge about sustainability in people. This could help them adopt ecofriendly habits in their daily lives and become committed stewards of the environment for life. Ultimately this could play a role, in creating a more sustainable and resilient future (Hungerford, 1989) (Chawla, 2012).

4. Case study: Mohamed Bin Zayed University for Humanities

Mohamed Bin Zayed University for Humanities (MBZUH) a known academic institution focusing on humanities and social sciences based in Abu Dhabi and Ajman caters to approximately 1000 students and holds a prominent position in promoting sustainability despite its primary emphasis on non-scientific disciplines. In demonstration of its dedication, to instilling consciousness and equipping students to tackle significant global issues MBZUH actively engages in various local and international programs including waste management workshops and participation in COP28.

4.1. Innovative campus initiatives: Pioneering environmental awareness

While MBZUH mainly emphasizes the humanities field of study it has made an effort to incorporate sustainability across its academic and extracurricular initiatives. The creation of the Environment and Sustainability Club, in May 2023 which initially

attracted 44 student members has provided a platform for individuals to delve into sustainability dialogues launch initiatives and spearhead campus wide efforts geared towards boosting eco consciousness. On average students participate in. Coordinate around 13–16 environmentally focused events annually comprising various projects, campaigns and activities. This club now plays a role in advancing the university's commitment, to sustainability.

In addition to that MBZUH utilizes cutting edge technologies like Artificial Intelligence (AI) to tackle concerns via workshops and joint projects. Educational programs provided by the university help students develop the abilities to propose answers to worldwide environmental problems.15 % of the courses at MBZUH cover sustainability subjects such as Natural Sciences course, Sustainable Development, in Islamic Law and its Applications and Shaikh Zayeds Sustainable Legacy course. This demonstrates the institutions dedication to including environmental education in its curriculum. The university's commitment to sustainability is evident, in its initiatives that equip students with the skills to address environmental challenges using a variety of disciplines.

The Ministry of Education Sustainability Workshops and other extensive educational projects have been key in supporting MBZUH initiatives as well as involving 1651 individuals from universities and schools in promoting environmental education and leadership skills development programs like the Leadership and Diplomacy Program (attended by 1437 participants) along with the Green Communities Program (with 218 participants) which offer practical experiences fostering a sense of responsibility, towards the environment.

4.2. Community engagement beyond campus: Expanding environmental footprints

MBZUHs commitment to causes goes beyond its campus boundaries by partnering with local and global groups. The university played a role in organizing five sessions at COP28 with the theme "Youth Leading Sustainability." These sessions discussed subjects such as Campus Environmental Projects, Country's Sustainable Education Programs and Women's Empowerment, through Environmental Awareness.

During COP28 events MBZH joined forces with organizations like the Ministry of Education and the UAE Ministry of Climate Change and Environment as well as esteemed universities such as Zayed University, Higher Colleges of Technology (HCT) and the University of Wollongong in Dubai (UOWD). The gatherings attracted 150 attendees with students receiving laptops in appreciation of their active involvement. Furthermore, students from MBZUH volunteered in COP28's designated zone to assist with event coordination and showcase the university's global commitment, to environmental issues.

After COP28 has concluded its activities MBZUH has engaged in sustainability initiatives. One notable example is the collaboration with Sorbonne University—Abu Dhabi and Total Energy where students from MBZUH took part in La Nuit des Idées. The event centered on reducing plastic usage. Brainstormed innovative ideas, like implementing a smart wall for segregating waste materials.

Furthermore, MBZUH's outdoor initiative known as the Green June Campaign had than 100 students engaging in planting mangroves to curb greenhouse gas emissions. This initiative showcased MBZUH's dedication to environmental work by giving students hands on experience, in tackling climate change.

4.3. Fostering global collaborations: Empowering youth for climate action

During COP28 conference participation at MBZUH saw them expanding their reach globally by emphasizing the role of people in addressing climate issues. In a representation provided in **Figure 1** it is depicted that faculty and students from the university collaborated with various prominent organizations such as the Ministry of Education and UAE Ministry of Climate Change and Environment along with international entities like the University of Europe for Applied Sciences in Germany, Manchester International Academy and Université Hassan II de Casablanca, in Morocco.

The collaborations allowed students at MBZUH join conversations about sustainability and connect with government officials and environmental experts to expand their networks and knowledge base on global climate strategies towards making meaningful contributions, to environmental initiatives in the future.

Sustainability efforts at MBZUH are fueled by a shared sense of responsibility and teamwork across departments within the institution. Collaborations with partners demonstrate the effectiveness of combining skills and resources to address climate challenges effectively. A significant portion of the faculty and staff at the university. 20% of faculty members and 10% of staff actively participate in these initiatives alongside students. This collective effort does not highlight MBZUH commitment, to environmental stewardship only but also fosters a collaborative atmosphere where students are encouraged to take charge and get involved in impactful sustainability projects. The university dedicates a budget ranging from \$20K to \$40K to sustain and advance its environmental initiatives and collaborations.



Figure 1. MBZUH collaborations during COP28: A network of institutional partnerships

4.4. Global goals, local action: MBZUH's role in achieving the SDGs

Mohamed Bin Zayed University for Humanities (MBZUH) despite its academic focus not being environmental science per se is actively supporting multiple United Nations Sustainable Development Goals (SDGs). The university efforts in education (as shown in **Figure 2**) sustainability practices and empowering young people have made substantial impacts, on the global sustainability mission by incorporating sustainability principles into diverse programs.

Mohamed Bin Zayed University for Humanities effectively contributes to achieving Development Goal 4 by focusing on providing quality education that promotes inclusive learning and lifelong educational opportunities for everyone involved in the educational process. Through its partnership with the Ministry of Education in the UAE; MBZUH successfully organized sustainability workshops that benefitted a total of 1651 students and educators. These workshops were not about raising awareness on environmental concerns only but also aimed at involving MBZUH students as mentors and facilitators empowering them to take charge and lead by example, in the education sector. By taking a role in learning and teaching alike students at MBZUH expanded their knowledge of sustainability matters and school students reaped the rewards of creative instructional approaches that cultivated a stronger respect, for nature.

Under the framework of Sustainable Development Goal 13 Climate Action (SDG 13) MBZUH has engaged in efforts to combat climate change effectively. During the university's Green June Initiative event more than 100 students actively took part in planting mangroves. This activity plays a role in capturing carbon dioxide and highlights the university's dedication to taking tangible steps, towards addressing climate change issues effectively. The Environment and Sustainability Club boasts 44 members serves as an engaging hub for students involved in various climate related endeavors such as projects and research while advocating for the importance of youth leading the way in climate action efforts.

MBZUHs commitment to Development Goal 11 Sustainable Cities and Communities can be seen in the university's initiatives to promote sustainable city living. The university organizes trips such as the Farz Waste Management Visit to give students a hands-on understanding of managing urban waste systems. This visit teaches students about the significance of waste segregation and recycling in building cities and how efficient waste management practices can minimize environmental harm. By incorporating these hands-on learning opportunities into their curriculum MBZUH empowers students to brainstorm solutions, for building sustainable urban communities.

The University has shown progress in promoting sustainable habits in line with SDG 12 on Responsible Consumption and Production both within the campus and outside it. During events like La Nuit des Idées students were tasked with coming up with ideas to cut down on plastic waste. Their efforts resulted in an award-winning proposal, for a waste separation wall. A breakthrough that underscores the university's dedication to promoting responsible consumption. The occasion motivated students to analyze waste management and encouraged them to discover creative methods to reduce the environmental impact of consumer behaviors.

MBZUHs involvement in SDG 17 illustrates the university's understanding of the significance of working to attain sustainability objectives. They have established partnerships with local and global organizations like Total Energy, Sorbonne University. Abu Dhabi, the UAE Ministry of Climate Change and Environment as well as other universities such as UOWD, Zayed University, and UAE University. These collaborations have enabled MBZUH to expand its sustainability initiatives, exchange expertise and create environmental initiatives. The partnership structure guarantees that the efforts by MBZUH not help the campus community only but also support the broader worldwide push, for reaching the Sustainable Development Goals (SDGs).

In **Figure 3** we can see the involvement of students at MBZUH in different environmental projects. This demonstrates how their actions are spread out among Sustainable Development Goals (SDGs). The display presents the range of student engagement with a significant focus on SDGs 4 (Quality Education) and 13 (Climate Action) which highlights the university's dedication to promoting environmental consciousness and initiatives, for climate change mitigation. The graph also highlights the significance of collaborations and eco-friendly approaches since students play a role in supporting Sustainable Development Goals 11 and 12 while also emphasizing Goal 17 Showcasing MBZUH commitment to promoting sustainability, on both a local and global scale.



Figure 2. MBZUH environmental initiatives alignment with SDGs.



Figure 3. The percentage of MBZUH students participating in each SDG.

5. Challenges and opportunities

Promoting youth empowerment and environmental education at Mohamed Bin Zayed University for Humanities encounters obstacles that also offer chances for progress and creativity. The availability of resources, like financial restrictions may limit the extent and range of projects. Incorporating education into the curriculum involves surpassing disciplinary boundaries and potential opposition to change from stakeholders used to conventional educational approaches. Moreover, Ensuring enduring sustainability present logistical and institutional hurdles. Nevertheless, there are possibilities to tackle these challenges efficiently. The increasing worldwide acknowledgment of the significance of learning and empowering young individuals has the potential to garner backing from government officials and schools alike. Teaming up with allies such as governmental bodies, non-governmental organizations (NGOs) and business players can broaden the influence and effectiveness of MBZUH. Progress in technology and the emergence of internet-based platforms present methods, for educating and involving young people. Furthermore, the global connectivity fosters teamwork with youth groups giving students the chance to exchange ideas gain insights from successful strategies and participate in the wider global environmental movement. By acknowledging and tackling these obstacles and making use of these chances MBZUH can further improve its initiatives in empowering people and educating about the environment ultimately nurturing a commitment, to climate activism and environmental sustainability.

6. Conclusion and call to action

In summary and to wrap it up nicely; empowering people and teaching them about the environment are key ingredients in driving climate action and building a future that's sustainable for all of us to thrive in together as a global community facing this climate crisis head on with urgency and unity being essential factors for success here; involving youth is vital for making real and impactful changes happen around us all as one unit working towards a better world for everyone involved out there as demonstrated by the experience at Mohamed Bin Zayed University for Humanities (MBZH) where they've shown us how integrating environmental education into their educational programs can make a significant difference while giving youths platforms to engage actively in solving environmental issues we face today.

The achievements at MBZUH showcase how involving people can make a significant difference in spreading awareness and coming up with creative solutions that promote lasting change and environmentally conscious behaviors by educating them on environmental matters and enhancing their problem-solving skills and critical thinking capabilities to enable them to play an active role, in building a sustainable and adaptable tomorrow.

Nevertheless, there are obstacles that remain. Issues such as resource constraints integrating curriculum, skepticism towards change and the ability to expand challenges that must be overcome. However, embedded within these obstacles are chances for advancement. Government and organizational backing working together with collaborators, advancements in technology and connections, within global youth communities present pathways to amplify the effectiveness of initiatives focused on empowering youth and promoting environmental education.

That's why we urge policymakers to take action and work together with educators and stakeholders.

Educational organizations and authorities should prioritize education by investing in integrating sustainability concepts into curricula and providing hands on learning opportunities, for students. This effort will equip people with the understanding and skills needed to address the issues brought about by the climate emergency.

Collaborating with partners like government agencies and non-profits along with industry stakeholders is essential for our efforts to be successful and have an impact, on empowering youth and advancing environmental education programs through shared expertise and combined resources.

Use technology progress to improve education and involve young people more actively in the process too by utilizing online resources and digital tools for easier access, to education and sharing knowledge to empower them to take part in global climate initiatives.

Appreciate the viewpoints and efforts of young people in addressing climate issues by ensuring that there are avenues, for youth driven groups and projects to participate in decision making processes and have their voices heard.

By adopting these measures, we can unleash the capabilities of empowering young people and promoting environmental awareness forming a potent driver for bringing about beneficial transformations, amidst the challenges posed by climate change.

Conflict of interest: The author declares no conflict of interest.

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ARTICLES FOR UTM SENATE MEMBERS

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7) Empowering sustainability practice via sustainability literacy: a mediated model (2024)

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Empowering sustainability practice via sustainability literacy: a mediated model

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Abstract

Purpose – Combating unsustainable activities is a crucial barrier to sustainable development, since they have drastically escalated the climate change which needs an immediate attention by the Z generation. The study aims to examine the role of sustainability literacy, institutional initiatives and individual factors in impacting university students' sustainable practices by giving due consideration to teacher support and student engagement.

Design/methodology/approach – With the descriptive design, a survey questionnaire was used to gather data for this investigation, collecting responses from 419 university students from the region of Karnataka, India, with an impressive response rate of 96%. Following the data collection, statistical techniques, such as regression analysis, one sample *t*-test and structural equation modelling, were applied to evaluate the direct and indirect impacts of numerous sustainability factors on student's sustainable practices.

Findings – Firstly, we found that students need to have strong sustainable literacy, institutional initiatives and individual factors to amplify their sustainable practices. Moreover, mediating influence of teacher support and student engagement were also observed in the current research. Interestingly, student's sociocultural environment and government initiatives played a moderating role in uplifting their sustainable practices.

Research limitations/implications – The results illuminate the involvement of all the stakeholders in contributing to sustainable future through sustainable practices. However, this study limits its scope to educational setting and gives no importance towards parental upbringing and influence which can be addressed in the future research.

Originality/value – We provided a broader range of influencing factors to promote sustainable future for the future generation.

Keywords Sustainability literacy, Institutional initiatives, Quality education, Teacher support,

Sustainable practices, Student engagement

Paper type Research paper

1. Introduction

The conception of sustainability has obtained increasing traction across several sectors and disciplines. Evolving from the Brundtland Commission's seminal report, sustainability is perceived as an advancement that satisfies the requirements of the present without hindering the access of future generations to satisfy their own requirements (Attfield, 2023; Solomon, 2023). This understanding of sustainability highlights the relationship of social, environmental and economic systems and emphasizes the significance of accountable resource management and balanced growth (Fischer *et al.*, 2023).

The vitality of addressing worldwide issues such as biodiversity loss, climate change and social inequality has accentuated the need for embedding sustainability principles into all facets of human living (Riandari *et al.*, 2023). In light of these challenges, there has been an expanding prominence on sustainability education, focused at enhancing the skills, knowledge and values indispensable for individuals to collaborate to a better sustainable day ahead (Finlay, 2023). Fundamental to this education lies the insights of sustainability literacy.

Sustainability literacy is the capability to understand the interrelatedness of social, environmental and economic systems and to resolve decisions that lead to a better sustainable

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future (Kuehl *et al.*, 2023). It is not restricted only in the understanding of the concepts of sustainability but also the ability to make them applicable in practical real–world circumstances. Accordingly, sustainability literacy gains significance as a predominant competency in effectively addressing the challenges of sustainability (Santin *et al.*, 2023).

In spite of the identified prioritization of sustainability literacy, there is a gap in the identification of the methodology in cultivating this competency, specifically among the students of the university who reflect the future visionaries and decision planners in widespread sectors (Biancardi *et al.*, 2023). While past studies have identified the efficacy of sustainability education content in progressing the sustainability literacy among students (Huang and Hsin, 2023), there is a narrow empirical validation on the translation of sustainability literacy among the student community of the university. The research gap is rightly identified as university students embody a crucial demographic, as they play a significant role in structuring the economic, societal and environmental trajectories. In spite of the expanding focus on sustainability education, there is a dearth of consensus on the approach that is highly effective for nurturing sustainability literacy on the sustainability practices is therefore vital for adapting the structure and application of sustainability education content and courses which are highly effective.

Sustainability has become an important topic across many fields because of the need to address problems like climate change, loss of biodiversity and social inequality. At the heart of this effort is the idea of sustainability literacy. This means understanding how social, environmental and economic systems are connected and learning how to make smart choices that lead to a sustainable future. Even though many people support sustainability education, there is still a big gap in figuring out the best ways to teach it, especially to university students who will be the future leaders and decision-makers.

This study brings in novelty by creating a model that focuses on what influences sustainable behaviours, especially on how students engage and how teachers can support them. Unlike other studies that focus on single aspects of sustainability, this research brings together different factors like sustainability knowledge, actions by institutions, individual habits and cultural influences. It considers direct effects and also explores how these factors work together, which hasn't been studied in detail earlier. This model shows how sustainability education can improve when schools focus on engaging students and supporting them through specific actions.

What makes this study unique is how it connects the efforts of schools, the support of teachers and the involvement of students. This new approach helps us better understand and predict how students can develop sustainable habits. It shows how teachers play a key role in supporting school initiatives, offering useful ideas for universities that want to make sustainability a part of their education programs. This combined approach to teaching sustainability is an important step forward in helping students learn the skills and motivation they need to practice sustainability both in their personal lives and in their future careers.

Therefore, this study aims to fill this gap by substantiating the interconnectedness between sustainability literacy and sustainability practices among the student community of the university.

2. Literature review and hypothesis development

Sustainability literacy in higher education enhances students' ability to address the issues on environmental, social and economic activities. Décamps *et al.* (2017) have highlighted the importance of sustainability literacy in higher education by developing an assessment tool to measure "education for sustainable development" and the "principles for responsible management education", which mainly contribute towards the raise in awareness on sustainability and measures the literacy on sustainability in worldwide. Moreover, Sharma (2023) stressed on the importance of implementing sustainable principles in the educational framework to foster social responsibility and to understand the global issues related to

sustainability, leading to the critical thinking, involvement in community and thoughtful Journal of Applied decision making among the students. Additionally, Chen et al. (2022) conducted a study on 2,548 students to know how sustainable knowledge will change the attitude and behaviour of students towards curriculum development, innovation and sustainable practice. Similarly, Klein et al. (2021) showed that participation of students in sustainability focused living practices enhances sustainability literacy, leading to the sustainable behaviour in students. However, some researchers have said that having knowledge on sustainability will not have any impact on the behavioural change. For instance, Murray and Salter (2014) highlighted the importance of community practice in the institutions to promote implementation of sustainability practice in society.

Despite of having a growing progress in sustainability, there is a gap in understanding how sustainability literacy leads to the practice through teachers support, governmental initiatives and sociocultural practices. Blanco-Portela et al. (2017) spoke on the effective governmental policies and infrastructure needed to create supportive environment to boost sustainable behaviour in society. The author also highlighted the various barriers that effect the achievement of sustainable development goals. Consequently, the study conducted by Solís-Espallargas et al. (2019) shows lack of training programmes and low presence of sustainability concepts in degree courses showing a challenge in getting a formal sustainability knowledge in educational institutions. So, in response to the growing importance of sustainability practice in society, the present study aims to fill this gap by substantiating the interconnectedness between sustainability literacy, individual factors and institutional initiative on sustainability practices through teachers support, student engagement, government support and socioeconomic condition among the student community of the university.

2.1 Theoretical framework

The sustainability literacy and practices are purported by the theory of planned behaviour (TPB) support. In TPB, attitude (awareness), subjective norms (social pressure to engage in sustainable behaviours) and perceived behavioural control (Ajzen, 1991) have an impact on student's intentions to participate in a particular sustainable activity (behaviour) (Blas Riesgo *et al.*, 2023), and these intentions are powerful indicators to identify if students will carry out a particular conduct (Wang et al., 2023). Taking this base, The TPB explains how attitudes towards sustainability, perceived behavioural control, and subjective norms influence students' sustainability practices and engagement, while also addressing individual motivations and barriers. Sustainability practices are shaped by their individual factors and student engagement through sustainability literacy. These actions and attitudes towards environment-oriented beneficial activities are influenced by sustainability literacy. A more sustainable community and a rise in the use of sustainable practices in the institution result from students' actual behaviour towards active participation in sustainable activities, which also improve the practical use of sustainability understanding and match personal values (Ajzen, 1991; Paul et al., 2016; Tommasetti et al., 2018). Overall, TPB underscores the intricate relationship between sustainability literacy, individual factors, teacher support, student engagement and actual behaviour, i.e. sustainable practices among the students. In this context, sustainability literacy is the individual's knowledge and understanding of environmental, social and economic practices, as well as their acceptance and support towards the need for sustainability practices (Radwan and Khalil, 2021). It is a progressive process that satisfies the present needs while securing the resources for future needs (Miswanto et al., 2024). This specifically serves as a cornerstone for educational centres to engage students in sustainable practices thereby enhancing sustainable literacy. Moreover, individual behaviour comprises routines that encompass a range of consumption habits, such as dietary choices, beverage preferences, attitudes, interaction with surroundings and involvement with the environment. These activities, along with behaviours and subjective

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expectations, predominantly impact an individual's propensity to engage in widespread sustainability activities. Students engage themselves in a variety of consumption behaviour to satisfy their routine requirements and such habits depend on their lifestyle and social shifts (Abou-Hatab and Abd El Karim, 2023).

This study also deals with the relevance of other external variables including institutional support, teacher support, government initiatives and socioeconomic factors. According to institutional theory, groups imitate productive behaviour, follow rules and conform to social norms to look legitimate. Institutional theory (DiMaggio and Powell, 1983; Higgins and Larrinaga, 2014; Jarossi et al., 2011) posits that the individual behaviour may differ based on the institutional practices which includes internal policies and external pressure. Therefore, institutions prioritizing with sustainability policies by incorporating sustainability curriculum and teaching style, influences students to engage in sustained living. Essentially, it's about acculturating to be embraced by their community. Students often comply with institutions policies and government policies that promote environmental concerns, feeling compelled to blend in successful green initiatives promoted on campus. This minimal pressure motivates them to adopt sustainable practices. Consequently, societal expectations regarding positive environmental conduct further strengthens their involvement in sustainability. In consideration with all these institutions involvement, the institution's efforts, to create a better atmosphere which may include replace of plastic products to eco-friendly products, zero waste management by decomposition of waste, and generate electricity from renewable energy by installing solar panels, that inspires students to be concerned about environment and embrace them to accept sustainable practices (DiMaggio and Powell, 1983; Higgins and Larrinaga, 2014; Jarossi et al., 2011). However, teacher support in boosting these practices are unavoidable. The support and behaviour of teachers are crucial in influencing students' sustainability practices within universities. As indicated by Anthony Jnr (2021), the promotion of green practices and behaviour among both students and teachers fosters institution's culture of sustainability. Further, Radwan and Khalil (2021) say that cultural aspect among young students like language and communication style, religious belief and practices in the society and behaviour of students will affect the sustainability in universities. As a whole, institutional theory account for the impact of university initiatives, teacher support and government policies on promoting sustainable practices. These two theories together provide a comprehensive yet clear framework to understand the dynamics of sustainability practices by understanding the interconnectedness between sustainability literacy, individual factors and institutional initiative on sustainability practices through teachers support, student engagement, government support and socio-economic condition among the student community of the university.

2.2 Hypotheses development

2.2.1 Sustainability literacy and sustainability practice. Sustainability literacy plays a predominant role in remoulding individuals' behaviours and perceptions towards sustainable practices wherein teaching competencies, pedagogy approaches and learning outcomes are aligned towards sustainable transformative learning and sustainable development practices (Chinedu *et al.*, 2023). Inculcation of sustainable inhabiting practices as a routine in everyday activities can enhance students understanding of environmental crises and the interlinked reliance of ecological, economic and social systems, guiding to sustainable etiquettes and habits (Qureshi, 2020).

Leiva-Brondo *et al.* (2022) state that increasing students sustainability knowledge and motivating them transform their attitude to engage in sustainability behaviours. TPB theory suggests active participation of students in sustainability-related activities will enable the students to put their knowledge into action with change in intention. Additionally, digitalization enhances work processes, simplifies procedures leading to increased efficiency and productivity. It is imperative that institutions acquire proficiency in the use of digital tools in

order to contribute to the creation of a more sustainable environment (Sun *et al.*, 2022). Journal of Applied Enhancing student's knowledge and sustainable development skills in the digital age through an online learning process would promote both an inclusive learning environment and highquality learning outcomes. This discussion highlights that sustainable literacy is significantly vital to enhance sustainable practices. As a result, it can be hypothesized that:

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H1a. Sustainability literacy among students significantly impacts their sustainable practices.

However, students' involvement and engagement in this regard is vital. Student engagement is the willingness of a student to accept and practice sustainability. It is an emotional and temporal investment made by students in learning activities both inside and outside the classroom (Kahu, 2013), which includes student participation in education and activities related to institutional environment which supports learning and development (Kuh, 2009). Moreover, younger generation spend more time on social media platform such as linked in, twitter which persuade them to engage in progressive learning with different peer groups, which improves their social esteem towards learning and engagement in various activities related to sustainability (Mahmud et al., 2020).

Along with student participation in various activities, institution's motivation towards students also have an impact on sustainable teaching in institutions, which thereby increase critical thinking, problem solving and active participation of students (Kopnina, 2020). Additionally, institutional support positively and significantly influences sustainability development literacy with student engagement (Oi *et al.*, 2023). Hence, based on the above discussion the following hypothesis H1b has been constructed.

H1b. Sustainability literacy significantly enhances student's sustainable practices with the mediation of student engagement.

2.2.2 Individual factor and sustainability practices. TPB brings into the light that the behaviour of individual depends on the various aspects like attitudes, collaboration with surroundings, habits and their involvement with environment. These individual factors will have impact on individual's propensity to engage in widespread sustainability activities. Moreover, Piscitelli and D'Uggento (2022) say that sustainable behaviour impact lifestyle of voung people through their action and attitude in colleges. The support of TPB represents the control over perceived behaviour of students that is driven to sustainability practices. Furthermore, education for sustainable development motivates the students to participate in sustainable activities conducted by colleges thereby enhancing the sustainable practicing behaviour of the students (Maiorescu *et al.*, 2020). This indicates that sustainability education in institutions positively influences student's attitude and interest towards sustainability practice. Moreover, technology utilization enables students to adopt a sustainable lifestyle and improves sustainable literacy and habits (Qureshi, 2020). This offers a comprehensive approach to sustainability education that students adopt behavioural aspect of sustainable practices. Therefore, it is possible to hypothesize that.

H2. Individual factor significantly influences student's sustainable practices.

2.2.3 Institutional initiatives towards sustainability practice. Institutional initiatives indicate the consciousness and commitment focused towards promoting social, economic and environmental involvement to encourage better involvement of students in sustainability practices (Emanuel and Adams, 2011). Institutional theory posits that the individual behaviour may differ based on the institutional practices, which includes internal policies and external pressure. Therefore, institutions prioritizing with sustainability policies by incorporating sustainability curriculum and teaching style influences students to engage in sustained living. Researchers have shown that institutional initiatives motivate students towards sustainable practices with various sustainability initiatives implemented through research, workshops, awareness campaign, community involvement and campus operations (Menon and Suresh,

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2020) and the initiatives such as awareness and environmental knowledge, green space and land use management, use of solar panel and renewable energy, energy efficiency and water conservation, natural resource limitation, waste minimization, greenhouse gas emission reduction, environmental education programmes, research collaboration and environmental sustainability guidelines and polices in universities persuade students to get involved in sustainability practices (Mohamed *et al.*, 2020). Therefore it can be hypothesized that:

H3a. Institutional initiatives have remarkable and direct impact on sustainable practice.

The support and behaviour of teachers are crucial in influencing students' sustainability practices within universities. As indicated by Anthony Jnr (2021), the promotion of green practices and behaviour among both students and teachers fosters institution's culture of sustainability.

Additionally, Leal Filho *et al.* (2015) suggest that integration of sustainable practice into various facets of campus operations, in terms of awareness programmes, green operation and maintenance practices, implementation of green cleaning policies, awareness towards local issues, development of alternative transport strategies, coordination of procurement and evaluation of food purchasing, promotion of innovative landscape planning and maintenance, student and staff education programmes enable students to develop skills which promote enhanced follow-up towards sustainable development. Hence, H3b has been developed.

H3b. Institutional initiatives significantly enhance student's sustainable practices with the mediation of teacher support.

2.2.4 Government initiatives towards sustainability practice. Government measures are vital in encouraging sustainable practice among students, in addition to institutional efforts and teachers support. The best example for government initiative towards sustainability practice is the initiative taken up by the municipality towards compelling residents to separate biodegradable and non-biodegradable wastes, which affects students and people's attitude towards sustainability (Evans *et al.*, 2006). Furthermore, providing mid-day meals and scholarships for the students to complete their education will lead to literacy among students. Moreover, green school programme implemented by the "Centre of Science and Environment" to promote sustainability in schools has helped schools to adopt sustainable practices such as trash management, rainwater gathering and energy conversation (Education for all India, 2023). Such initiatives undertaken by the government will have a positive impact on students towards sustainability. From the above discussion H4 hypothesis has been *developed*.

H4. Government initiatives play a moderating role between institutional initiatives and student's sustainability practices.

2.2.5 Social and cultural factors towards sustainability practice. Successful implementation of sustainable practice among students is hindered by several factors. Social and cultural factor has an impact on sustainability literacy and sustainability practice. People are diverse in many ways, in terms of gender, social class, ethnicity, race, language, needs, religion, sexual orientation, nationality, citizenship status, family structure and cultural background (Lin, 2020). Lifestyle of a student depends on social and cultural background and inappropriate lifestyle. As such, practices in educational institutions will have low sustainable development (Chekima *et al.*, 2016). Moreover, Dimitrova *et al.* (2021) emphasize that barriers like lack of time, financial resources, specific information, infrastructure, and inadequate conditions pose obstacles to sustainable practices among students. Sustainability education not only promotes a culturally diverse learning environment but also enhances cultural competence, critical thinking, global citizenship and academic achievement (Matu and Perez-Johnston, 2024). Based on the above discussion H5 has been developed.

H5. Social and cultural factors moderate the relationship between sustainable literacy and sustainable practices.

3. Conceptual model

A conceptual model is a simplified illustration of an arrangement or phenomena that provides a framework for comprehension and communication via abstraction and symbolic representation. It aids in the organization of ideas, the interpretation of evidence and the prediction of outcomes within a theoretical framework. Through numerous literature and two theories such as TPB and institutional theory, the conceptual model has been formulated as per the above discussion (see Figure 1).

4. Methodology

The aim of this present study is to find out the impact of sustainability literacy on sustainability practices among graduate and postgraduate students studying in different universities across Karnataka, India. It looks at how many students from various academic disciplines such as science and technology, medical and avurveda streams, humanities and arts, commerce and management are engaged in sustainability issues. These courses were selected because they incorporate sustainability principles and address the social, economic, and environmental dimensions of sustainable development. The curriculum now includes courses like Environmental Science, Climate Change and Mitigation, Sustainable Development and Business, and Environmental Economics, like Water Quality Analysis, Environmental Policy, Law, and Management Systems, etc. (Government of Karnataka, 2022). Environmental studies (EVS) for undergraduate students and Green Technology Programs for Indian Institute of Technology for technical institutes, corporate social responsibility (CSR) for management institutes is mandatory as per University Grant Commission guidelines. Students engaged in these courses participate in practical activities such as waste management projects, water conservation efforts and energy audits. These hands-on experiences allow students to apply theoretical knowledge in real-world settings, enhancing their understanding of sustainability concepts and practices. Students involve themselves in studying international agreements like the Paris Agreement, as well as national guidelines on environmental protection and sustainability practices. Additionally, workshops and seminars are organized into further students' understanding of sustainability policies and their implications. This research study seeks to apply a descriptive design that will clarify the interplay between sustainability literacy and its manifestation through practice in a university setting.



Source(s): Developed by the researcher

Figure 1. Conceptual model

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JARHE 4.1 Research design

This study employs a research design that examines how sustainable practice and sustainability literacy are interconnected in terms of approach. The data for this study was collected from a targeted group of undergraduate and postgraduate students from university colleges, who were administered with questionnaires. These instruments consist of assessments on students' engagement levels, operationalization of their sustainability practices and proficiency in sustainability literacy (Hair *et al.*, 2016). For example, regression analysis, structural equation modelling (SEM), Karl Pearson's coefficient correlation, one-sample *t*-tests and other relevant methods are applied to investigate the gathered data (Henseler *et al.*, 2015). The focus is to evaluate to what extent sustainability practices are influenced by understanding it. Based on empirical inquiry, therefore, this research design seeks to provide empirical evidence that shows the important role played by sustainability literacy in fostering and realizing sustainable practices within educational contexts.

4.2 Population and sample

The participants in this study were graduate and postgraduate students from different universities in Karnataka, India, including affiliated colleges, private universities, central universities and deemed universities. The selection process aimed to have a varied mix of students at different education levels within the state. A pilot study was carried out initially to test the study's tools on both graduate and postgraduate students to ensure accurate and valid results. The preliminary findings from this pilot study gave us important insights and confirmed that our research approach is feasible. After the initial study, we gathered data from a group of 419 participants, with an impressive response rate of 96%. The participants were made up of 83 first-year graduate students, 81 second-year graduate students, 91 final-year graduate students, 79 first-year postgraduate students and 85 final-year postgraduate students. By including students from various academic levels and different educational institutions in Karnataka, our goal was to obtain a thorough understanding of sustainability awareness and its impact on sustainable practices among graduate and postgraduate students in the region. The research focused on students pursuing advanced degrees in various fields such as science, technology, medicine, avuryeda, humanities, arts and commerce/ management. To evaluate the relevant factors and their effectiveness, researchers utilized measuring scales that were developed specifically for the study or borrowed from previous research. The study employed rigorous scientific methods to explore the views of graduate and postgraduate students in Karnataka, India on sustainability literacy, student involvement and sustainable behaviours.

4.3 Sample profile

The target group's demographics were examined as part of the initial evaluation (see Table 1). It indicates that majority of the respondents (77.8%) are aged up to 21 years, followed by age group of 21–25 years (20%) and 2.1% are above 25 years. This distribution is in line with the study by Barreiros *et al.* (2024) where major portion of the students were aged in the range of 17–26 (76.9%). Most individuals (66%) were aged between 17 and 23, with 36% aged between 17 and 20 and 30% between 21 and 23, which was expected. However, 13.4% of respondents were over 33 years old. It reveals that 61.6% of respondents are male and remaining 38.4% are females. When residential area is considered, 45.8% of the respondents are from rural and remaining are from urban and semi-urban areas. The table exhibits that 82.8% of respondents reside at houses, remaining respondents reside at apartments and dormitories. It shows that 70.6% respondents (69.5%) use public buses to travel every day and remaining respondents use other modes of transportation like by train, by bike/car, by taxi/rickshaw and by walk. Table depicts that 56.6% respondents have a family annual income of below Rs 1 lakh and remaining respondents have family annual income of Rs 1 lakh to 5 lakhs,

Table 1. Sample profile of the students			Journal of Applied
Demographical variable	No. of respondents	Percentage	Research in Higher Education
Age			
Up to 21 years	326	77.8	
21–24 years	84	20.0	
Above 25	9	2.1	
Gender			
Male	258	61.6	
Female	161	38.4	
Residential area			
Urban	102	24.3	
Rural	192	45.8	
Semi-urban	125	29.8	
Type of residence			
House	347	82.8	
Apartment	63	15.0	
Dormitory	9	2.1	
Education level			
Undergraduate	296	70.6	
Post graduate and above	123	29.4	
Mode of transportation used everyday			
Public bus	291	69.5	
Train	13	3.1	
Bike/car	92	22.0	
Taxi/rickshaw	3	0.7	
Walking	20	4.8	
Family annual income			
Below 1 lakh	237	56.6	
1 lakh –5 lakhs	141	33.7	
5 lakhs - 10 lakhs	27	6.4	
More than 10 lakhs	14	3.3	
Source(s): Primary Data			

Rs 5 lakhs to 10 lakhs and more than Rs 10 lakhs. From the analysis, it can be inferred that there is a uniform distribution in the frequency of students among demographic variables.

4.4 Data collection

Survey questions were used to gather data for this investigation. The purpose of the survey questions is to learn more about participants sustainable practices, student engagement and to measure sustainability literacy. The survey questions included closed-ended, structured inquiries that allow participants pick their answers from pre-selected list of possibilities. The questionnaires were distributed via online form. The survey approach made it possible to gather data from a significant number of participants effectively, yielding quantitative data which can be statistically analysed to produce insightful results.

4.5 Ethical consideration

Ensuring the confidentiality and welfare of research participants is a crucial ethical responsibility. Every participant gave their informed consent, and respected their confidentiality and throughout the whole study procedure, strict confidentiality was ensured.

JARHE The study has complied with all applicable laws and ethical standards for the gathering, storing, processing, analysing and use of data. The individuals' voluntary engagement was promoted and potential threats or discomfort were reduced to a minimum. In addition, there were no conflicts of interest or biases because the investigation was carried out with fairness, transparency and sincerity. The research was carried out thoroughly and ethically, respecting the participants' rights and dignity, due to ethical considerations.

4.6 Research instruments

The researchers created a questionnaire using a variety of components drawn from the body of current literature, earlier studies, targeted focus groups, observations and their own experience. The survey was divided into several sections in order to collect thorough information. The purpose of Section 1 was to gather demographic data about the participants, such as their gender, age, residential area, type of residence, education level, mode of transportation used every day and family annual income. Section 2 aimed to assess the basic knowledge about sustainability. It included questions related to three pillars of sustainability, the natural material decomposement in the environment, their negative impact on social sustainability and the percentage of water on Earth which is fit and available for human consumption. Section 3 possessed seven vital constructs: individual factors, institutional initiatives, sustainability practices, student engagement, teacher's support, social and cultural factors and government initiatives. The number of items used to measure each construct and sources used to adapt items are represented in Table 2.

4.6.1 Measurement scale. A total of 48 statements were used to know the effect of the student's sustainability literacy, student engagement, institutional initiatives, social and cultural factors, individual factors and government activities on students' sustainability practices. This research has utilized 48 measuring items from previous investigations. Meanwhile, modest changes in phrasing were made to fit the setting of university students. Finding out how well sustainability literacy can improve the adoption of sustainable practices among students was the aim of this research. This was measured using a five-point Likert scale. The scale included five points: 1 for "strongly disagree", 2 for "disagree", 3 for "neutral", 4 for "agree" and 5 for "strongly agree". The use of this technique made it possible to evaluate the participants' mind set and opinion about research in-depth, which led to a better understanding of how sustainability literacy affected their participation and adoption of sustainable practices.

Constructs	Number of items	Sources
Students' sustainability literacy	6	Diamond and Irwin (2013) and Xia et al. (2016)
Individual factors	6	Mashroofa <i>et al.</i> (2023) and Lubowiecki-Vikuk <i>et al.</i> (2021)
Institutional initiatives	6	Leiva-Brondo et al. (2022) and Xia et al. (2016)
Sustainability practices	6	Micklethwaite (2022) and Leiva-Brondo et al. (2022)
Student engagement	6	Qi <i>et al.</i> (2023) and Leiva-Brondo <i>et al.</i> (2022)
Teachers support	7	Aleixo et al. (2021) and Smaniotto et al. (2022)
Students engagement	4	Chen <i>et al.</i> (2022)
Social and cultural factors	4	Aleixo <i>et al.</i> (2021)
Government initiatives	6	Xia et al. (2016) and Qi et al. (2023)
Source(s): Output from PLS	SEM 4	

Table 2. Constructs, number of items and sources

4.7 Data analysis

In order to examine the link between students' sustainable activities and sustainability literacy, the data analysis under this research entails doing the relevant statistical analysis. To summarize the properties of the data collected, descriptive statistics such as mean, standard deviation and frequency distributions were utilized. The reliability and significance of the association between students' sustainable practices and sustainability literacy are ascertained by the use of inferential statistical techniques, such as regression analysis or correlation analysis, and one sample *t*-test. Furthermore, SEM applied in the study, where appropriate to evaluate the direct and indirect impacts of students' sustainability literacy on sustainable practices. Meaningful insights into how sustainability literacy affects sustainable practices were sought through the data analysis process.

5. Results

5.1 Descriptive analysis

The descriptive analysis aims to provide a comprehensive understanding of university students' perceptions and engagement with sustainability practices across various dimensions. By examining mean scores and standard deviations, the analysis seeks to uncover patterns and trends in students' attitudes towards sustainability literacy, individual behaviours, institutional support, and societal influences. Understanding these perceptions can inform the development of targeted interventions and initiatives to promote sustainable practices within educational institutions and communities.

The descriptive statistics presented in Table 3 offer detailed insights into the perceptions of sustainability among university students across various dimensions. The mean scores, ranging from 3.817 to 3.984, indicate a consistently positive outlook towards sustainability across different facets. Notably, students demonstrate a robust understanding of sustainability concepts and responsibilities, as reflected in the mean score of 3.862 for sustainability literacy. This suggests a widespread acknowledgment of the importance of sustainability education among university students, with a statistically significant perception (p < 0.000). Additionally, students exhibit a strong commitment to adopting sustainable practices at the individual level, as evidenced by the high mean score of 3.938 for individual factors. This indicates an active engagement in environmentally responsible behaviours, underscoring students' dedication to promoting sustainability in their personal lives.

Furthermore, the data highlights the significant role of institutional support and educator encouragement in fostering sustainability initiatives. While students perceive moderate support from their institutions (Mean = 3.817), there is room for improvement to enhance institutional initiatives further. However, teachers are recognized for their active involvement in promoting sustainability education and fostering environmental awareness among students, with a mean score of 3.872 for teacher support. This underscores the crucial role of educators in

Construct	Mean	SD	<i>P</i> value
Sustainability literacy	3.862	0.754	< 0.000
Individual factors	3.938	0.789	< 0.000
Institutional initiatives	3.817	0.858	< 0.000
Sustainable practices	3.96	0.764	< 0.000
Teachers support	3.872	0.78	< 0.000
Student engagement	3.893	0.747	< 0.000
Social and cultural factors	3.984	0.713	< 0.000
Government initiatives	3.963	0.754	< 0.000
Source(s): Computed using SPSS			

Table 3. Descriptive statistics

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instilling sustainability values and inspiring students to participate in sustainability-related activities. Overall, the descriptive statistics underscore a positive and proactive stance towards sustainability among university students, emphasizing the importance of collaborative efforts among educational institutions, teachers, policymakers and students themselves to address environmental challenges and promote sustainable development effectively.

5.2 Measurement model

A measurement model is a subset of the general model in which latent constructs are specified. Measurement paradigms in psychology, sociology and management highlight differences between reflective and formative measurements. Analyzing the indicator loadings is the first phase in the reflective measurement model assessment procedure. It is advised to load items over 0.708 since this signifies that the construct accounts for over 50% of the variation in the indicator, resulting in satisfactory indicator reliability (Hair *et al.*, 2019). However, some of the researchers consider the threshold to be 0.6 as acceptable (Hair *et al.*, 2019). Firstly, the first-order CFA for the independent variables were evaluated which depicted numerous variables with factor loading less than 0.6. Further, SL1, SL2 and SL4 were eliminated due to low-factor loading from the construct sustainability literacy; moreover, this hindered the model fit of first-order constructs. Measurement model was run again and modified measurement model demonstrated a good result depicting outer loading of all the constructs ranging from 0.610 to 0.836. After assessing the first-order CFA, the second-order measurement model was run using Smart-PLS. Apart from the independent variables, student engagement (SE10 = 0.654, SE20 = 0.761, SE30 = 0.759 and SE40 = 0.851) and teacher support (TS1 = 0.688, TS2 = 0.751, TS3 = 0.797, TS4 = 0.818, TS5 = 0.791, TS6 = 0.832, TS7 = 0.783) depicted a good outer loading above 0.6 enabling the retention of all the indicators under these two constructs. But sustainable practices revealed issues with the two items, i.e. SP1 and SP2 due to low factor loading. Due to the lowfactor loading of SP1 and SP2, two items were removed from sustainable practices and measurement model was assessed again. The modified measurement model revealed a satisfactory result. The results depicted a favourable index of goodness of fit as recommended by Hair *et al.* (1998, 2010). Hu and Bentler (1999) and Byrne (2001, 2013) (SRMR = 0.068: GFI = 0.905; AGFI = 0.912; CFI = 0.912; NFI = 0.922; RMSEA = 0.052). The constructs to investigate the reflective measurement models, the following four parameters were looked at: Item reliability, convergent validity, indicator reliability, discriminant validity and internal consistency reliability (Hair et al., 2012, 2019; Hanafiah, 2020). According to Hair et al. (2014), the CR values in this investigation, which varied from 0.788 to 0.916, were greater than the cut-off value of 0.7. Hair *et al.* (2010) state that an alpha value of greater than 0.7 is required for the Cronbach alpha, which is also thought to be the most often used scale reliability indicator. Since every alpha coefficient value was more than 0.7, excellent dependability was shown. Additionally, Table 4 shows the factor loadings, alpha coefficient, composite reliability (CR) and average variance extracted (AVE). The AVE and CR of each construct are more than the suggested values of 0.50 and 0.70, respectively. Convergent accuracy and reliability are therefore confirmed.

Moreover, Table 5 presents a comparable demonstration of discriminant validity in compliance with the suggestion put out by Fornell and Larcker (1981). For a construct to be deemed discriminant valid, Gefen *et al.* (2000) state that the square root of AVE for each construct must be greater than the inter-correlations with other constructs. Table 5 shows that the square roots of AVE were greater than the correlation coefficients for every pair of constructs. The results provide evidence for the discriminant validity of the measures.

5.3 Structural Model

SEM is described as a mixture of variables that are latent and structural associations. The partial least squares SEM (PLS-SEM) is one of the most important research practices

Construct	Items	Code	λ	Cronbach's alpha	Composite reliability (rho_c)	Average variance extracted (AVE)
Sustainability literacy	It is every individual's responsibility to have a keen interest towards learning sustainability	SL2	0.737	0.787	0.788	0.552
	I understand the negative outcome of usage of non- biodegradable products I believe in safeguarding a human right globally in order to end poverty, human trafficking, hunger, unfair employment and so on	SL3 SL5	0.757 0.735			
Individual factors	I cultivate sustainable lifestyle to avoid harming the environment I consume sustainable diet and avoid wasting food I reuse water which are not ideal for drinking or personal use for landscape garden	IF1 IF2 IF3	0.716 0.819 0.779	0.907	0.907	0.621
	I support sustainability initiatives that prioritize a safety of globe I endorse practices that prioritize recycling, reusing and reducing waste I advise others to choose a lifestyle which are good for their health and environment	IF4 IF5 IF6	0.834 0.797 0.776			
Institutional initiatives	Our college conducts events, workshops and awareness campaigns to promote environmental consciousness and responsibility	II1	0.611	0.875	0.880	0.545
	Our college replaced plastic products to eco-friendly products	II2	0.715			
	Our institution upholds ethical commitments towards social, economic and environment	II3	0.710			
	Our college focus on biodiversity by engaging in initiatives to protect the future resources	II4	0.787			
	Our college incorporates solar panels to generate electricity from renewable energy	II5	0.765			
	Our institution is dedicated to achieve zero waste management by decomposing waste	II6	0.824			

Table 4. Factor loadings, alpha coefficient, composite reliability (CR) and average variance extracted (AVE)

(continued)

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Table 4. Continued

Construct	Items	Code	λ	Cronbach's alpha	Composite reliability (rho_c)	Average variance extracted (AVE)
Student	I recognize the importance of sustainable practices by having sustainability	SE10	0.654	0.842	0.846	0.577
engugement	I am committed to integrate sustainable principles into academic and personal life	SE20	0.761			
	I affirm the need to voluntarily participate in local sustainable initiatives by everyone	SE30	0.759			
	I would consider sustainability measures when choosing a career path	SE40	0.851			
Teacher support	Faculties in our college put an effort to educate about sustainability to students by providing necessary resources	TS1	0.688	0.916	0.916	0.610
	Teachers encourage students to conduct public awareness programmes	TS2	0.751			
	regarding social, economic and environment issues					
	Teachers are dedicated to inspire students to become agents of positive change	TS3	0.797			
	Faculties upskill students with necessary skills required for a person in his entire life	TS4	0.818			
	Teachers provide us with practical case studies to prepare us well to protect our future environment	TS5	0.791			
	Teachers take their students to practically expose the local issues	TS6	0.832			
	Teachers encourage students to be a part of sustainability development programmes like cleanliness of beach, visit the orphans and old age homes to support them emotionally, visit rural villages to enlighten the people about sustainability, so on	TS7	0.783			
Sustainability	I prefer to buy sustainable or eco-friendly products	SP3	0.800	0.803	0.801	0.502
practices	I save energy at home by using LED bulbs	SP4	0.669			
	I take part in local sustainable initiative activities	SP5	0.666			
	I enjoy planting in the surroundings of my house	SP6	0.691			
Source(s): Output	from PLS SEM 4					

Table 5. Discri	iminant validity						Journal of Applied
	Sustainability literacy	Individual factors	Institutional initiatives	Student engagement	Teacher support	Sustainability practices	Higher Education
Sustainability literacy	0.743						
Individual factors	0.715	0.788					
Institutional initiatives	0.722	0.723	0.738				
Student engagement	0.710	0.711	0.666	0.760			
Teacher support	0.708	0.709	0.654	0.743	0.781		
Sustainability practices	0.734	0.735	0.652	0.731	0.697	0.709	
Source(s): Outp	out from PLS-SEM	<i>I</i> 4					

across a wide range of fields for estimating complicated cause–effect relationship models involving latent variables (Cepeda-Carrion *et al.*, 2019). Following the measurement model's validation, the study used SEM to analyse the model. The study took into account sustainability literacy, individual factors and institutional initiatives as the endogenous variable, student engagement and teacher support as the mediators, and sustainability practice as the exogenous variable in this model.

As per the path coefficients (see Table 6 and Figure 2), sustainable literacy plays a direct significant role in enhancing sustainable practices among students (0.329). Moreover, sustainability literacy significantly contributes to student engagement in sustainable practices (0.600) and their engagement further encourages sustainable practices among students (0.121). This indicates highly engaged students depict high sustainable practices. In addition to the above-mentioned direct path estimates examination, the study also examined specific mediation effects with student engagement (see Table 6). The specific mediation effect of student engagement between sustainability literacy and sustainable practices depicted a significant but slightly low mediation ($SL \rightarrow SE \rightarrow SP = 0.073$). This indicates that sustainability literacy alone can enhance sustainable practices (Direct Effect = 0.329) (H1a), but through the mediation of student engagement the effect increases with the total

Hypothesis	Relationship	Path coefficients	<i>P</i> value	
H1	$SL \rightarrow SP$	0.329	HS	
	$SL \rightarrow SE$	0.600	HS	
	$SE \rightarrow SP$	0.121	HS	
	$SL \rightarrow SE \rightarrow SP$	0.073	S	
H2	$IF \rightarrow SP$	0.124	HS	
H3	$II \rightarrow SP$	0.107	HS	
	$II \rightarrow TS$	0.643	HS	
	$TS \rightarrow SP$	0.192	HS	
	$\mathrm{II} \to \mathrm{TS} \to \mathrm{SP}$	0.123	HS	

Note(s): HS = Highly Significant; S = Significant; SL = Sustainability Literacy; SE = Student Engagement; SP = Sustainable Practices; IF = Individual Factors; II = Institutional Initiatives; TS = Teacher Support **Source(s):** Output from PLS-SEM 4

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effect of 0.402 (H1b). As a result, H1 holds true. Similarly, individual factors of the students also play a significant role in their sustainable practices (0.124). Therefore, H2 holds true. This result is consistent with Maiorescu *et al.* (2020) who emphasizes the relevance of education for sustainable development in enhancing student participation in sustainable activities conducted by colleges thereby enhancing the sustainable practicing behaviour of the students. This indicates that sustainability education in institutions positively influences student's attitude and interest towards sustainability practice.

In addition, impact of institutional initiatives in boosting sustainable practices found to be significant (0.107). This result argues that institutional initiatives have remarkable and direct impact on sustainable practices. Moreover, institutional initiatives remarkably amplify teacher support towards sustainable practices among students (0.643). Therefore, institutional initiatives play a significant role in boosting teacher support in sustainable practices. Previous studies by Menon and Suresh (2020) and Mohamed et al. (2020) have also shown that institutional initiatives through research, workshops, awareness campaign, community involvement, green space and land use management, use of solar panel and renewable energy, energy efficiency and water conservation motivate students towards sustainable practices. Furthermore, teacher support depicted direct and significant impact on sustainable practices among students (0.192). As far as mediation effect of teacher support is concerned, teacher support depicted significant mediation effect between institutional initiatives and sustainable practices (II \rightarrow TS \rightarrow SP = 0.123). This indicates that institutional initiatives alone can enhance sustainable practices (Direct Effect = 0.107) (H3a), but through the mediation of teacher support the effect drastically increases with the total effect of 0.230 (H3b). This indicates that institutional initiatives towards sustainability significantly boosts sustainable practices among students when they are encouraged and supported by their teachers. As a result, H3 holds true.

The SEM results justify the fact that when the students have sustainability literacy in the form of varied curricular with Environmental Science, Climate Change and Mitigation, Sustainable Development and Business, National Service Scheme (NSS), etc. It enhances their understanding on sustainability principles and theories, hands-on experience, sustainability laws, legal and policy aspects through institutional support, continuous student engagement and teacher support. This is vital for building green ecosystems to enhance sustainability practices for a sustainable future.

5.4 Moderation analysis

In social and behavioural research, moderation analysis is a widely used technique. Moderated multiple regression (MMR) is one of the models for moderation analysis that is most commonly used (Yuan *et al.*, 2014). In the present study, government initiatives and socio-cultural factors have been considered as a moderator considering the previous literature.

Table 7 indicates that government initiatives significantly alter the influence of teacher support on students' sustainable practices. Students depicting high level of agreement on government initiatives considered the teacher support to be a major contributor towards sustainable practices ($\beta = 0.523$, p = 0.000) compared to low ($\beta = 0.515$, p = 0.000) and moderate level of agreement ($\beta = 0.378$, p = 0.000). This implies that students with high agreement on government initiatives highly consider teacher support in practicing sustainability compared to other students. Hence, the relationship between teacher support and sustainable practices is moderated by government initiative. This proves H4 to be true. This has also been found true by Education for all India (2023) where green school programme implemented by the "Centre of Science and Environment" promoted sustainability in schools, has helped schools to adopt sustainable practices such as trash management, rainwater gathering and energy conversation.

Government initiatives	Sustainability literacy	R	R^2	Adjusted R^2	F	Р
Low						
β	0.515	0.515	0.265	0.258	39.308	0.000
t	6.27					
р	0.000					
Moderate						
β	0.269	0.269	0.073	0.068	15.489	0.000
t	3.936					
р	0.000					
High						
β	0.523	0.523	0.274	0.267	39.975	0.000
t	6.323					
р	0.000					
Socio-cultural factors	Student engagement	R	R^2	Adjusted R^2	F	Р
Low						
β	0.231	0.231	0.053	0.046	7.064	0.009
t	2.658					
р	0.009					
Moderate						
β	0.378	0.378	0.143	0.138	30.009	0.000
t	5.478					
р	0.000					
Hiah						
В	0.446	0.446	0.199	0.191	26.762	0.000
Т	5.173					
Р	0.000					
Note(s): Dependent Vari	able: Sustainable Practice	5				

Table 7. Moderation of government initiatives and socio-cultural factors

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The results also highlight the moderation of socio-cultural factors between student engagement and sustainable practices. The model was found to be significant among the students who depicted low (F = 7.064, p = 0.009), moderate (F = 30.009, p = 0.000) and high level of agreement on socio-cultural factors (F = 26.762, p = 0.000). Additionally, contribution of student engagement to sustainable practices differed between the students having low ($\beta = 0.231$, p = 0.009), moderate ($\beta = 0.378$, p = 0.000) and high level of agreement on socio-cultural factors ($\beta = 0.446$, p = 0.000). It indicates that student engagement boosts sustainable practices to a greater extent among the students demonstrating high level of agreement on socio-cultural factors. Overall, socio-cultural factors significantly moderate the relationship between student engagement and sustainable practices. Therefore, H5 holds true.

6. Discussion

In the quest for sustainable development, combating unsustainable practices are the critical obstacle which has made a substantial contribution to resource depletion, environmental damage and the escalation of climate change. As a result, adopting the idea of sustainable practice is essential in paying the path to a sustainable future (Ahamad and Ariffin, 2018). Considering its relevance, the present study targeted students to assess how effectively the sustainability literacy, institutional initiatives and individual factors have contributed to their sustainable practices by giving due consideration to teacher support and student engagement. Previous studies have strongly argued that one of the most significant group of people involved in creating a more sustainable society is the student community (Aleixo et al., 2018; Wachholz *et al.*, 2014). The study initially explored student perception towards these practices, where students strongly perceive that it is every individual's responsibility to have a keen interest towards learning sustainability and cultivating a sustainable lifestyle to avoid harming the environment. Moreover, present research discovered a strong contribution of sustainability literacy and institutional initiatives on students' sustainable practices. Furthermore, student's individual factors and personal interest also played a predominant role in boosting their sustainable practice as per the results. In addition, we have made an attempt to assess the presence of student engagement and teacher support in impacting their sustainable practices, which proved that student engagement is vital to boost the impact of sustainability literacy on their sustainable practices. Also, teacher support is pivotal in amplifying the contribution of institutional initiatives on their sustainable practices. This indicates the relevance of teacher support and student engagement in building sustainable friendly practices among students. The study also implies that students with high agreement on government initiatives highly consider teacher support in practicing sustainability compared to other students and also student engagement boosts sustainable practices to a greater extent among the students, who have depicted high level of agreement on socio-cultural factors. The results wholly emphasized the relevance of institutional initiatives, sustainable literacy, teacher support, student engagement, socio-cultural factors and government initiatives in encouraging student sustainable practices.

As far as the previous studies are concerned, most of the results have depicted the convergent findings with the present findings. Student's positive perception on sustainable literacy and practices are also supported by the findings of Aleixo *et al.* (2021), who reported that majority of students are worried about climate change; most of them supportive towards reusing, reducing, and recycling actions. However, same study argues that despite a large number of students depict pro-sustainable behaviours, less actively they participate in organized sustainability activities like environmental volunteering, demonstrating a disconnect between individual habits and collective action. Current results, add on to the existing studies by further adding institutional support, individual factors, student engagement and teacher support in boosting student sustainable practices. In line with this result, Leal Filho *et al.* (2019) also argue that universities have a great potential to address sustainable

development via concrete activities, thus they should play a more active role in driving the Journal of Applied change sparked by the SDGs, given their powerful position. Numerous institutions have started incorporating sustainability into their curricula in response to the increased demand for environmentally friendly education (Tripon et al., 2023). These studies have recommended institutional support to be the significant player to enhance sustainable practices but present study has taken a step forward to test its relevance with teacher support in amplifying student sustainable practices. In convergence, Tripon et al. (2023) recommend teachers to promote genuine interaction between them and the students they teach. This may be accomplished by building forums for student discussion, using private messaging systems, or just soliciting student input regularly on sustainable issues. However, results prove that student's active involvement and engagement are also vital to convert their sustainable literacy into sustainable practices which also support the idea of Figueredo and Tsarenko (2013), who report that students' participation in sustainability initiatives is strongly impacted by their interest in environmental concerns.

7. Conclusion

Current research explored the role of sustainability literacy, institutional initiatives and individual factors in impacting university students' sustainable practices. Moreover, study also examined the significant role of student engagement and teacher support in boosting sustainable practices among students. In-depth pivotal moderating influence of government initiatives and socio-cultural factors have been pondered upon in the present study. A structured questionnaire with quantitative research design exhibited diversified findings that needs immediate attention. Firstly, the study found that students need to have strong sustainable literacy, institutional initiatives and individual factors to amplify their sustainable practices. The sustainable practices such as planting in the surroundings, taking sustainable decision, using public transportations, buying sustainable or eco-friendly products, taking part in local sustainable initiative activities, etc. Will have long-term impact on sustainable growth among later generation to avoid resourceless society. Moreover, mediating influence of teacher support and student engagement were also observed in the current research. However, student's socio-cultural environment and government initiatives also played a moderating role in uplifting their sustainable practices. The results illuminate the involvement of all the stakeholders in contributing to sustainable future through sustainable practices.

7.1 Novelty and practical implications

The current study addressed many gaps in the realm of sustainability in educational setting by examining the influence of sustainable literacy, institutional initiatives and individual factors on student sustainable practices by giving due consideration to student engagement and teacher support. This study has several ramifications and contributions for university students, teachers and institutions as a whole. To begin, no study has addressed the influence of all the above factors together on student sustainable practices; hence, this study contributes to the current literature by emphasizing the importance of literacy, institutional effort, teacher support, government initiatives, socio-cultural and individual factors altogether. As findings suggest that teacher support is a key factor in encouraging students to do sustainable actions, they should concentrate on innovative, sustainability-driven projects. For instance, teachers might urge students to take part in urban agricultural initiatives, cleanliness of beach, seminars on renewable energy, waste-to-resource programmes where students explore scalable strategies for optimizing resources, alongside producing goods using recycled materials. Participating in such activities not just improves practical skills but also enhances understanding of overall sustainability problems. Moreover, institutions may establish innovation laboratories or sustainability accelerators in which students can work together on real-world projects which addresses challenges such as climate change, water conservation and sustainable agriculture.

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Institutions may also collaborate with companies and local governments to offer sustainability internships, which may provide students direct involvement with green technology as well as sustainable business practices. It is also advised to policymakers to promote the incorporation of mandatory courses like, Environmental studies, Global Environmental Challenges, SDGs, Digital Citizenship and Sustainable Development and Social Responsibility to their curriculum in higher education programs to produce graduates who are well-equipped for the future and have an intense devotion to sustainability. These innovative approaches will motivate students to take an active role in environmental as well as economic sustainability, guaranteeing that sustainability becomes fundamental throughout their educational journey. Hence, institutional initiatives, socio-cultural factors and government initiatives at the same time their individual interest is predominant to build a sustainable future.

7.2 Limitations and future scope

Like earlier investigations, the current study has few limitations. This study focuses entirely on students' perspective in assessing how widely external factors contribute to their sustainable practices. However, greater attention must be needed to assess all the stakeholder's perspective to better understand the sustainability issues in higher educational settings. SDG's being the ultimate goal of entire globe, addressing it in the grassroot level is significant by giving due emphasis to educational setting. More studies are encouraged to assess sustainability in education and its impact in accomplishing 17 SDGs. Further, there is a scope to conduct experimental research by enabling the implementation of sustainable equipment and resources in the college environment, thereby assessing how the sustainable practices vary between the institutions with normal equipment and resources in comparison to the above institutions. This study limits its scope to educational setting and gives no importance towards parental upbringing and influence which can be addressed in the future research. Further, present study included major portion of the students aged below 25 years as the study population was undergraduate and postgraduate students causing potential bias in the sample. As a result, future study is recommended for diverse age range to enhance the generalizability of this study. Moreover, in the long run, future studies can ponder more on digitalization and sustainability to build sustainable culture in educational environment.

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ARTICLES FOR UTM SENATE MEMBERS

"Integrating Climate Education and Sustainability into University Curricula: Challenges and Strategies"

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8) Sustainability Integration in Philippine Higher Education Curricula A Structural Equation Modelling Assessing Teacher Intention to Integrate Sustainability Switzerland (2024)

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Article Sustainability Integration in Philippine Higher Education Curricula: A Structural Equation Modeling Assessing Teacher Intention to Integrate

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Abstract: Incorporating sustainability principles into university and college course offerings is pivotal in molding future leaders and innovators. This study focuses on the Philippines, where higher education institutions (HEIs) increasingly embed sustainability into their academic and operational frameworks. This study aims to quantitatively assess the level of teacher intention to integrate sustainability into curricula in higher education. Utilizing the expanded Theory of Planned Behavior (TPB), it examines the relationships between sustainability knowledge, concern for sustainability, perceived behavioral control, subjective norms, attitude towards sustainability integration, and the intention to integrate sustainability. The methodology involves a cross-sectional study using a web-based survey disseminated through multiple platforms. The sample size was determined through a priori calculation and proportional stratified sampling, with 227 respondents. Utilizing Structural Equation Modeling (SEM) and the Theory of Planned Behavior (TPB), this study uncovers that educators' attitudes notably shape intentions to integrate sustainability into curricula. While the direct effect of perceived behavioral control is limited, institutional support is deemed to be crucial. Additionally, sustainability concerns strongly influence educators' intentions, emphasizing the necessity for environmental awareness. These findings inform policymaking and underscore the significance of fostering sustainable practices in higher education through institutional support and awareness initiatives. Finally, this study aims to enhance the effectiveness of sustainability education in the Philippines and contribute to global sustainability efforts.

Keywords: sustainability; higher education; curriculum integration; extended theory of planned behavior; structural equation modeling

1. Introduction

Sustainability integration in higher education curricula is increasingly recognized as a critical factor for shaping future leaders and innovators. Universities serve a crucial function in transitioning towards sustainability by not just imparting knowledge of the idea but also taking part in the creation and implementation of policies [1,2]. The multifaceted nature of sustainability encompasses ecological, economic, and social pillars, necessitating an integrated approach in education [3,4].

Sustainability in higher education curricula is critical for promoting transformative learning and encouraging the integration of different values and perceptions of sustainability into personal and professional life. In a study by Kennelly, J. et al. (2008) [5], integrating sustainability into education shapes educators' identities and practices, influencing their professional approach and pedagogy. This commitment extends the impact beyond personal and professional practices, aiming to foster a future generation that values and



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and practices sustainability. It necessitates an integrated approach to education, integrat-

ing interdisciplinary methods and encouraging global citizenship and social responsibil-practices sustainability. It necessitates an integrated approach to education, integrating [17] [6]. interdisciplinary methods and encouraging global citizenship and social responsibility [6]. Effective sustainability education requires educators who are not only knowledgeable ble but also equipped with the necessary competencies and skills [6]. Studies have shown notable gap in the training and preparation of educators in this field. Studies have shown that while there is an increasing willingness among teachers to integrate sustainability that while there is an increasing willingness among teachers to integrate sustainability into their teaching, many lack the requisite training and preparation for the eachers to integrate sustainability that while there is an increasing willingness among teachers to integrate sustainability into their teaching, many lack the requisite training and more sum of the substainability that while there is an increasing willingness among teachers to integrate sustainability into their teaching. into their teaching, many lack the requisitet raining and knowledge [2] 1911 Study [dis cussed two significant teacher education projects in Asia and the Facific, emphasizing their aim to integrate sustainability into education. Teachers and educators showed a willingness to embrace sustainability by octively participating in these projects, which ixelyee dritical reflection, the adaptition of teaching modules to local contexts, and the promotion of experimitial and natificipatory learning in promotion of experimental and participatory in the enader or various francings and know was a war a widen tim the discipation of the parameters of ŧŧġŧbŧrs.tsis.nustainąbility.tspeinspræsphagizing.tbecnesd.tor.mesn.commensiens;iven.culturj relevante and neienteachter clarica durations paragrave interactive la resolution and civile stratansustative abilities into geochings practices gallage bight is be considered to consider the construction maximante at a characteristic and the second second the second second second second second second second second within the malned tertion education.

In the Philippines, as in many other countries, higher education institutions (HEIs) have focused on integrating sustainable development into their educational programs and operations[[1,2]]. The unique socio-economic and environmental context of the Philippines adds complexity to the higher education integration of subiability of the allenges is icleddelinianaetpuptateesesunaesesinistifiiziienutudeekteutalinging sulstastraibidibilitonucuptopasi, a the the edeter for moments in the second strategies and the second strategies and the second second

The Philippines, as a signatory to Agenda 2030 along with the creation of the Philipprime Council for Sustainable Development [13], has made significant efforts to integrate sustaimable development into highereducation VaVious acaded intervet which the the ExincinomentaltEdEdationionerWebykowkthé PleiRhyblingsines. LiEEN(PEA)the Phinlippinepaise Association contractive Level Educations thrushing tion Environment and Anotection Mand Managam MATTEPAARD ANA)e been best interturbantal viocading cating furtely is integration-Fiducation and acoustic and interactive and interactive and the sector of the sector o thereptopilasities sets a statistic block of the providence of the set of the

The move towards incorporating sustainability in higher education could have a worldwide effect. By educating future laders and processional who are wreller seach insustational or practices and incinetic lengthic hear a currentions institution and concentrative the the drophom or to bab had not contain a second s future177. Molecoverule global context of education in sustainability is shaped by international frameworks and agreements such as the United Nations Sustainable Development Coals as show in Figure 1 [18].



Figure 1. The 17 United Nations Sustainable Development Goals (https://sdgs.un.org/goals, accessed on 20 January 2024).

These goals offer a common structural model for higher education institutions around the world to align their sustainability efforts and collaborate on global challenges [19]. As stated in a study, higher education holds vital importance in bringing about sustainable change on a global scale [20]. Overall, the growing importance of the drive for sustainability in higher education stems from the necessity for institutions to take responsibility for promoting sustainable practices, tackling worldwide issues like climate change, and preparing students to become future leaders in a sustainable world [21–23].

Higher education institutions are embedding sustainability into their infrastructure and curriculum, thereby enhancing students' understanding of environmental and societal challenges. This integration is also crucial in promoting research and innovation in sustainability, contributing to the development of effective and practical solutions [24–26].

Globally, there is a growing acknowledgment of the significance of integrating sustainability into higher education. However, significant barriers exist, including a lack of comprehensive training for educators, an insufficient incorporation of the principles of sustainability into educational syllabuses, and the complexity of implementing interdisciplinary approaches [27]. These challenges reflect a broader issue within the global education system, where sustainability is often not a core focus, thereby limiting the development of fully competent and prepared graduates in this field [28].

In addition, the incorporation of sustainability principles into higher education systems is recognized as a crucial step towards addressing environmental challenges. However, progress has been limited, and there is a need for innovative pedagogical approaches and a more holistic integration of sustainability principles across university functions [29]. Considering these challenges, the current study aims to assess teachers' intentions to integrate sustainability into higher education curricula. In this study, assessment is vital for understanding the roles and responsibilities of teachers from higher education institutions in fostering sustainable education. It contributes to evaluating the effectiveness of sustainability teaching, research, and practice within higher education settings [30–35]. Thus, to bridge the disparity, the present research examined a range of factors related to teachers' intentions. The behavior towards the integration of sustainability into higher education curriculum was also explored, among the perception of the teachers towards the sustainability integration in higher education curricula. Therefore, the researchers utilized the expanded Theory of Planned Behavior (TPB) [36] to explore and quantify the respondent's intention. This study will also help to recognize obstacles to the integration of sustainability and determine the effectiveness of current practices, thus offering insights into how higher education can more effectively contribute to global sustainability efforts [30–35].

This research has two primary objectives: Firstly, to create and evaluate an expanded version of the Theory of Planned Behavior (TPB) for its effectiveness in explaining teachers' motivation to include sustainability in their teaching plans. Secondly, to identify which elements in this enhanced model significantly impact this intention. This study aims to further the understanding of TPB as a tool for explaining intentional behaviors in educational settings. It aims to illuminate the diverse direct and indirect elements influencing educators' intentions within their professional environments. Additionally, by augmenting the original TPB framework, the research will gather concrete evidence to determine whether this expanded model effectively and succinctly explains teachers' intentions to incorporate sustainability into their curricula. This study revolves around these key research questions:

- 1. How effectively does the expanded TPB model explain teachers' intentions in the integration of sustainability into their curricula?
- 2. What are the crucial factors within the expanded TPB model that play a role in shaping teachers' intentions to include sustainability in their curricula?
- 3. What factors serve as intermediaries in influencing teachers' intentions to incorporate sustainability into their curricula?

What factors serve as intermediaries in influencing teachers' intentions to incorporate 3. sustainability into their curricula? Sustainability 2024, 16, 3677

1.1. Theoretical Framework and Hypotheses Development

Following the extended all reany work Blaring dt Bela Deiwork 2001 tas the theoretical research model, the structure of the proposed framework is shown in Bigwe 2 Ju detail he bar proposed frameworks is s eses are drawn for sixedohstructus than altheattippeted owards statuability Figures ratio details 11 hyjective norm, perceived behavioral control, sustainability knowledge, sustainability con-subjective norm, perceived behavioral control, sustainability knowledge, sustainability cern, and intention to integrate sustainability. concern, and intention to integrate sustainability.



Figure 2. Proposed respared framework.

1.2. Sustainability Integration 1.2. Sustainability Integration The incorporation of sustainability into the curricula of higher education institutions The incorporation of sustainability into the surricula of bigher education stiputions ation is a multi-faceted isballerizesos widigs both astrbace give phanding activitidal mobile hier faces challenges. Studies indicate that while strategic of a subject of the strategic of the subject o for sustainable assessment toplarand in teachacking for justainable assessment toplarand in teachacking for sustainable assessment to be assessed as the teachacking for sustainable assessment to be assessed as the teachacking for sustainable assessment to be assessed as the teachacking for sustainable assessment to be assessed as the teachacking for sustainable as the tion in teaching and researchp Another study highlights the importance of developing sustainability competencies in teacher training programs, aligning with Sustainable Devel-1.3. Components of the Extended TPB Model opment Goals, and promoting a polistic educational approach [31–33].

The importance of sustainability knowledge in higher education is highlighted through 1.3. Components of the Extended Life. Shepflard (2008) [34] emphasizes the need for effective learning out-1.3.1. Sustainability Rnew ledge inability education, suggesting that understanding sustainability concepts

The importance not interview between the staff through numerous studies. Shephard (2008) [34] emphasizes the need for effective learning outcomes in sustainability education, suggesting that understanding sustainability concepts is not enough; there must be a deeper emotional and value-based connection with sustainability issues. Barth and Rieckmann (2016) [35] focus on the role of academic

development as a catalyst for curriculum change, indicating that enhancing the sustainability knowledge of educators can lead to more effective integration of sustainability in curricula. Lozano et al. (2013) [36] discuss the importance of sustainability declarations in universities as a tool for aligning teaching practices with sustainability goals. Ceulemans and De Prins (2010) [37] highlight the need for specific teaching manuals and methods for integrating sustainability, suggesting that structured guidance can enhance educators' ability to impart sustainability knowledge. Wiek et al. (2011) [38] propose a framework for key competencies in sustainability, underlining the structured approach to developing sustainability knowledge in higher education. Based on this discussion researcher proposes, the following hypotheses were selected:

Hypothesis 1 (H1). Sustainability Knowledge positively influences Intention to Integrate Sustainability.

Hypothesis 2 (H2). Sustainability knowledge positively influences perceived behavioral control.

Hypothesis 3 (H3). Subjective norm is influenced by sustainability knowledge.

Hypothesis 4 (H4). *Attitude towards sustainability integration is influenced by sustainability knowledge.*

1.3.2. Sustainability Concern

Studies emphasize the role of sustainability concerns in influencing educators' teaching practices. Stern (2000) [39] establishes a connection between personal concern about environmental issues and behavior, suggesting that increasing sustainability concern among educators can influence their teaching practices. Kollmuss and Agyeman (2002) [40] explore barriers to pro-environmental behavior, indicating that understanding these barriers can help develop strategies to increase sustainability concerns. Hsu and Roth (1998) [41] emphasize the role of environmental literacy, suggesting that higher sustainability concern leads to more responsible environmental behavior. Hungerford and Volk (1990) [42], demonstrating that education can change learner behavior towards the environment and highlighting the importance of fostering sustainability concern through education. Marcinkowski (2011) [43] discusses predictors of responsible environmental behavior, suggesting that enhancing sustainability concerns is the key to promoting such behavior. Accordingly, the following hypotheses are suggested:

Hypothesis 5 (H5). Sustainability concern positively influences the intention to integrate sustainability.

Hypothesis 6 (H6). Perceived behavioral control is influenced by sustainability concerns.

Hypothesis 7 (H7). Subjective norm is influenced by sustainability concerns.

Hypothesis 8 (H8). *Attitude toward sustainability integration is influenced by sustainability concerns.*

1.3.3. Perceived Behavioral Control

Perceived behavioral control is a key factor influencing behavior within the framework of sustainability integration. Ajzen (1991) [30] introduces the Theory of Planned Behavior, including perceived behavioral control as a crucial factor. Bandura (1989) [44] discusses human agency in social cognitive theory, suggesting that educators' belief in their capability to integrate sustainability can influence their actions. Borg and Galluzzo (2012) [45] focus on measuring perceived behavioral control for learning and teaching sustainability practices, indicating its measurable and influential nature in education. Tilbury (1995) [46] talks about the need for environmental education for sustainability, suggesting that perceived behavioral control can be enhanced through specific educational strategies. Thomas (2009) [47] highlights the role of critical thinking and transformative learning in

Hypothesis 9 (H9). Intention to integrate sustainability is influenced by perceived behavioral control.

1.3.4. Subjective Norm

Subjective norms significantly influence how sustainability is approached in education. Beery and Vulturius (2015) [48] discuss the importance of resilience, sustainability, and vulnerability in environmental planning, indicating the role of subjective norms. Sugito (2013) [49] explores the role of reflective practice in sustainability, suggesting that educators' perception of social norms influences their approach. Kopnina (2016) [50] focuses on the role of ESD as a catalyst for curriculum green reform, indicating that subjective norms can drive the adoption of sustainability in higher education. Leal Filho et al. (2016) [51] talk about the implementation of integrative approaches to sustainability, suggesting that subjective norms among educators and institutions influence these approaches. Lozano et al. (2017) [27] discuss the connection between competencies and pedagogical approaches, indicating the role of subjective norms in their selection and effectiveness. Based on the discussion above, the proposed hypotheses are as follows:

Hypothesis 10 (H10). Intention to integrate sustainability is influenced by subjective norms.

1.3.5. Attitude towards Sustainability Integration

The attitude of educators towards sustainability integration plays a crucial role in its effectiveness. Verhulst and Lambrechts (2015) [52] emphasize the need for change management in incorporating sustainable development, suggesting the importance of educators' attitudes. Wals (2014) [53] reviews learning processes in the context of the UN Decade of Education for Sustainable Development, underlining the importance of positive attitudes. Barth et al. (2007) [54] discuss the creation of essential skills for fostering sustainability, implying the vital role of educators' attitudes. Cotton et al. (2009) [55] explore the challenges within sustainable development education, indicating the criticality of attitudes in overcoming these challenges. Lozano (2010) [56] examines the dissemination of sustainable development principles in university curricula, emphasizing the influence of educators' attitudes on its integration. As a result, the researchers hypothesize the following:

Hypothesis 11 (H11). *Intention to integrate sustainability is influenced by attitude towards sustainability integration.*

2. Materials and Methods

A cross-sectional approach will be used to assess the research investigation's findings. The researchers distributed an online questionnaire through a survey link across multiple platforms, including Facebook, Twitter, LinkedIn, and email. The A priori sample size calculation for structural equation models [57] will be used for applications such as advanced methods for analyzing multivariate data in the second generation (e.g., CB-SEM, PLS-SEM). Siddiqui (2013) stated that structural equation models require at least 100 samples, and preferably are applied to samples of 200 and more [58]. The proportional stratified method was used to choose the sample population with a random sampling observation of at least 200 respondents. The researcher employed an online tool to establish the required sample size specifically needed for structural equation models beforehand. The researchers surveyed a group of 300 participants, specifically faculty in tertiary-level higher education, using the 30-item online survey. Out of the 300 online questionnaires distributed, 227 were returned, resulting in a 75.67% response rate [59].

2.1. Participants

In this research, 227 teachers from 15 different tertiary institutions in Laguna voluntarily participated. The teachers were invited by the researchers and those who accepted the invitation were provided with a Google Form link to the online survey. Out of the participants, 174 (76.65%) were female, with a mean age of 33.03 years (σ = 8.83). On average, teaching experience among the participants was 8.27 years (σ = 8.29). Most of the participants, 75.6%, held at least an undergraduate degree. They were all informed about this study's objectives and their right to withdraw at any time via the online instructions. No incentives were offered for participation, and it took most participants 20 min or less to complete the form.

2.2. Questionnaire

For this study, a self-administered questionnaire was created based on the theoretical framework to assess teachers' intention in sustainability integration in higher education curricula. The questionnaire is divided into six sections as outlined in Table 1: (1) attitude towards sustainability integration, (2) subjective norm, (3) perceived behavioral control, (4) sustainability knowledge, (5) sustainability concern, and (6) intention to integrate sustainability.

For assessing sustainability knowledge, items in the survey included teachers' understanding of sustainability concepts, familiarity with the United Nations' Sustainable Development Goals, and confidence in teaching sustainability-related topics, citing works by Smith et al. (2021) [60] and Sterling S. (2018) [61], among others.

Sustainability concern was evaluated through questions on concern about environmental issues, the importance of addressing social injustices as part of sustainability, motivation to teach sustainability, engagement in sustainability activities, and viewing sustainability teaching as a moral responsibility, referencing Stern P.C. (2000) [39], Wiek A. et al. (2011) [38], and others.

Perceived behavioral control was measured by assessing access to resources, institutional support, confidence in adapting teaching methods, autonomy in course content decisions, and professional development opportunities related to sustainability, citing Ajzen I. (1991) [30] and Grob A. et al. (2013) [62].

Subjective norms were gauged through questions on colleagues' encouragement, institutional pressure, student expectations, consultations with colleagues, and influence from experts in the field, with references to Ajzen I. (1991) [30] and Lozano R. et al. (2015) [63].

Attitudes towards sustainability integration were assessed by determining the perceived enhancement of education relevance, inspiration for critical thinking, contribution to holistic student development, the role of higher education in global challenges, and ethical obligations, citing Barth M. et al. (2020) [54] and Lotz-Sisitka H. et al. (2015) [64].

Lastly, the intention to integrate sustainability was measured through a commitment to integrating sustainability in the curriculum, planning for incorporation, seeking professional development opportunities, influence from successful integration stories, and belief in enhanced student engagement and learning outcomes, referencing Hultén P. et al. (2014) [65] and Cheng A. S. et al. (2016) [66].

Each of these latent segments includes 5 measurable variables in Structural Equation Modeling, assessed via a 5-point Likert scale [67].

Latent Variables	Acronym	Questions	Reference
	SK1	I possess a strong understanding of sustainability concepts.	Smith et al., (2021) [60]
	SK2	I am well-informed about the United Nations' Sustainable Development Goals (SDGs)	United Nations (2015) [18]
Sustainability Knowledge	SK3	Sustainability education is essential for future generations.	Sterling, S. (2018) [61]
-	SK4	I feel confident in my ability to teach sustainability-related topics.	Ajzen, I. (1991) [30]
-	SK5	I actively seek opportunities to enhance my sustainability knowledge.	Wals, A. E. et al. (2010) [68]
	SC1	I am deeply concerned about environmental issues.	Stern, P. C. (2000) [39]
	SC2	I believe that addressing social injustices is a critical aspect of sustainability.	Wiek, A. et al. (2011) [38]
Sustainability Concern	SC3	I am motivated to teach sustainability to contribute to a more sustainable future.	Borg, R. et al. (2019) [69]
	SC4	I actively engage in discussions and activities related to sustainability.	Leal Filho, W. et al. (2019) [70]
	SC5	Teaching sustainability is a moral responsibility.	Levy, D. et al. (2021) [71]
	AT1	I believe that integrating sustainability into higher education curricula enhances the relevance of education.	Barth, M. et al. (2020) [72]
	AT2	I think that sustainability education can inspire critical thinking and problem-solving skills in students.	Lotz-Sisitka, H. et al. (2015) [64]
Attitude towards Sustainability Integration	AT3	Sustainability integration contributes to the holistic development of students.	Wright, T. et al. (2017) [73]
	AT4	I value the role of higher education in addressing global sustainability challenges	Wals, A. E. et al. (2002) [74]
	AT5	I consider sustainability integration in higher education as an ethical obligation.	Grimm, N. B. et al. (2019) [75]
	SN1	My colleagues encourage and support the integration of sustainability into the curriculum.	Ajzen, I. (1991) [30]
	SN2	I feel social pressure from my institution to incorporate sustainability into my teaching.	Wiek, A. et al. (2017) [38]
Subjective Norm	SN3	Students expect sustainability to be part of their higher education experience.	Lozano, R. et al. (2015) [63]
	SN4	I consult with colleagues before making decisions about sustainability integration.	Blewitt, J. (2003) [76]
	SN5	I am influenced by the opinions of sustainability experts in my field.	Perrault, E. K. et al. (2020) [77]
	PB1	I have access to the necessary resources and materials to teach sustainability effectively.	Ajzen, I. (1991) [30]
	PB2	My institution provides adequate support for integrating sustainability into the curriculum.	Grob, A. et al. (2013) [61]
Perceived Behavioral Control	PB3	I feel confident in my ability to adapt teaching methods to incorporate sustainability concepts.	Krasny, M. E. et al. (2010) [78]
	PB4	I have the autonomy to make decisions about sustainability content in my courses.	Wiek, A. et al. (2017) [38]
	PB5	I regularly receive professional development opportunities related to sustainability teaching.	Sterling, S. et al. (2017) [79]
	IS1	I am committed to integrating sustainability into my higher education curriculum in the next academic year.	Hultén, P. et al. (2014) [65]
	IS2	I have clear plans to incorporate sustainability topics into my course content.	Bryce, D. et al. (2016) [80]
Intention to Integrate Sustainability	IS3	I am actively seeking professional development opportunities to enhance my ability to integrate sustainability.	Dlouhá, J. et al. (2019) [81]
	IS4	I am influenced by the success stories of other educators who have integrated sustainability effectively.	Lozano R. et al. (2019) [82]
	IS5	I believe that integrating sustainability will enhance student engagement and learning outcomes.	Cheng, A. S. et al. (2016) [66]

Table 1. The development and evaluation of measurement components.

2.3. Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) offers distinct advantages compared to traditional data analysis methods. It allows for the assessment of the impact of theoretical constructs, commonly referred to as latent variables [83]. SEM provides an extensive statistical framework for the exploration of both observed and latent variables [58]. In SEM, six latent variables were investigated, namely sustainability knowledge, sustainability concern,

Sustainability 2024, 16, x FOR PEER REVEW towards sustainability integration, subjective norm, perceived behavioral controls and intention to integrate sustainability.

3. Results Table 2 outlines the descriptive statistics for each variable. Table 3 details the scale relia Eightes, 3 illustrates the primeral structural equation (mondel of FM) 1.9489. These resultes tanghewsitintensteen torintearstensustainabilityoin ta our tireveal Based the che, fremawork sustainability knowledge, perceived behavioral control, subjective norm, and attitude towards interption are inferred (latent) variables, each measured by indicators (SK1-SK5, perveen interption are inferred (latent) variables, each measured by indicators (SK1-SK5, Phe AGF1 SN1 SF1 values stood with 935 of a down strength strength strength; The AGFI and GFI values stood at 0.932 and 0.913 indicating the strong fit of the model; For example, sustainability knowledge's indicators have loadings like 0.941, showing a respectively. The INISEA metric was reported to be 0.0000, falling below the advised strong link to the latent variable. Subjective norm is influenced by perceived behavioral benchmark. Lastly, fable 4 also includes the indirect, direct, and total effects. To ensure control (0.048) and attitude towards intention is affected by subjective norm (-0.012), the reliability and validity of the results, fit of the model measures were used as shown in sustainability knowledge (-0.090), and sustainability concern (-0.116). The main outcome, lable 5. The current study utilizes an extended form of the Theory of Planned Behavioral (TPB) to evaluate the factors that affect the intention of the achieves to integrate sustainability control (0.922), attitude towards intention (0.935), and subjective norm (0.927), emphasizing into higher education curricula in Laguna. the critical influence of these variables on sustainability integration intentions.



Figure 3. Initial Structural Equation Modelling including metrics for assessing educators' intentions to incorporate sustainability into their curriculums.

	Table 2nD	espuipttly, statispidalted	Structural Equatior	n Modeling (SEM) was	s developed through
Factor	the exclus It ene thodol hance the	ion of certain hypoth ogy [84]%[an djustm fit of the model - F	leses. In line with e lents w StDav ade ba liqure 4 displays th	arlier research that he Factor L Ised on the adjustme Laitial Model Performed Model	is adopted the SEM oading ont of indices to en- to Final Model to address
Sustainability Knowledge	Skitention (Skitention) Skitek Skitens (–(Skitens)	toward in Stronger edge slightly boosts orrelation 95n contra 0.140), subgesting hi sustainability. Howe	g sustainability into perceivea behavic ist, sustainability co gher sustainability ever, sustainability	higher Calcation cu oral control 240.030), oncern rOcaloes the in concern Datainish pe concern Batainish pe	rricula. Stainabil- indication of minor mpact of 000 jective erceived s000 al pres- on attitud 940 wards
	Signtention	is negligibly (+0.004)). Perceinent behavio	oral contrologegative	ly affects sorbjective
Sustainability	SC2	3.91	0.91	0.916	0.939
Concern	SC3	3.89	0.94	-0.942	0.889
	SC4	3.95	0.94	0.936	0.939

ntral	PB3	4.00	0.90	0.917	0.929	
mioi	PB4	3.92	0.90	-0.934	0.000	
	PB5	3.83	0.88	0.935	0.925	
	Sustainabil ‡3 1024 , 16, 3677	3.98	0.93	0.938	0.908	l0 of 17
0	IS2	3.91	0.86	0.911	0.915	
	IS3	norms (-0.056	6), implying greater person	al control reduces the	influence of social n	orms.
ty	IS4	Subjective No	rm has a minipal positive e	effect or PinBen tion to i	ntegrate (0.9.54 6), an	d atti-
	IS5	tudotowards i	intention modestly increase	s the like longod of inte	egrating s gsonj abilit	y into



Table 2 outlines the descriptive statistics for each variable. Table 3 details the scale reliabilities, including Cronbach's alphas, which varied from 0.916 to 0.948. These figures align with those reported in similar studies [80]. Table 4 reveals that the CFI, TLI, and IFI values surpassed the suggested limits of threshold of 0.90, proposing a strong correlation between the proposed model's construct and the data that were collected. Additionally, the AGFI and GFI values stood at 0.932 and 0.913, indicating the strong fit of the model, respectively. The RMSEA metric was reported to be 0.0000, falling below the advised benchmark. Lastly, Table 4 also includes the indirect, direct, and total effects. To ensure the reliability and validity of the results, fit of the model measures were used as shown in Table 5. The current study utilizes an extended form of the Theory of Planned Behavior (TPB) to evaluate the factors that affect the intention of teachers to integrate sustainability into higher education curricula in Laguna.

			Factor Loading		
Factor	Item	Mean	StDev	Initial Model	Final Model
	SK1	3.89	0.96	0.914	0.983
Custoinability	SK2	4.00	0.91	-0.929	0.000
Vnauladaa	SK3	3.95	0.88	0.900	0.000
Knowledge	SK4	3.91	0.91	0.941	0.000
	SK5	3.94	0.86	0.890	0.944
	SC1	3.81	0.91	0.886	0.905
	SC2	3.91	0.91	0.916	0.939
Sustainability	SC3	3.89	0.94	-0.942	0.889
Concern	SC4	3.95	0.94	0.936	0.939
	SC5	4.00	0.89	0.921	0.000
	AT1	3.94	0.89	0.926	0.960
Attitude towards	AT2	4.00	0.91	-0.900	0.000
Sustainability	AT3	3.82	0.98	0.912	0.913
Integration	AT4	3.98	0.89	-0.913	0.869
	AT5	3.81	0.95	0.899	0.907
	SN1	3.97	0.89	0.900	0.865
	SN2	3.92	0.87	0.935	0.987
Subjective Norm	SN3	3.91	0.90	0.894	0.000
	SN4	3.95	0.86	0.928	0.826
	SN5	3.93	0.85	-0.926	0.893
	PB1	3.85	0.94	0.941	0.923
Demosity	PB2	4.06	0.81	-0.926	0.000
Perceived Reheasierel Caratral	PB3	4.00	0.90	0.917	0.929
benavioral Control	PB4	3.92	0.90	-0.934	0.000
	PB5	3.83	0.88	0.935	0.925
	IS1	3.98	0.93	0.938	0.908
Intention to	IS2	3.91	0.86	0.911	0.915
Integrate	IS3	3.89	0.89	-0.915	0.000
Sustainability	IS4	3.98	0.92	0.932	0.954
	IS5	4.02	0.80	0.912	0.931

 Table 2. Descriptive statistical results.

 Table 3. Model of construct validity.

	Reliability Statistics				
Constructs	Cronbach's Alpha	No. of Items			
AT	0.943	5			
IS	0.948	5			
PB	0.916	5			
SN	0.947	5			
SC	0.940	5			
SK	0.928	5			

 Table 4. Direct effect, indirect effect, and total effect.

No		Variables		Direct Effect	p Value	Indirect Effect	p Value	TotalEffect	p Value
1	AT	\rightarrow	IS	0.542	0.452	0.000	0.994	0.052	0.542
2	AT	\rightarrow	PB	0.960	0.000	0.001	0.961	0.001	0.961
3	AT	\rightarrow	SC	0.004	0.958	-	-	0.004	0.958
4	PB	\rightarrow	IS	0.012	0.872	-	-	0.012	0.872
5	SC	\rightarrow	IS	0.882	0.000	0.002	0.884	0.002	0.884
6	SC	\rightarrow	PB	0.140	0.013	-	-	0.140	0.013
7	SK	\rightarrow	IS	0.052	0.495	-	-	0.052	0.495

Goodness of Fit Measures of the SEM	Parameter Estimates	Minimum Cut-Off	Suggested by
Incremental Fit Index (IFI)	0.960	>0.90	Sarstedt (2019) [86]
Tucker–Lewis Index (TLI)	1.001	>0.90	Hu and Bentler (1999) [87]
Comparative Fit Index (CFI)	1.000	>0.90	Sarstedt (2019) [86]
Goodness of Fit Index (GFI)	0.932	>0.80	Gefen et al. (2003) [88]
Adjusted Goodness of Fit Index (AGFI)	0.913	>0.80	Gefen et al. (2003) [88]
Root Mean Square Error of Approximation (RMSEA)	0.000	<0.07	Steiger (2007) [89]

Table 5. Fit of the Model.

The strong Cronbach's alpha values in this study (e.g., 0.943 for attitude and 0.948 for intention to integrate sustainability) suggest that the constructs are reliably measured. This is crucial in psychological research, as reliable measurement tools are fundamental for valid conclusions [30,60,90]. The high reliability of these scales indicates that the items within each construct cohesively measure a single concept, supporting the integrity of this study's findings.

The direct effect of attitude on intention to integrate sustainability, quantified at 0.542 with a significant *p*-value (0.000), strongly supports the TPB's assertion that attitudes significantly influence intentions. This finding aligns with [91], in which the critical role of positive attitudes in predicting sustainable behaviors is noted. The substantial size of this effect underscores the importance of fostering positive attitudes towards sustainability to enhance intentions to engage in sustainable practices.

The minimal and insignificant impact of perceived behavioral control on intention (0.012, *p*-value 0.872) challenges some of the conventional TPB findings. This could indicate that in the context of sustainability, perceived control may not be as pivotal in shaping intentions as previously thought, or it could reflect a more nuanced relationship in this domain. Study [92] suggests that in the context of environmental behaviors, other factors such as ecological values or external barriers might play a more significant role.

The effect of sustainability concern on intention, with an effect size of 0.882 and a *p*-value of 0.000, is striking. This suggests that concern for sustainability is a potent motivator for intending to integrate sustainability practices. This trend is in line with emerging research emphasizing the growing impact of environmental concern on behavior [92,93]. It highlights the potential of leveraging sustainability concerns in interventions and policies to promote sustainable behaviors.

Considering the total effects, which encompass both direct and mediated influences, provides a more holistic understanding of the relationships among the constructs. For instance, the total effect of attitude on intention to integrate sustainability remains significant at 0.542, underscoring the robustness of this relationship. Analyzing total effects is crucial in TPB applications, as it acknowledges the interconnected nature of these psychological constructs and their combined influence on behavior [92,94].

This study explores the integration of sustainability into higher education curricula in the Philippines through the lens of the Theory of Planned Behavior (TPB). The research utilizes statistical analyses such as Structural Equation Modeling (SEM) to understand the factors that influence educators' intentions to incorporate sustainability concepts into their teaching.

The results highlight several key findings. Attitudes towards sustainability play a significant role in influencing educators' intentions to integrate these concepts, underscoring the importance of fostering positive attitudes towards sustainability in education. Perceived behavioral control, or the perception of ease or difficulty in performing the behavior, show a more nuanced influence, suggesting that while educators may be inclined towards sustainability integration, its actual implementation may require institutional support and resources. This study also emphasizes the impact of sustainability concerns on educators' intentions, indicating that a higher awareness and concern for sustainability issues can drive the motivation to integrate these topics into the curriculum.

Overall, this study relates these findings to the broader research objectives and the theoretical framework provided by the TPB, suggesting that to effectively integrate sustainability into higher education curricula, efforts must be made to improve educators' attitudes towards sustainability, increase institutional support, and enhance awareness of sustainability issues. These findings are in line with previous research that emphasizes the importance of these factors in promoting sustainable education practices.

4. Conclusions

This study provides insightful findings that enhance our understanding of the determinants influencing educators' intentions to integrate sustainability into their curricula, utilizing Structural Equation Modeling (SEM) in the context of the Theory of Planned Behavior (TPB) [30].

Firstly, the high reliability coefficients for the constructs, ranging from 0.916 for perceived behavioral control to 0.948 for intention to integrate sustainability, underscore the robustness of the measurement instruments used in this study. This important level of internal consistency, evident in the Cronbach's alpha values, ensures the reliability of the constructs [86].

The SEM analysis revealed the crucial role of attitudes toward sustainability in shaping teachers' intentions to integrate sustainability into their curricula, as indicated by the significant direct effect of attitude on intention to integrate sustainability (0.542, *p*-value < 0.001). This discovery is consistent with the TPB, emphasizing the pivotal role of positive attitudes in fostering behavioral intentions [30].

Interestingly, perceived behavioral control showed an insignificant direct effect on the intention to integrate sustainability (0.012, *p*-value 0.872), suggesting that, in the context of higher education, factors other than perceived control might play a more significant role in influencing teachers' intentions. This could indicate the need for institutional support and resources [95].

The substantial influence of sustainability concerns on teachers' intentions (0.882, *p*-value < 0.001) highlights the importance of fostering environmental awareness among educators, suggesting potential impacts on professional development programs [96].

This study's implications extend beyond the academic sphere, offering insights for policymakers and educational institutions in developing effective strategies and policies aimed at promoting sustainable practices in higher education [97].

The research on integrating sustainability in Philippine higher education offers significant insights that can inform global efforts in sustainability education. It emphasizes the crucial role of educators' attitudes, institutional support, and sustainability concerns in shaping intentions to integrate sustainability into curricula. These findings suggest that despite cultural, educational, and policy differences, the core elements identified can guide the design of institutional support and awareness initiatives worldwide to strengthen sustainability education. This study also highlights the need for practical applications that enable educators and policymakers to promote sustainable practices more effectively.

Theoretical Contribution

This research contributes to the current body of knowledge on the incorporation of sustainability in the Philippines, offering several theoretical insights. The primary contribution involves exploring the elements influencing the integration of sustainability into higher education curricula. Utilizing Structural Equation Modeling (SEM), this study simulates and analyzes the intention to incorporate sustainability, considering a range of factors [98]. The SEM results provide a credible depiction of the structural model, illustrating how the variables interact. Additionally, this study serves as a valuable reference for applying similar theories like the extended Theory of Planned Behavior (TPB), which provides a solid foundation for future research and policy development in this vital area.

5. Limitations and Future Research

This study primarily concentrated on assessing the factors contributing to teachers' intention to integrate sustainability into curricula. The insights from our study are invaluable for both researchers and practitioners. For researchers, the unique findings on perceived behavioral control invite further investigation into how this construct operates within the sustainability context. Practitioners, especially those involved in policymaking and sustainability campaigns, can leverage the noteworthy influence of attitudes and concerns to design more effective communication strategies and interventions.

Future research could explore the mediating or moderating roles of other variables, such as environmental literacy or specific situational factors, in the relationship between the TPB constructs and sustainability intentions. Furthermore, long-term research could shed light on the development of these connections over time, especially in reaction to swiftly shifting environmental scenarios and varying degrees of public consciousness.

While acknowledging the geographic specificity of the research results, this research opens up opportunities for its applicability in diverse contexts, inviting further studies to explore these dynamics across diverse cultural or educational settings. This exploration could validate and extend the work, ensuring the global relevance of sustainability integration efforts in higher education.

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Sustainability education in nursing degree for climate-smart healthcare: a quasi-experimental study

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Abstract

Purpose – In light of the world's accelerating march towards a sustainable future, the education for sustainable healthcare must be sufficiently acknowledged in health professions curricula. Early integration of these competences into nursing degree programme emphasizes its importance and applicability. This paper aims to investigate the effectiveness of an educational sustainability intervention in higher education to change nursing students' attitudes towards sustainability and climate change, and environmental awareness.

Design/methodology/approach – A quasi-experimental study was performed with repeated measures between September 2019 and May 2023. Undergraduate students were introduced to sustainability and climate change in the context of healthcare using scenario-based learning and augmented reality over the courses in nursing degree. Participants' attitudes and awareness were collected by online questionnaires.

Findings – The educational intervention showed effectiveness in significantly improving attitudes towards climate change and sustainability, and the environmental awareness for changing their clinical practice (p < 0.01). However, students struggled to apply sustainability and address unsustainable practices in healthcare settings.

Originality/value – This study shows an effective model of curricular sustainability that can be implemented in other universities and health disciplines. The findings highlighting the importance of sustainability education in nursing and its potential to drive positive change in healthcare practice and society at large. Embedding key topics aligned with sustainable development goals in the curriculum prepares nursing or health workforce to address planetary health and implement sustainable practices that provide climate-smart care.

Keywords Sustainability education, Nursing degree, Attitudes, Awareness

Paper type Research paper

Introduction

The environment is a determining factor in the well-being and health of the population. When the environment is toxic or unbalanced it causes a negative impact on health (Kiang and Behne, 2021). Additionally, the provision of health care contributes to environmental



International Journal of Sustainability in Higher Education Vol. 25 No. 9, 2024 pp. 278-292 Emerald Publishing Limited 1467-6370 DOI 10.1108/IJSHE-01-2024-0061 © Carmen Álvarez-Nieto, Laura Parra-Anguita, Cristina Álvarez-García, Eva Maria Montoro Ramirez, María Dolores López-Franco, Sebastián Sanz-Martos and Isabel María López Medina. Published by Emerald Publishing Limited. This article is published under the Creative Commons Attribution (CC BY 4.0) licence. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this licence may be seen at http:// creativecommons.org/licences/by/4.0/legalcode changes, for example, through considerable greenhouse gas emissions, the use of harmful products, and the production of enormous waste volumes (Aronsson *et al.*, 2020). Health professionals are becoming increasingly concerned about the health impacts of climate change and the challenges they will face when delivering healthcare. It might be possible to create a health service workforce cognizant of the evidence with clinical care strategies that enable resilience in the face of extreme weather events or decreased resource availability. Establish greater ambitious leadership in healthcare sector for delivering sustainable climate smart health care offers opportunities for financial, environmental, and social gains – a "triple win" (Kiang and Behne, 2021). The International Council of Nurses (ICN, 2021) stated that:

[...] nurses collaborate and practice to conserve, support and protect the natural environment and are aware of the health consequences of environmental degradation. They advocate for initiatives that reduce environmentally harmful practices promoting health and wellness.

Thus, ICN has called for nurses to act as leaders in building climate-resilient health systems. Education is essential to building an adaptative nursing workforce that achieves environmental sustainability. To advance in that, nursing students' attitudes should be investigated, as they are associated with their environmentally sustainable behaviours (Verplanken and Orbell, 2022). On the other hand, students require awareness of the health impacts of climate change and an understanding of the environmental impacts of healthcare delivery (Goodman and East, 2014). Integrating sustainability education into nursing curricula promote proactive changes in clinical practice especially if is supported by managers and clinical mentors (Aronsson *et al.*, 2020). The present study aims to investigate the effectiveness of a sustainability educational intervention for improving nursing students' attitudes towards sustainability and climate change, and their awareness to implement sustainable practices in clinical work. This educational intervention is carried out through scenario-based learning and augmented reality as an innovative and effective teaching methodology. Measurements were taken before and after the educational intervention to assess its effectiveness.

Literature review

The 2030 Sustainable Development Goals clearly state the need for education on sustainable development to maintain planetary health (Shaw *et al.*, 2021), but the educational directives that dictate health professional training are notoriously slow to change. Clinical educators at the faculty and dean level have generally resisted the inclusion of planetary health in their undergraduate and postgraduate curricula, either because they are not aware of how important the topic is or because they tend to focus on illness treatment over presentation. In all settings, there is a dearth of curricular space and faculty expertise (Walpole *et al.*, 2019).

Environmental knowledge, attitudes and values (Paço and Lavrador, 2017; Liobikienė and Poškus, 2019; Maurer and Bogner, 2020) are key to fostering impactful pro-environmental behaviours (Whitmarsh *et al.*, 2021). Importantly, all are core elements of the Value-Belief-Norm (VBN) model of environmental action (Stern *et al.*, 1999), which posits that proenvironmental behaviour is driven by one's environmental values and awareness of environmental problems. Environmental sustainability and stewardship need to be taught so that nurses and students not only understand, but also have the ability to initiate change (Butterfield *et al.*, 2021), become confident climate and health advocates, and be leaders in resilient and sustainable healthcare. Different investigations describe and analyse the implementation of education programs on environmental sustainability and climate change in the training of nursing students in different contexts (Cruz *et al.*, 2018; Richardson *et al.*, 2019; A quasiexperimental study

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Linton *et al.*, 2020; Moustafa Saleh and Elsabahy, 2022; La Torre *et al.*, 2023; Tang, 2023). Through this, nursing students are helped to develop critical thinking and skills in the adaptive delivery of health care (Cruz *et al.*, 2018). Training on climate change and/or sustainability significantly increases the level of knowledge (Linton *et al.*, 2020; Moustafa Saleh and Elsabahy, 2022), beliefs (about the anthropogenic causes of climate change and vulnerability to its impacts) (Tang, 2023), awareness (Richardson *et al.*, 2019) and attitudes (Cruz *et al.*, 2018; Richardson *et al.*, 2019; Linton *et al.*, 2020; Moustafa Saleh and Elsabahy, 2022), although attitudinal changes was not significant in all cases (Tang, 2023). It is essential empowering the role that students and healthcare professionals can play in disseminating information about climate change and even encouraging the creation of policies to prevent the rapid progression of climate change and its consequences. This allows building resilient communities (raising awareness among the public), and promoting sustainable practices within healthcare settings (La Torre *et al.*, 2023).

On the other hand, providing training and education to healthcare staff on sustainable practices and the importance of reducing emissions can foster a culture of environmental responsibility within the institutions. Climate change mitigation in general is important, but the literature finds that hospital professionals feel little responsibility for climate change mitigation. Besides there are conflicting perceptions between reducing emissions and providing high-quality healthcare. This conflict could be reduced if emission reductions were not only justified as a contribution to mitigation, but also as a contribution to disease prevention (Quitmann *et al.*, 2023).

A student-centred learning approach emphasizes the development of self-awareness and environmental responsibility. Humanistic education is very effective in enabling students to develop rationality, autonomy, creativity, and concern for humanity, as well as teamwork, critical thinking, and problem-solving skills, and will help empower students to become agents of change (Veugelers, 2011; Chen and Schmidtke, 2017; Colonna, 2020). Therefore, these principles are best suited to help students not only reflect on and understand their activities concerning sustainability but also to enable them to contribute to mitigating problems arising from unsustainable human activities and to provide environmentally lowimpact health care. Integrating planetary health education in curricula is a key action necessary to raise awareness of how the many activities of health care provision, e.g. procurement, high energy and water demands, and large volumes of generated waste, lead to greenhouse gas emissions. Practical advice exists in terms of how and when integration can happen (Lopez-Medina et al., 2019; Tun, 2019; Walpole et al., 2019; Schwerdtle et al., 2020). Still, some barriers have been described (Maurer and Bogner, 2020): the perception that sustainability is not relevant to health care (Richardson et al., 2014), the lack of educator expertise (Richardson et al., 2016; Tun, 2019; Amerson et al., 2022), the challenge of including yet another topic within what are currently crowded curricula and the lack of existing assessment approaches (Tun, 2019).

Scenario-based learning is founded on situated learning theory and valuing contextual knowledge, encouraging opportunities for active learning and bringing students closer to the issues they will need to address in their intended profession (Grose *et al.*, 2015). Given the potential for universities to act as transient agencies for sustainability (Grose *et al.*, 2015), the teaching of this in higher education can benefit from using real-world practice-based scenarios introducing the students to sustainability issues relevant to their discipline. Interactive scenarios have enabled students to improve their awareness, attitudes, and behaviours on the health effects of climate change beyond knowledge acquisition in some European universities. They have used the free, online evidence-based sustainability literacy and competency resources in nursing education: NurSusTOOLKIT (www.nursus.eu/). These

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pedagogies encompass the real-life challenges of climate change and place students at the centre of identifying and evaluating solutions, which can help facilitate interdisciplinary learning (Thew *et al.*, 2021). On the other hand, augmented reality (AR) helps enrich educational scenarios with visual, audio, and virtual information, enabling active and participatory learning by enriching real scenarios and increasing student motivation, which is very effective for acquiring nursing competencies (Mendez *et al.*, 2020). Based on the NurSus framework for Sustaining Literacy and Competency (NurSus Project), can cross-disciplinary training throughout the degree using scenario-based learning and augmented reality improve undergraduate nursing students' attitudes towards climate change and sustainability and their environmental awareness? The authors hypothesize that an approach to education for sustainability in healthcare will raise their attitudes and environmental awareness, and consequently, they will apply their competencies in clinical practice.

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Method

Study design

A quasi-experimental study was designed using a pre-and post-educational intervention evaluation to assess attitudes and awareness in nursing degree students through repeated measures during the four-year academic university program using scenario-based learning and augmented reality related to sustainability, climate change, and health. It follows the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) (von Elm *et al.*, 2008) and TIDieR (Template for Intervention Description and Replication) guidelines (Hoffmann *et al.*, 2014).

Participants

The target population was all enrolled undergraduate first-year nursing students in a Spanish university in 2019. All students who expressed their desire to participate were included. Later, in years 2 and 3, this purposive sample participated in three teaching sessions specially designed to create environmental awareness and develop competencies in sustainability, climate change and health.

The sample size was established to be a minimum of 65 pairs to achieve 80% power, a confidence level of 95%, and detect a difference of 1.5 points with a standard deviation of 2.5 points based on the previous pre-post study to measure the impact of a sustainability-focused, scenario-based learning educational intervention on the attitudes and knowledge of student nurses (Richardson *et al.*, 2017).

Educational intervention

The educational intervention scenario-based sessions were integrated within healthcare education, where the aim is to focus on student"s ability to assimilate knowledge and build practical skills that they can transfer to clinical practice. The intervention consisted of three health and sustainability and climate change evidence-based scenarios delivered to over 120 nursing students during the degree in mandatory training sessions (there were a maximum of 15 students per session, and the duration of each one was 150 min). The sessions were designed to represent clinically relevant scenarios that engage students in discussion, fact-finding, and practical work about the impact of healthcare on the environment and issues regarding sustainability and climate change (Richardson *et al.*, 2019). Augmented reality facilitated the students' deep "immersion" in the clinical situation with more realistic visualization. The linked digital content (3D images and videos) was obtained from the applications MOZAIK education®, Sketchfab®, Biodigital® and MERGE®. As markers to

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activate digital information, QR codes and MERGE cubes were used to increase the learning potential in the scenarios. Students accessed the augmented reality integrated into the learning scenarios using tablets or mobile phones.

In Year 2, the first evidence-based scenario was about an asthmatic child exposed to pollutants at home, school, and city, whose health and care were compromised by the housing conditions and environment in which he lives (extracted from NurSus topic J3_A1, subject session 1: Children and Adolescence Nursing). The case study was based on real circumstances of the effects of climate change and problems arising from excessive industrialization in an Andalusian city. High levels of air pollution exacerbate asthma and increase greenhouse gas emissions. In groups of four to five, students discussed issues arising from the assessment, case analysis, and evidence collection, and suggested solutions or care formulation. The teacher guided students to critically think about the problems and identify solutions. Further information seeking and critique of proposed care regimens from each group were encouraged to promote learning.

In Year 3, two sessions were developed:

- (1) An evidence-based scenario about waste management related to bladder catheterization, which reflected a healthcare treatment with high environmental impact; a nurse performing this procedure does not correctly use infection prevention materials, discards unused open material, and does not recycle the large amount of waste generated (extracted from NurSus topic P2_B1, subject session 2: Clinical Nursing). Excessive use of resources and inadequate waste management is an unsustainable practice that aggravates climate change without increasing procedural safety. Students should analyse the relationship between preventing urinary tract infection and the rational use of material, proper waste separation, and environmental, and economic costs of healthcare waste management.
- (2) An evidence-based scenario about an older person who is poly-medicated, multipathological, mobility impaired and dependent in need of a caregiver. Episodes of extreme heat are becoming more frequent and intense and heatwaves add a negative factor to climate change, which is posing a serious global health problem. Due to high summer temperatures and a 3-day heatwave, the older person shows signs and symptoms of dehydration (extracted from NurSus topic E3_B2, subject session 3: Ageing Nursing). In this simulation, the students should analyse the consequences of climate change on the health of this population group, which is vulnerable to temperature changes.

All scenarios were as realistic as possible to reflect the care situation that students might experience in their future placements. The aim was to provide the exposure to a reliable environment for a correct handling of clinical procedures, which in turn will increase the level of attitudes and develop awareness in future exposures, together with a sustainable way of delivering quality care.

Data collection and instruments

The questionnaire used included the *Sustainability Attitudes in Nursing Survey* (SANS_2) (Box 1) that evaluates nursing students' attitudes towards climate change and sustainability and comprises five items whose response options range from 1 (strongly disagree) to 7 (strongly agree) on a Likert-type scale, with a maximum score of 35 points. Reliability analysis showed a Cronbach's alpha of 0.82, and the five items loaded on a single factor explained 58% of the total variance (Richardson *et al.*, 2016). Level of attitudes was categorized as *Excellent* (score >90%), *Very good* (score 70–89%), *Good* (score 50–69%), *Not*

enough (score 30–49%) and *Poor* (score <29%) (Álvarez-Nieto *et al.*, 2022b). In addition, items 6–9 were included in the survey for this study for students in years 2, 3, and 4 to investigate sustainability awareness in nursing practice (Box 1) (Richardson *et al.*, 2019). Also, response options range from 1 (strongly disagree) to 7 (strongly agree) on a Likert-type scale, with a maximum score of 28 points. No previous reliability data exists.

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Susta	inability attitudes in Nursing survey (SANS_2) items	
(1)	Climate change is an important issue for nursing.	
(2)	Issues about climate change should be included in the nursing curriculum.	
(3)	Sustainability is an important issue for nursing.	
(4)	Sustainability should be included in the nursing curriculum.	
(5)	I apply sustainability principles at home.	
Awar	eness in nursing practice survey items	
(6)	I apply sustainability principles in my nursing practice.	
(7)	I am aware of unsustainable practice in my work environment.	
(8)	I challenge unsustainable practice in my work environment.	

Students starting the Nursing degree in September 2019 were asked to complete the SANS-2 questionnaire (Box 1) in academic year 1 before students had any exposure to sustainability teaching (to avoid reporting bias). Later, the same students participated in three educational sessions (one in year 2 of the degree and two in year 3). All the learning materials used are available at: www.nursus.eu/ (Erasmus + KA2 Project, 2014–2017). Attitudes (Box 1, items 1–5) were measured after the three educational sessions (in year 3) and upon completion of the degree. Further items (items 6–9, Box 1) were included in the survey for this current study to investigate sustainability awareness in nursing practice (Richardson *et al.*, 2019), being measured as follows: in the year 2 after the first sustainability educational session and completing the clinical placement I (336 h that equivale to 12 ECTS); in the year 3 after the second and third sustainability educational sessions and completing the clinical placement I (336 h that equivale to 12 ECTS); in the year 3 after the second and third sustainability educational sessions and completing the clinical placements II and III (24 ECTS); and at the end of the degree after the last clinical internship period (in total 2352 h that equivale to 84 ECTS). The data collection procedure and instruments used are shown in Figure 1.

Self-administered questionnaires were completed through an online tool (Survey Monkey) in computer classrooms or using their own laptops or mobile phones.

Data analysis

Questionnaire data are presented as mean and standard deviation: SANS_2 mean value (items 1 to 5), Awareness mean (items 6 to 9) and mean individual items (1–9), and as total survey scores (SANS_2 and Awareness). Reverse scoring was undertaken for item 9 because it is worded negatively. Reliability was calculated by Cronbach's alpha. The normal data distribution was tested by the Kolmogorov-Smirnov test, analysis of skewness and kurtosis, and visual analysis of the Q-Q plot and histogram for both pre-intervention and post-intervention distributions. SANS_2 mean and total score and items 1–9 were compared for



surveys completed in year 1 or 2 and 4 using a paired Wilcoxon test procedure. Effect sizes, and rank biserial correlation, were calculated for variables with statistically significant differences. The level of significance was established at 0.05. Data were entered into JASP 0.17 version for analysis.

Ethical considerations

This study was approved by the Research Ethic Committee of the University of Jaen (JUL.19 / 3.PRY) and was performed following the ethical standards laid down in the Declaration of Helsinki. All students were informed and gave consent to participate in the study. The confidentiality and anonymity of personal data were guaranteed by coding students' identities. No risks were foreseen in participating in this study, but any participant could leave the study at any time without affecting their academic situation.

Results

The sample in the first year included 119 nursing students (of 120 enrolled); however, only 76 completed the questionnaires at all four collection points (36.13% lost). Demographic data are reported in Table 1.

SANS_2 and awareness surveys followed a non-normal distribution. The SANS_2 scale (items 1–5) showed good reliability (0.79 for the first measure, 0.81 for the second measure and 0.8 for the final score).

Attitudes towards climate change and sustainability

Questionnaires were matched to ensure that the same participants were compared across the three times. No statistically significant differences were found in the evaluation before and after the intervention according to the gender of the participants, method of access to university education, or having received any training on environmental sustainability before the nursing degree (p > 0.05). Table 2 shows the values of attitudes towards climate change and sustainability before the intervention.

Demographic data		A quasi- experimental
Age (M/SD)	23.61 (4.29)	study
Gender Male Female	<i>n</i> (%) 20 (26.3) 56 (73.7)	-
Pathway to university Baccalaureate Professional training Other university degree Over 45 years old	43 (56.6) 30 (39.5) 1 (1.3) 2 (2.6)	285
Attended a sustainability session Yes, within the prior three months No Yes, more than 3 months prior Source: Authors' own creation/work	6 (7.9) 67 (88.2) 3 (3.9)	Table 1.Demographic data of the sample ($n = 76$)

08) 0.362 63) 0.821	
08) 0.362 63) 0.821	
63) 94) 0.831	
04) 0.831	
0.4) 0.831	
JHJ 0.001	
44)	
)	
78)	
.09) 0.552	Table 2
02)	Attitudes towards
51)	alimate change and
	cuinate change and
	(SANS 2)
	94) 0.831 44) 78) 09) 0.552 02) 51)

Significant differences were found between the pre-and post-intervention measures (in both years 3 and 4) for the SANS_2 mean and total score, and for each item mean except item 5 (*I apply sustainability principles at home*), which showed lower values after the complete educational intervention (between year 1 and 4). Neither found significant differences for item 2 (between year 1 and 3). Table 3.

The *Excellent* level of attitudes increased in post-intervention statement (39.48%) with respect to pre-intervention (18.42%). The *Good* category of attitudes decreased slightly after the intervention (18.42% before to 14.47% after), and the *Not enough* level disappeared (3.95% to 0%), obtaining the highest percentage in the *Very good* category in the post-intervention group (46.05%). Nobody at any time had *Poor* attitudes. Statistically significant differences were found in the categories between the two measurements ($\chi^2 = 17.010, p = 0.009$).

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Mean and total awareness scores showed significant differences between years 2 and 3, and after completing the degree clinical placements and the educational intervention. Nursing students scored the lowest for item 9: I feel unable to challenge unsustainable practice in the work environment (3.57 for the first measure, 4.5 for the second and 4.03 for the final). After completing the educational intervention, an increase was found in all items of the environmental awareness survey but only reached statistical significance in items 6 (*I apply* sustainability principles in my nursing practice) and 7 (I am aware of unsustainable practice in mv work environment) (Table 4).

Discussion

This study aimed to explore the effectiveness of an educational sustainability intervention in higher education using scenario-based learning and augmented reality to improve nursing students' attitudes towards sustainability and climate change and awareness that has allowed changes in clinical practice to enhance sustainability. As in previous studies (Richardson et al., 2019; Linton et al., 2020; Moustafa Saleh and Elsabahy, 2022), the results showed a significant improvement in environmental attitudes and awareness after the training sessions and those maintained over time or lightly decreased, even though there were no further education sessions. Specifically, both the attitude about the importance of climate change and sustainability for nursing, as sustainability inclusion in the nursing curriculum, improved notably after completing the educational intervention, similarly to another researches (Cruz et al., 2018; Richardson et al., 2019; Linton et al., 2020). However,

	Statement	Year 1	Year 3	RBC	Year 4	RBC
	1. Climate change is an important issue for nursing 2. Issues about climate change should be included in the	6.16 (1.18)	6.45 (1.19)*	0.415	6.44 (1.08)*	0.465
	nursing curriculum	5.12 (1.47)	5.51 (1.56)	0.260	5.61 (1.37)*	0.386
	3. Sustainability is an important issue for nursing	5.68 (1.31)	6.25 (1.16)*	0.493	6.11 (1.22)*	0.386
	4. Sustainability should be included in the nursing curriculum	5.04 (1.34)	5.61 (1.54)**	0.387	5.61 (1.30)**	0.400
Table 3	5. I apply sustainability principles at home	5.42 (1.45)	5.46 (1.21)	0.006	5.34 (1.21)	-0.096
Comparisons of	Mean	5.48 (1.01)	5.86 (0.92)**	0.348	5.82 (0.92)**	0.397
SANS_2 score	Total	27.42 (5.03)	29.28 (4.59)**	0.349	29.11 (4.59)**	0.358
among pre and post intervention	Notes: $*p < 0.05$; $*p < 0.01$; RBC = Rank biserial correlation					

	Statement	Year 2	Year 3	RBC	Year 4	RBC
Table 4. Comparisons of awareness statements among pre and post intervention	6. I apply sustainability principles in my nursing practice 7. I am aware of unsustainable practice in my work environment 8. I challenge unsustainable practice in my work environment 9. I feel unable to challenge unsustainable practice in my work environment Mean Total Notes: $p < 0.05$; $p < 0.01$; RBC = Rank biserial correlation Source: Authors' own creation/work	4.49 (1.51) 5.96 (1.32) 4.55 (1.51) 3.57 (1.87) 4.64 (0.87) 18.57 (3.48)	5.01 (1.54)* 6.08 (1.30) 4.97 (1.50) 4.05 (1.97) 5.03 (1.44)** 20.12 (4.18)**	0.335 0.075 0.307 0.229 0.382 0.382	5.11 (1.57)* 6.36 (0.88)* 4.63 (1.58) 4.03 (1.95) 5.03 (0.88)** 20.12 (3.51)**	0.341 0.379 0.026 0.237 0.369 0.369

this was not transformed into the application of these sustainable principles at home. Perhaps that is because the training focused on what should be done in the workplace without extrapolating this attitude to being responsible citizens or because of the idea that health professionals are examples for the population. Nevertheless, the mean score obtained for applying sustainable practices at home was higher in the students who had just started nursing training than that obtained by Richardson *et al.* (2019), leaving fewer improvement opportunities.

Given that attitude is an antecedent for behaviours (Verplanken and Orbell, 2022), measuring students' attitudes is very helpful in promoting environmentally sustainable practices in nursing. Globally, the improvement in attitudes was greater in a previous study (Álvarez-Nieto *et al.*, 2022a) but in the present study, the baseline values were high with an initial percentage of excellent attitudes of 18,42% and reaching almost 40% in the final of the study. Congruently with this quantitative data, qualitative research on students states that nurses' work can contribute to a sustainable healthcare system through research, leadership and education (Anåker *et al.*, 2021).

Learners are more likely to challenge unsustainable practices in the work environment after participating in all scenario-based learning sessions. In general, students applied more sustainability principles when their clinical practice training increased, and most importantly they are increasingly aware of the importance of nursing practices aligned with sustainability and of unsustainable practices. However, perhaps because they are students, they feel unable to challenge institutional policies to bring about a general change in unsustainable practices. These results are in line with previous research (Aronsson *et al.*, 2020; Ergin *et al.*, 2021; Tuna *et al.*, 2022; Álvarez-Nieto *et al.*, 2022b) where nursing students felt they did not have sufficient authority and confidence to challenge unsustainable practices and the resistance to change. (Aronsson *et al.*, 2020) reported that only some students felt able to change their own practice (in terms of waste disposal/recycling or by ensuring sustainable use of equipment) and even influence others (by challenging their behaviour or educating them on sustainable practice) after being exposed to all sustainability scenario sessions.

Educating nursing students about these topics is required to empower nurses to take leadership for change as future health professionals. There is evidence of varying attitudes towards the inclusion of sustainability and climate change in nursing curricula in different countries (Richardson *et al.*, 2019; Aronsson *et al.*, 2020; Linton *et al.*, 2020). Teaching materials and approaches need to be culturally and contextually specific as adapting information to the local and real-world context will provide relevance. Our study developed three sessions on key sustainability topics, adapted to the Spanish context, that should be included in the nursing curriculum, concerning vulnerable populations, such as children and the elderly, and the responsible use and recycling of medical devices. Early introduction and integration of competencies in the curriculum emphasize its importance and its relationship with professional identity (Shaw *et al.*, 2021).

Nursing students demand more training in low environmental impact healthcare (López-Medina *et al.*, 2022) and innovative educational practices are effective in this regard. Appropriate Sustainable Healthcare Education can make future health professionals more environmentally aware and enable them to lead the shift towards climate-smart healthcare (sustainable care based on collective efforts to reduce gas emissions that support development and enable people to anticipate, absorb and adapt to climate shocks) (López-Medina *et al.*, 2022). There are limited studies that determine the extent to which universities have incorporated planetary health, although there have already been some higher education institutions that have included education on sustainable development in their A quasiexperimental study

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curricula, not just as a one-off activity (Shaw *et al.*, 2021). Notably, this is the first time a cohort of students has received comprehensive, cross-curricular training in sustainability and health throughout their degree in a Spanish university. Using scenario-based learning in the context of clinical skills creates a unique and interesting approach that is both instructional and clinically relevant (Richardson *et al.*, 2017). The combination of augmented reality and scenario-based approach to learning used in this research made students more receptive to the training and the acquisition of nursing competencies is more effective (Mendez *et al.*, 2020). Previous research has demonstrated that the use of augmented reality stands out to more faithfully stage the cases and also add a more playful part to the training (Álvarez-Nieto *et al.*, 2022b). That, along with supporting intrinsic motivation and student engagement through humanistic principles, leads to student initiatives and empowerment (Huss *et al.*, 2020) and facilitates the development of self-knowledge including an awareness of their natural environment and how they relate to that environment (Colonna, 2020).

Implications for clinical practice

Early introduction and integration of content on sustainable healthcare into the nursing curriculum emphasizes its importance and its relationship with professional identity. Given the current situation, where care for the environment is key, it is necessary to expand this experience to other universities to train health professionals in these sustainable competencies and work towards planetary health. The applicability of the results in other university contexts requires the use of a consistent methodology, adequate teacher training and the creation of inter-university collaboration networks to promote a homogeneous and sustained implementation. However, this process may encounter obstacles such as resource availability and institutional resistance to change, among others. The use of case-based learning and augmented reality are innovative learning strategies that add gamification, making them attractive and suitable for teaching environmental health with a background of gaining attitudes and environmental awareness. Nevertheless, more emphasis should be placed on extrapolating these sustainable practices to homes and personal lives, making health professionals examples of sustainability in the community.

It is also necessary to promote during the training the idea that nurses, and health professionals in general, are agents of change in health policy and have the power to lead the healthcare workforce in efforts to mitigate negative outcomes through sustainable practices, both in the workplace and home environment. Nurses, as frontline healthcare providers, can contribute to reducing the environmental footprint of healthcare delivery, promoting public health, influencing public attitudes and advocating for policies that support sustainability and climate resilience. Training nursing students in low environmental impact healthcare practices enables them to develop sustainable behaviours during their clinical training in healthcare facilities and can also be advocates for climate-smart healthcare.

Promoting sustainable healthcare practices can enhance the reputation of healthcare organizations, attracting environmentally conscious patients and investors. Therefore, the findings of this and future research can inform policymakers about the importance of incorporating sustainability education into healthcare professional training programs. Future research can build upon these findings by exploring long-term outcomes and evaluating the scalability and sustainability of similar interventions in diverse educational settings.

The implications derived from this research demonstrate the potential for educational interventions to foster sustainability awareness and action among nursing students, ultimately benefiting healthcare practice, education, policy, research and societal well-being.

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Conclusions

A sustainability educational intervention in higher education using scenario-based learning and augmented reality improved nursing students' attitudes towards sustainability and climate change, and awareness to implement sustainable practices in clinical placements. Students involved in the intervention are more aware of the importance of sustainability training for environmentally sound work, however, they show difficulty in applying sustainable principles at home or challenging unsustainable behaviours in clinical practice.

In future studies, in addition to expanding the sample to include other universities internationally and other disciplines, it would be recommendable to add greater emphasis in training on the importance of health professionals as examples of sustainable practices and agents of change. The sustainability educational sessions could have contents more focused on the realization of sustainable behaviours at home and the ability to challenge unsustainable practices with specific communication strategies and examples. The cases designed to be worked on during the educational sessions must be extracted from real data of local patients so that the students feel more identified with them and are culturally congruent, as in this study by showing cases of specific cities in Spain (with a lot of pollution due to factories that are exacerbating childhood asthma). This training, more focused on personal attitudes, should be added to the last training course during the last clinical placements as it requires greater technical ability and critical thinking. This would also help to maintain positive attitudes towards sustainability and to continue improving in this critical period as it is the final phase of academic training. The environmentally aware nursing students will become professionals able to provide sustainable healthcare that focuses on improved health and better healthcare delivery, rather than only late intervention in disease, with consequent benefits for patients and for the environment on which human health depends. In this way, they can provide high-quality healthcare now without compromising the ability to meet the health needs of the future.

Despite the strengths of this study, some limitations can be noted. First, the study did not include a control group for comparison, which limits the ability to attribute the observed changes in attitudes and awareness solely to the educational intervention. Moreover, the study was restricted to a single university and there was a loss of sample during the study in part due to transfers and mobility grants to other universities, and because new students who could not be surveyed at the beginning of the study in 2019. However, the sample loss was less than a third of the participants and this fact is implicit in longitudinal studies. Utilization of a purposive sample of only one university limits the generalizability of the results to other undergraduate students. Finally, item 9 is worded negatively and may be confusing to the respondents.

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Further reading

NurSus Project, available at: www.nursus.eu/uk/(accessed 03 January 2024).

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Embedding Sustainability across a Teacher Education Course: Teacher Educator Experiences

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Abstract

Education for Sustainable Development (ESD) remains an urgent priority to combat the numerous social, environmental and political crises prominent in the 21st century. This article shares the experiences of teacher educators who integrated ESD into discipline-specific units of study for pre-service teachers. Using a collaborative auto-ethnographic approach, we explore how curriculum change for ESD was navigated and discuss how institutional support was essential for providing legitimacy and necessary resources. Drawing on Noddings' approach to ethics of care, we emphasise the significance of valuing the perspectives and experiences of stakeholders involved in curriculum change and advocate for inclusive and responsive approaches that engage individuals meaningfully throughout the process.

Keywords: Collaborative auto-ethnography; ESD; sustainability; teacher educator experiences

Introduction

The need to embed Education for Sustainable Development¹ (ESD) across all levels of education was recognised over 50 years ago at the International Union for Conservation of Nature (IUCN) Conference on Environment and Conservation Education. At this time, progressing environmental education in primary, secondary and teacher education was fore fronted on education agendas (International Union for Conservation of Nature & Natural Resources, 1972). Since then, we have seen a commitment by the United Nations, declaring 2005–2014 as the 'Decade of ESD' (UNESCO, n.d.-b), and in 2015, advocating education as a key driver for achieving all 17 sustainable development goals (UNESCO, n.d.-a) alongside explicit educational targets 'that by 2030 all learners will have the necessary knowledge and skills to promote sustainable development' (United Nations, 2019, section Goal 4 targets 4.7). Even the World Economic Forum advocates the importance of 'climate education' (Ramirez, 2020) and ESD (Diop & Jain, 2020).

In Australia, ESD is present in the policy context at all levels of the education system. The Alice Springs (Mparntwe) Education Declaration emphasises the need to prepare young people for a changing world (Education Council, 2019). The Early Years Learning Framework encourages integrating sustainability into early childhood education (Australian Government Department of

¹For the purpose of this article, we use the term education for sustainable development, though recognise that it is interchangeable with education for sustainability. We acknowledge the existing fruitful debate regarding definitions that surround these terms and those similar (Kidman et al., 2020; Redclift, 2005).

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Education, 2022), and the 'sustainability cross-curriculum priority' in the Australian curriculum commits to embedding sustainability principles from Foundation to Year 10 (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2016). While such mandates are to be celebrated, critiques abound (e.g., Barnes et al. (2019); Dyment and Hill (2015)), revealing that the translation from policy to practice is patchy and disparate at best, and absent in schools and across the education sector more generally. Further, ESD is not included in the Australian Professional Standards for Teachers (APST) which govern accreditation (Australian Institute for Teaching and School Leadership [AITSL], 2017), and therefore, can be easily overlooked by initial teacher education (ITE) providers (Evans, Stevenson, Lasen, Ferreira & Davis 2017). Tertiary education occurs in the context of the Talloires Declaration, which is supposed to serve as a unifying platform for universities dedicated to environmental sustainability, outlining a comprehensive 10-point strategy that encompasses integrating sustainability into teaching, research, operations and community engagement (University Leaders for a Sustainable Future, 2020). Though, it appears that the Talloires Declaration is being utilised more as a means for universities to signal their commitment to ESD, rather than as a framework to guide institutional transformation (Zutshi & Creed, 2018). While ESD appears in Australian education policy frameworks, educators continue to face challenges in effectively integrating sustainability into educational practices (see Bosevska & Kriewaldt, 2020; Dyment et al., 2015; Salter et al., 2013).

Globally, it is recognised that without supporting educators to develop competencies in ESD, it becomes challenging to envision how they will empower their upcoming students to cultivate the essential skills needed to address sustainability challenges like climate change and poverty (Evans, Inwood, Christie & Ärlemalm-Hagsér 2021). Mulà and Tilbury (2023) argue that teacher education is an important catalyst for leveraging innovation and redesigning learning opportunities across the education system (p. 5). Yet, even with supposed encouraging policy conditions (Brandt et al., 2019), a review of four decades of ESD found ITE and professional learning of teachers in the field lacking (UNESCO, 2018), with inadequate teacher training identified as a primary issue (Ferreira et al., 2014; del Carmen Pegalajar-Palomino, Burgos-Garcia & Martinez-Valdivia 2021).

Like others (Davis & Davis, 2021; Eames, 2022; Evans et al., 2021; del Carmen Pegalajar-Palomino et al., 2021), we recognise that an implementation gap exists between what is advocated for in policy and how this is put into practice on-the-ground in ITE courses. In this paper, we offer our experiences – as teacher educators in a Bachelor of Education (Primary) – of embedding sustainability into an ITE course. We hope that by sharing our journey, we contribute towards bridging the gap between policy and practice. We offer our learnings which may be useful to others working in ITE contexts (and beyond) seeking to embed ESD in higher education.

Literature review

While research and policy suggest embedding ESD is a priority, it remains sporadic and underrealised in teacher education globally (Eames, 2022). To better understand why this may be the case, we first consider constitutions of sustainability in education and teacher education specifically, and review the barriers to successful integration of ESD as well as the elements from the literature that indicate success. We highlight the structural and individual dimensions that influence ESD integration and build the argument that for integration to be successful, moving beyond either/or top-down mandates and bottom-up activities is needed.

Constituting ESD

Sustainability, akin to concepts like art and justice, is often contested, lacking a universally accepted definition (Gallie, 1955). This complexity arises from divergent ontological and epistemological perspectives across disciplines and ideologies, complicating efforts to define and

implement ESD (Gale et al., 2015). Further to this, the global dominant paradigm – sustainable development (Lafferty & Eckerberg, 2013) – is underpinned by sustaining (economic) growth, recognising nature as a form of capital (Adelman, 2017) and resource conservation as means to perpetuate human development. Thus, the very definition advanced by the pioneering Brundtland report Our Common Future reflects an anthropogenic view of sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (United Nations World Commission on Environment & Development, 1987). While a detailed analysis of the concept is beyond the scope of this paper, it is important to highlight the controversy in definition and the effects of the taken for grantedness of anthropogenic framings in policymaking for sustainable development (Holden et al., 2014) in the education system.

The result of definitional obscurity in the field has meant that a variety of principles intended to guide ESD implementation are available. The Australian Research Institute for Environment and Sustainability (2009) identified *envisioning a better future, critical thinking and reflection, participation, partnerships for change* and *systems thinking* as five key principles of Education for Sustainability. In a report on issues and trends in ESD for UNESCO, an emphasis was placed on content relevant to equipping teachers to teach for and about contemporary sustainability challenges and included poverty reduction, biodiversity loss and sustainable consumption (Leicht et al., 2018). Equally, intended to guide ESD, competencies including embodying sustainability values, embracing complexity, envisioning and acting for sustainability have been identified as a sustainability competence framework in Europe (Bianchi, Pisiotis, Giraldez, Pisiotis & Cabrera Giraldez 2022).

In their sensemaking of ESD, Kidman, Chang, and Wi (2020) review the field and propose a theoretical framework that highlights ESD as 'a process that motivates and engages people in creating sustainable futures' (p. 5). This points to education needing to do more than merely transmit knowledge, but rather, ontologically and epistemologically engage with what it means to be and act sustainably in the world. Therefore, to fully embed ESD, integration should encompass programmes, the institutional vision and pedagogical practices (Evans, Ferreira, Davis & Stevenson 2016). However, achieving this is challenging (Albareda-Tiana, García-González, Jiménez-Fontana & Solís-Espallargas 2019; Eames, 2022; Evans, Inwood, Christie & Newman 2023).

Approaches to embedding ESD in teacher education

Integrating sustainability education in ITE, like other courses, often hinges on either top-down or bottom-up initiatives. Top-down strategies involve policies and directives from governing bodies or institutions, while bottom-up approaches focus on grassroots efforts initiated by communities or individuals. Both approaches can contribute to advancing sustainability education, with top-down methods recognised for providing institutional support and resources (Evans et al., 2023; Falkenberg & Babiuk, 2014; Ferreira et al., 2007), and bottom-up efforts fostering local engagement and innovation (Evans et al., 2023). Integrating the strengths of both approaches is essential for creating comprehensive and inclusive sustainability education programmes (Parnell, 2016; Sterling, Maxey & Luna 2013).

In this vein, embedding ESD in teacher education is most successful when initiatives are responsive to the socio-political, geographical and cultural contexts of place and institution and can lead to sustained systems change (Evans et al., 2021; Evans et al., 2016). Conversely, teacher education programmes with insufficient strategic and professional development support for academics (Davis & Davis, 2021), a lack of leadership at the faculty level (Falkenberg & Babiuk, 2014; Summers, 2013), time and resource allocations to deliver change (Albareda-Tiana et al., 2019; Mills & Tomas, 2013; Sims & Falkenberg, 2013) and siloed disciplinary content (Eames, 2022; Evans et al., 2017) tend to be less successful in integration efforts.

The European Sustainability Competencies Framework evidences a decreasing emphasis on disciplinary-based knowledge needs and instead encourages learning that engages with values, complexity, possibility and action (Bianchi et al., 2022). In their edited book on the integration of SDGs in diverse formal and informal education contexts, Beasy et al. (2023) showcase how community connections and collaborations enrich the integration of ESD teaching. However, throughout the more than 40 chapters, minimal evidence of interdisciplinary and multiple-goal experiences was discussed. This highlights the many challenges that exist for educators who must first recognise and disrupt disciplinary silos, to unlearn and re-learn what teaching and learning can be (McLeod et al., 2020).

While structural support and strategic direction are integral to curriculum change initiatives, the motivations and commitments from individuals should not be underestimated and are equally as fundamental to integrating ESD (Almeida, Moore & Barnes 2018). Predominantly, curriculum transformation in support of ESD remains undertaken by those with content knowledge about sustainability (Evans et al., 2017). Grassroots efforts and motivated staff members – who bring their personal, lived experience and ethical perspectives – are essential to achieving ESD and play a pivotal role in launching and coordinating sustainability goals (Warr Pedersen et al., 2017; Grabs et al., 2016). They are individuals, and often personal activists, who are change makers in terms of product, process, or method within an organisation (Anderson & Bateman, 2000). They are often known for risk-taking, the possession of referent power, being 'heroes', and having courage, passion, commitment, persistence and an identification with a societal cause (Anderson & Bateman, 2000; Bosman, 2021; Hedman & Henningsson, 2016).

Communities of Practice (CoP) can offer space for such individuals to engage in peer directed professional development, sharing and learning with colleagues of shared interests (Warr Pedersen, 2017). As a mechanism for enabling collaboration and cross-disciplinary approaches, which are known as effective strategies for enabling sustainability initiatives in higher education (Annan-Diab & Molinari, 2017; Jones & Galloway, 2015), CoPs offer a loose structure and a potential way of bridging the top-down/bottom-up binary (Sterling et al., 2013). However, key strategies needed before such initiatives can be successful are building trust and rapport (Sims & Falkenberg, 2013) and having a shared language to speak with (Siedlok & Hibbert, 2013). In what follows, we introduce our research context and explain how we approached our particular curriculum change activities.

Research context

The University of Tasmania (UTAS), which forms the context of this study, is committed to environmental, economic and social sustainability and its effective implementation – including integration in the curriculum – and is a signatory to the Talloires Declaration (https://ulsf.org/96-2/#Australia). Sustainability is one of the key areas of the University's Strategic Plan and Strategic Framework for Sustainability. Some examples of this commitment include being certified carbon neutral since 2016, and achieving divestment from fossil fuel-exposed investment funds in 2021. UTAS was named the Sustainability Institute of the year at the Green Gown Awards Australasia 2021 and was highly commended the following year in the same category of the International Green Gown Awards; ranked 5th in the world by the 2023 Times Higher Education Impact Rankings for its performance against the United Nations Sustainable Development Goals (SDGs), and 1st (for the second year running) in relation to SGD 13: Climate Action (Jack, 2023).

The School of Education is likewise committed to ESD, as explicitly referenced in the Bachelor of Education course objectives (UTAS, n.d.), and in the recent ESD-focussed academic appointments and development of new courses. However, as noted in the literature (Evans et al., 2017), teacher education programmes remain constrained by accreditation mandates which has necessitated innovative solution-seeking of integrating ESD meaningfully into existing course design.

In 2021, the School of Education initiated the creation of an internal service role, termed the Sustainability Curriculum Facilitator (SCF), aimed at promoting ESD integration within its ITE courses. The lead author of this paper assumed this role for a 12-month period and during this time undertook curriculum mapping of the school's offerings, orchestrated a school-wide roundtable session to enhance staff awareness of ESD and assisted teacher educators in integrating ESD principles into their teaching. The SCF worked with school leadership and teacher educators to embed ESD throughout the degree programme, thereby enabling pre-service teachers to experience sustainability-related curriculum in diverse curriculum areas and with diverse pedagogical approaches (Evans et al., 2017). The SCF centred care in interactions with colleagues and the work of Noddings (1984) was used to theoretically inform her approach.

In recognising care as a pivotal aspect of human interactions (Noddings, 1984, 1988), and the importance of trust and rapport in ESD initiatives (Sims & Falkenberg, 2013), the SCF established a relationality that was conducive to trust, openness and experimentation (Hagenauer, Muehlbacher & Ivanova 2023). In the context of education, Noddings (1984) advocated that caring should form the foundation of interactions between teachers and students, wherein teachers attentively listen, anticipate needs and nurture students' intellectual and personal growth.

Noddings (1988, 2012) identified three key attributes essential for fostering a caring teacherstudent relationship, including engrossment, commitment and motivation, which were embodied in the SCF's ways of working. While the SCF did not take on the role as 'teacher', the attributes identified by Noddings were helpful in supporting the operationalisation of an ethic of care in practice. For instance, the SCF was 'engrossed' in the experiences and backgrounds of her colleagues and exhibited a 'commitment' to listen, seek to understand and accept ideas of those looking to embed sustainability into their teaching. And finally, the SCF was 'motivational', prioritising colleagues' needs and aspirations rather than her own.

Three teacher educators were open to exploring how ESD could be embedded into their teaching and worked with the SCF in the form of a collaborative auto-ethnographic study to reflect and make sense of their experiences of doing so. At the time of writing, the four participants in this research, including three teacher educators and the SCF were all working in the School of Education, with a balanced teaching and research load. Below, we provide some background on our contexts, as well as the discrete units (subjects) that are discussed in the context of our experiences of integrating ESD in this paper.

Jessie, the SCF, is a Senior Lecturer with a disciplinary and teaching background in geography and environmental sustainability. Over the last decade, they had been teaching and researching across education contexts (formal and informal) to support transformational change and sustainable futures.

Sidney has worked in ITE over the past decade in a range of units in Bachelor of Education degrees. Their teaching is now focused on supporting entering ITE students to develop the necessary skills to successfully complete their studies and graduate as effective teachers. Sidney's research interests are divided into two areas, under the theme 'education equity, access and experience': 1) scholarship of teaching and learning, and 2) Languages education.

Peyton is a Senior Lecturer in English Education. They have coordinated a number of English and Literacy units for the Bachelor of Education and Master of Teaching courses, as well as played a major role in the university initiative to equip undergraduate students across Schools and Colleges with knowledge and understanding of global sustainability and local responses in the Southeast Asian region.

Darcy is a lecturer with a disciplinary and teaching background in Design and Technologies. Past research focus has included the importance of the nexus between theory (ITE) and classroom practice in order to enhance ITE programmes and student experience.

The units below are core units in the Bachelor of Education (Primary) degree, and each teacher educator is the Unit Coordinator - the top-level role of delivering a unit.

Academic literacies: This unit, co-ordinated by Sidney, is meant to be studied in ITE students' first semester of their first year in their degree (and is thus offered in both Semester 1 and 2). As a mandatory introductory generalist unit, it provides essential skills in the areas of: communication; academic reading, writing, researching and referencing; and the required system skills for the utilised learning platforms and software. As students in most courses must enrol in this unit, it was identified as a logical first touchpoint for introducing ESD.

Foundations of English: This mandatory curriculum-specific unit, co-ordinated by Peyton, is offered in Semester 1 of students' first year and is also offered during summer school (after Semester 2). This unit includes two modules with the first focusing on the nature of language, culture and how young people learn to use language from birth, and the second provoking curiosity about language functions and forms, text types and their role in culture and society.

Design and technologies: This mandatory unit, co-ordinated by Darcy, is scheduled as a first semester second year curriculum-specific unit. Students focus on development and creation of an authentic classroom task which showcases the design process of the discipline.

Methods

Research design

We utilised collaborative autoethnography as an appropriate methodology to investigate the experiences of embedding ESD into an existing ITE course (Hains-Wesson & Young, 2017; Nairn et al., 2015). The research question - 'how do teacher educators experience integrating Education for Sustainable Development into ITE?' framed the investigation.

A collaborative autoethnographic approach was adopted to enable recognition of researchers as participants in a shared community and experience (Chang, Ngunjiri & Hernandez 2016). This approach enabled an in-depth exploration of a phenomenon from an insider's experiential perspective, while the inclusion of multiple voices and perspectives added rigour to autobiographical interrogation (Chang et al., 2016). The study was underpinned by an interpretive paradigm (Smith, 2008) that emphasises understanding human experience by exploring its underlying meanings, purposes and interpretations (Morehouse, 2012).

In recognition of the contested nature of ethical considerations in such research, the teacher educators as participant-researchers engaged with ethical principles including obtaining voluntary consent to participate by all group members and ensuring that all participant-researchers were comfortable with the representation of personal reflections and conversations in this manuscript (Chang et al., 2016; Forber-Pratt, 2015; Guyotte & Sochacka, 2016; Lapadat, 2017). The process of generating data is adopted from the concurrent autoethnographic approach developed by Chang et al., (2013), where the authors themselves become the subject of research. In this approach, all the researcher-participants actively took part in creating individual written reflections and engaging together in critical conversation (Beasy et al., 2020). Each participant-researcher engaged in writing personal reflections about their experiences of integrating sustainability education materials into their course materials during one semester. Reflections were guided by inquiring and prompting questions: Why did you decide to integrate ESD into your unit? How do you plan to make this work? How is implementation going? What are the challenges/enablers in the implementation? How is implementation going? What are the challenges/enablers in the implementation? and, how did it go? What worked well? What would you do differently?. Reflections were collected by Author 1 and stored in a OneDrive folder shared by the team.

At the end of the semester, researcher-participants met online via Zoom (60 min) to reflect on the written materials produced and to collectively deepen insights through inquiring and questioning the experiences of each other. Through this critical conversation, the group identified challenges and drivers in their experiences as well as developed insights into how teacher educators engaged in such work could be supported in the future. Themes from the data are presented below, followed by a discussion of how to progress the agenda of embedding ESD in teacher education degrees in ways that value and build the capacities of all staff engaged in the process.

Analysis

While collaborative autoethnography supports iterative thinking-reflecting-writing processes, Authors 2 and 3 undertook a process of thematic coding together by following the six-phase process outlined in Table 1 by Braun & Clarke (2006, p. 87). A defined approach supported our emerging understanding of the developing themes and co-construction of themes. Each phase was undertaken beginning with the reading and familiarisation of the data. Phase two involved inductively creating initial codes while going through each transcript. Phase three saw initial codes grouped by overarching theme headings and sub themes. The next phase of analysis comprised reviewing and refining codes, where similar themes were collapsed into one (e.g., 'examples', 'vehicle') and moving sub codes to be better positioned in other main codes (e.g., finding resources). Phases four and five were undertaken concurrently with the reviewing of themes, refining descriptions and the addition of names. Further refinement and interpretation of our collective experiences were refined through the process of collaborative writing (Phase six, producing the report). Additional elements undertaken beyond the phases outlined by Braun and Clarke (2006) and supported by the work of Nowell et al. (2017), included the data being analysed by more than one researcher, peer debriefing and reflexive writing through the coding process. All of these additional element's aid in establishing credibility and trustworthiness of the thematic analysis process. In referring to the data throughout the paper, we indicate the source of data in this way: written reflection (WR) and critical conversation (CC). Pseudonyms are used throughout.

Findings

In this section, we share the main themes that surfaced through the collaborative analysis process of the reflections and conversations. Four main themes emerged and included: (1) Drivers for embedding ESD, (2) Practical actions to embed ESD, (3) Enablers and (4) Challenges. We explore each in turn below before discussing their implications further in the paper.

Drivers for embedding ESD

Findings revealed that both internal and external factors motivated teacher educators to include sustainability in their units. The internal influences included benefits for students, and personal and professional alignment, while external factors comprised expectations to include ESD from the Department for Education, Children and Young People (DECYP) and the School of Education at UTAS.

Internal influences

We found that views and beliefs of sustainability, in both personal and professional settings, influenced how teacher educators engaged in embedding ESD in their units. Peyton's drive to embed ESD in teaching arose from both 'my personal way of living and awareness for the environment coupled with my professional needs' (WR), an alignment which Jessie noted during the group reflection 'seems to really help in why you were able to take this up' (CC). Darcy's personal beliefs of sustainability meant that they wanted to 'demonstrate the importance of SDGs to students' (WR) and in alignment with their professional teaching philosophy of authenticity, 'ensure the SDGs are not just added in a manner that is a token gesture' (WR).

influences extended to the educators' beliefs that there were a range of benefits to students by embedding ESD in units.

In addition, each teacher educator spoke of a range of benefits to students from embedding ESD into units. All believed that giving a consistent message of the importance of sustainability throughout units was seen to help students see its significance and develop their own knowledge and understanding of the concept. This is highlighted by Darcy's statement that students need to 'make connections with an influential area that has a direct connection and impact on all, worldwide' (WR). This is expanded on by Peyton's view that 'ensuring a sustainable society and environment for our later generation is crucial and education is a powerful weapon' (CC). Embedding ESD consistently throughout learning and creating these connections aims to develop a transferable skill, which pre-service teachers can implement in their own teaching practice and educate future generations on a topic which has local and global importance.

The integration of teaching ESD concepts through other curriculum areas was also highlighted as a benefit through this study. Darcy uses their discipline-specific unit of Design Technologies to model to pre-service teachers how to integrate other curriculum areas and cross-curricula priorities, because 'if they have an opportunity to see and practice integration it will assist them in future practice' (WR). They elaborated on this idea when saying 'you want to make those connections [local through to global] so students can see the importance and the relevance of what they're doing' (CC). This importance of educating future teachers for the benefit of future generations motivated teacher educators to embed ESD in their units.

External influences

Institutional expectations for ESD were identified as external influences that motivated integration. Teacher educators were aware of the University's School of Education strategic aim (and understood by those in this paper, as a requirement), of embedding ESD. Jessie's role as the School's SCF further reinforced the perceived commitment of the School of Education relating to embedding ESD. Jessie expanded on how they interpreted this role during the reflective process:

'During 2021 and 2022, I took on the role for the School of Education as the Education for Sustainability Curriculum Lead. I was tasked with supporting staff to integrate ESD into their units. This included facilitating a roundtable, where a guest speaker from the Department of Education came to share how the Department approached sustainability in primary and secondary education as well as short presentations from lecturers within the School about their interpretations and inclusions in units'. (WR)

The second external influence identified was the push from the DECYP for schools to be teaching ESD, so therefore, teacher educators assumed responsibility as ITE providers, who should be modelling this and preparing graduates for the task.

Practical actions to embed sustainability

To embed ESD in units, the three teacher educators undertook a range of actions. While each took a different approach, from the data, two sub-themes emerged about practical actions undertaken, comprising ideas around opportunities and approaches.

Identifying opportunities

When looking to include new concepts into teaching, mapping was done by each of the teacher educators to decide where it would be best placed in the unit. Jessie explained that once the participant had sought their expertise,

'The process we undertook involved an initial meeting one-on-one, whereby the individual walked me through their unit, including weekly content, overall learning objectives and assessment tasks. It was at this point that through a process of co-construction and co-thinking, that opportunities within the unit to do this work emerged'. (WR)

As part of the mapping process, tensions arose regarding alignment between making ESD fit within current unit content. Darcy encapsulates this tension when saying 'I think we all talked about this in some form or another about staying true to our own units or staying true to the purpose that we have behind our unit' (CC). This demonstrates how the teacher educators did not want to force links between content and the SDGs, or feel they had to remove core content to make space for it. This tension is displayed in Darcy's comment that their 'initial thoughts on incorporating the SDG's into Design and Technologies was how to do this while retaining the core essence of design thinking' (WR). In grappling with this tension, they reflected that 'my feeling is the only way to achieve this is to embed SDG in both content and assessment, so it becomes a key element within the unit and also addresses the nexus between theory and practice' (WR). Sidney also talked about this tension of alignment when mapping ESD to unit content: 'I was a bit concerned at first at embedding ESD into my unit. As a general unit, it can sometimes be the place everyone sees everything as fitting, making it rather crowded with concepts and themes' (WR). During the reflective group discussion, Darcy synthesises this: 'we wanted to keep that essence of our unit without losing that when we added something new in' (CC). It was clear from the written reflections and critical conversation that initially, embedding ESD was seen as a threat to teacher educators' current unit goals and content, highlighting the need to make this authentic and meaningful rather than an ad hoc 'bolt on' approach to dispel such feelings. Through sitting with someone they deemed knowledgeable on ESD and mapping the unit to find integration opportunities, these reservations dissolved.

Taking an approach

Sidney and Peyton both implemented ESD in current tasks, making them the 'vehicle' for ESD teaching. In Academic Literacies, the first semester saw Jessie provide the prompts and resources for two targeted ESD essay topics. Thinking about the next semester, Sidney reflected:

'I realised I could go further with this, and link all my essay topics to the SDGs. I had already been removing topics based on lack of student engagement and difficulty, and it seemed natural to now extend this with better embedding of ESD' (WR).

This led to a more meaningful approach, with all essay topics linked to relevant SDGs, and a reflection activity for students to explain how their direction within the topic aligned. From the initial prompt from the SCF, Sidney was able to better embed ESD in their unit for the next semester. Through conversation with Jessie, Peyton identified that texts used in the Foundations of English unit for learning activities would be an appropriate place as an introductory touchpoint. Considering their method of embedding ESD, they explained 'we include ESD in this English unit through the selection of texts as I teach grammar and text types using picture books and written texts' (WR), a recognised approach (Bhagwanji & Born, 2018). Peyton did not exhibit the tension displayed by Sidney and Darcy about alignment to current unit content, as the resources for some tutorials and assessment became the vehicle for students to engage with ESD ideas.

In the second-year Design and Technologies unit, Darcy used the assessment task to embed ESD by requiring students to have 'made a connection with SDGs by linking their created design question to a relevant SDG and target' (WR). Strong integration was a key factor in the way Darcy chose to embed ESD in this unit, which is shown in the way the SDGs are taught and assessed, compared to the approach of Sidney and Peyton, who used a touchpoint approach and introduced ESD through already established activities.

Enablers

Reflections revealed two key enablers for teacher educators to embed ESD successfully in ITE units including having access to guidance and developing knowledge and confidence on ESD.

Access to 'Expert' guidance

The key enabler was the guidance teacher educators received from the SCF. This is demonstrated by Peyton's comment to Jessie 'I couldn't have done this without your support' (CC). Sidney also made a similar comment, explaining that 'Jessie really helped my own understanding' (WR) when they had initial confusion linking the SDGs authentically to essay topics. Darcy referred to Jessie as the 'centre-point' and 'common denominator' (CC) in the group, as the three teacher educators went back and forth between checking in with Jessie and developing their own knowledge. In their role, Jessie described:

'There seems to be this balance between guided learning. So, I guess my role in providing materials on ESD or clarifying what it is and starting points ... [while] equally important is that self-directed learning, so actually doing your own research and having the time and space to do that' (WR).

In Jessie's reflections, the importance of providing ESD-related starting points to stimulate the teacher educators' thinking about relevant connections to their units was noted. However, it was the side-by-side approach that seemed to enable successful and authentic embedding of ESD in units. Importantly, there was ongoing engagement between the teacher educators and the SCF:

'We set up times to get together to discuss and check in with how it was going. Opportunities to do this seemed invaluable, both in terms of maintaining momentum and reminding everyone that this was an important undertaking, and also creating a community whereby lessons were learnt and shared 'imposter syndromes' could be laughed about' (WR).

Embedding ESD into units alongside colleagues and with the help of an SCF provided strong collegiality during this undertaking, with a chance to share ideas, strategies, successes and challenges.

These opportunities for the SCF to help the teacher educators develop understanding and provide reassurance of their actions led to improved knowledge and confidence to successfully embed ESD in their units.

Developing knowledge and confidence

In the beginning, participants lacked knowledge around the concept of sustainability. Through the embedding process, Sidney explained the benefit of developing knowledge to be able to authentically present the content in the unit: 'it's been really interesting just to broaden my knowledge and really understand sustainability better' (CC). This notion of professional development to best integrate ESD into units is also demonstrated by Peyton, who said: 'it's beneficial for my own development, my awareness' (CC). The teacher educators all wanted to feel confident in what they were teaching around ESD. Developing a clear understanding of ESD was truly evident in Darcy's unit, due to the integration that occurred in both learning and assessment tasks in the unit. Sidney highlighted this when they commented to Darcy:

'I think out of the three of us you implemented the most and it was the most active and the students had to really engage with it. So they were asking you questions, and you had to know how to answer. Because you were explicitly teaching it and getting the students to really engage with it' (CC).

This highlights the importance of having the knowledge and confidence to engage with students around ESD, to ensure they get the correct understanding and have faith in the educator's own content knowledge.

Findings revealed that the development of knowledge led to those involved building confidence in ESD, which enabled them to effectively embed the material in their unit. This was an important part of the process and is encapsulated by Darcy's argument that 'I think it's the balance between having the confidence in your own knowledge, enough to be able to put it into your unit and feel like you have ownership of it and an understanding of it' (CC). Teacher educators also spoke about the need for confidence to respond to student queries about any of the ESD content accurately. Working alongside a SCF was found to support the development of the teacher educators' confidence. Jessie noticed that 'the individuals seemed to have a greater confidence in themselves once their thinking had been validated by me' (WR). All teacher educators noted that with greater confidence, they were willing to go further in their efforts to embed ESD.

Access to a SCF acted as the professional development bridge that teacher educators needed to build their knowledge and gain confidence to successfully embed ESD in their units. This is summarised by Sidney when they said: 'I have found this a really valuable exercise in developing my own understanding and am proud that my unit can contribute to the embedding of ESD in the SoE courses' (WR). This knowledge and confidence development suggests a sense of ownership of the content, leading to a more successful embedding of ESD in units instead of an external 'bolt on' approach which feels forced. If teacher educators do not fully understand the embedded content, then they can lack the confidence to teach it and can thus inadvertently communicate to students a lack of importance of ESD when teaching.

Challenges

While the above enablers helped the teacher educators embed ESD in their units, there were key challenges that emerged as part of the embedding process. Two key themes were identified: uncertainty, and authenticity and alignment.

Uncertainty

Reflections highlighted how teacher educators were initially unsure of the concept of ESD and where to start in terms of embedding ESD in their units. Sidney shared 'I first thought 'what can I do in my unit?'. I had very narrow-minded thinking, which related to tangible actions' (CC). A lack of understanding of ESD can be a first hurdle to thinking about how to embed it in a unit. Peyton also expressed their concern about effectively embedding ESD as 'that's actually not our expertise, or what we are teaching' (CC), suggesting a concern for teaching outside of their comfort zone. Darcy highlighted 'when I was putting this into my unit, while I was really positive about including it, I didn't know very much ... I think the three of us probably felt that we didn't have a lot of background' (CC). As previously identified, personal and professional drivers led the teacher educators to this point, but uncertainty around ESD was an initial challenge. Regarding the SDGs specifically, this is encapsulated by Sidney who admitted 'the challenge was how little I knew about the SDGs and what they actually mean' (WR), so the first step was self-development around these ideas.

Participants were also unsure about where to find suitable resources, such as examples of ESD in schools, or a range of text genres on sustainability topics. This is demonstrated by Darcy who said: 'There is also an acknowledgement of the need to improve my own knowledge regarding SDGs and explore examples of best practice when implementing this concept into the classroom' (WR). This is reiterated by Peyton, who explained, 'I deliver this unit twice a year. So, for assessment tasks or tutorials, I need lots of texts ... If I want to continue to do this, then I need to find more resources' (CC). Bringing ESD into units in an authentic manner with suitable resources was obviously a priority for these educators.

Authenticity and alignment

While teacher educators were keen to introduce new and relevant material into their unit, they were also concerned about the authenticity of adding cross-curricular elements. Darcy voiced this view by saying 'I didn't want it to be just a token gesture, you know, just throwing it in and having it in there, I wanted it to be part of the unit and a useful part' (CC). This rejects the notion of a top-down, 'bolt on' approach. How content is perceived by students was outlined by Darcy as an important consideration to how the embedding was performed, as 'with our students, it has to be clear, it has to be in the content, it has to be aligned to tutorial tasks ... and assessment' (CC). This comment highlights the importance teacher educators placed on ensuring any changes made to their units aligned with key aims and outcomes.

For Darcy, authenticity was achieved through ensuring examples were tangible and that students could see explicit real-world applications of the sustainability integration materials: 'it's always really powerful to have a real example in the unit so that students can see, okay, we're just not doing this to make it difficult, where it's going to apply' (CC). Embedding content this way enabled students to see the importance and relevance of ESD, not just as an additional assessment requirement.

The tension of trying to embed new concepts in an authentic manner is shown by Sidney's reflection when questioning how explicit the information about the SDGs needed to be, given the unit's focus on academic literacies. As a non-assessed learning activity, Sidney reflected that aligning the essay topics to the SDGs and highlighting this to students:

'Would not really help them understand the SDGs unless they chose to look into them themselves. Was this OK, though? Was it my unit's place to teach them about the SDGs, or just raise awareness of them and highlight they would engage more with them in other units? If it was my unit's place to teach about the SDGs, in how much detail? Was it going to be a natural or forced link?' (WR).

These types of questions highlight the importance the teacher educators placed on ensuring any integration of ESD was not seen by students as tokenistic or out of place, but rather, aligned with key outcomes of the unit and authentically building students' understanding of ESD.

Discussion

By collectively reflecting on our experiences, we came to recognise the interplay of an enabling structure – a SCF in the School, and the relationships formed amongst those engaged in enacting curriculum change for ESD.

The policy to practice gap remains a recognised and pervasive hole in the ESD transformation agenda (Davis & Davis, 2021; Eames, 2022; Evans et al., 2021; Rammel & Vettori, 2021; del Carmen Pegalajar-Palomino et al., 2021). Findings from our experience suggest that how change initiatives are undertaken matters to their likely success or failure. This aligns with Lozano's (2022) advice that for change to be successful, it must be adopted by a range of stakeholders and be implemented long enough to become part of the culture. Noddings (1988) reminds us that 'in every caring occasion, the parties involved must decide how they will respond to each other. Each such occasion involves negotiation of a sort: an initiation, a response, a decision to elaborate or terminate' (p. 222). As shown in our experience, enablers and barriers were an important part of navigating the embedding process. Both must be addressed, as Lozano et al. (2022) argues, 'drivers to change must be fostered, and resistance to change must be overcome, in order to institutionalise the changes' (p. 85). The journey to embed ESD looked different for each of those engaged in the process and provides a steadfast reminder that one-sized-fits-all approaches to curriculum change agendas are problematic (Evans et al., 2021). Instead, our experiences demonstrate the importance

of creating conditions where receptivity – seeing and feeling with those that are on the same journey – is central (Noddings, 2013).

A supportive structure

Establishing the SCF role through a top-down approach lent credence to the endeavour of integrating ESD into the curriculum of the School. This role symbolised institutional endorsement and recognition of the value of ESD, argued by both Falkenberg and Babiuk (2014) and Summers (2013) as being important at a Faculty level to the success of ESD integration. This was a sentiment echoed by Peyton, Sidney and Darcy, who emphasised its importance. However, we would advocate, based on our experiences, that delivering on change requires more than change to governing structures, and instead relies on action by all stakeholders to create a more comprehensive change (Weiss et al., 2021). Further, we agree that change is most aptly achieved when 'the growth of those [involved] is a matter of central importance' (Noddings, 1988, p. 221).

In finding opportunities to embed ESD into diverse curriculums, each of us needed to be open to thinking differently and *doing* differently. Oftentimes, institutionally driven initiatives have predetermined outcomes which are not sensitive to those they *act* upon (Mazon et al., 2020). Instead, working within an ethic of care reminded us that 'true dialogue is open; that is, conclusions are not held by one or more of the parties at the outset' (Noddings, 1988, p. 223). In our interactions, the SCF needed to commit to listening (Noddings, 1988) and to be engrossed (Noddings, 1988) in the backgrounds of those seeking to transform their ways of teaching. This required each of us 'throughout a dialogue, [to be] are aware of each other . . . no matter how great [our] ideological differences may be, [we] reach[ed] across the ideological gap to connect with each other' (Noddings, 2002, p. 17). It was in dialogue and through playing with ideas that eventually, the confidence of Peyton, Sidney and Darcy grew and the co-construction of ESD teaching was realised.

Relating with care to support ESD

We found that fostering relationships through a lens of care was pivotal in cultivating an environment conducive to the openness and trust necessary to engage in change (Hagenauer et al., 2023). Within the confines of higher education, we grapple with a system that often imposes constraints, making transformative change challenging to enact unless there are shifts in the governing structures (Rammel & Vettori, 2021).

Acquiring a deeper comprehension and the capability to integrate ESD principles into disciplinary contexts bolstered Peyton, Sidney and Darcy's confidence in ESD. While existing research emphasises the significance of environmental beliefs as predictors of engagement in ESD (Almeida et al., 2018), we highlight the pivotal role of individuals in generating their own momentum through the visibility of others' practice and struggles, by fostering connections and feeling a sense of community (Bosevska & Kriewaldt, 2020; Warr Pedersen, 2017). For instance, Sidney articulated their uncertainty, stating, 'I was unsure how [ESD] is done in other courses, so I was wary of being too explicit in saying that students would find it embedded in other units' (WR). Here, we see a key element that enabled those involved - the exposure to diverse approaches of others and opportunities to work collaboratively in the integration of ESD across various units.

Implications

In this paper, our focus has been on illustrating how incremental change, leading towards necessary transformation, can be realised within a single aspect of the education system – ITE. We explored our approach to working with institutional structures to create change for ESD. While we do not offer readers anything new in terms of ESD, the insights captured here tell a story of *how*

curriculum change for ESD can be successful. We reveal the way Nodding's ethic of care was integrated into the SCF role and was used to guide ESD implementation.

Recognising the importance of access to relevant ESD knowledge and information to support integration efforts (Evans et al., 2016), we emphasise the significance of institutional support mechanisms, in this case a delegated SCF role, as crucial for the enduring success of initiatives. Our experiences demonstrate how both top-down and bottom-up approaches to change agendas can be harmonised. While institutional support is essential for providing legitimacy and necessary resources, it is vital to engage with stakeholders in a collaborative manner that acknowledges their perspectives and experiences and invites them on the journey, with space to meander on their own (but not alone) path.

Finally, we feel that we have shown through our experience one way that top-down initiatives can be implemented through Noddings' principles of care and enable the conditions for trusting in each other, sharing practice, being creative and building confidence among those engaged in the ESD curriculum integration. We believe the novelty of this work is in highlighting how top-down initiatives, when engaged through an ethic of care, can support broad ESD curriculum change agendas.

As Noddings (2012) suggests, our actions should be responsive to the unique needs and contexts of those involved, rather than adhering to rigid principles or expectations. Drawing upon Sterling's (2013) call to move beyond the dichotomy of top-down versus bottom-up approaches, we acknowledge that our efforts may not have introduced a completely novel 'third way' of governance; However, we like to think that we have revealed one way that the utilisation of existing frameworks can support change for ESD and beyond.

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