



Strengthening Education for Sustainable Development in Teacher Education: Insights from Pre- and Post-Survey Analysis of Teacher Educators in Europe and Africa

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Abstract: Education for Sustainable Development (ESD) is recognised as a critical approach for addressing interconnected environmental, social, and economic challenges, as well as for preparing future teachers to engage meaningfully with sustainability issues. Within higher education, teacher educators play a central role in shaping the knowledge, skills, values, and pedagogical practices of future teachers. However, despite growing global emphasis on ESD, its integration into teacher education remains uneven across diverse contexts. This study examines the impact of four ESD-focused workshops, delivered both in person and online over a nine-month period, on teacher educators' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD-related teaching practices. It also explores changes in their understanding of ESD, its integration into teaching, and perceived implementation challenges. The study was conducted within the Future Teacher Education for Sustainable Development (FUTE) project, a Global North-South collaboration involving four higher education institutions, two from Finland, one from Namibia, and another one from Tanzania, bringing together perspectives from Africa and Europe. A mixed-methods pre- and post-survey design was employed, with surveys administered before and after the workshops. The analytical sample consisted of 24 teacher educators from the participating institutions who completed both surveys. Quantitative data was analysed using paired-samples t-tests and Wilcoxon signed-rank tests, while qualitative responses were examined through thematic analysis to capture participants' perspectives on ESD understanding, integration, and challenges. The findings indicate statistically significant improvements in perceived behavioural control ($M = 3.55$ to 4.18 , $p < .001$), subjective norms ($M = 3.17$ to 3.59 , $p = .006$), and ESD-related teaching practices ($M = 3.40$ to 3.69 , $p = .025$), reflecting medium to large effect sizes. These results suggest that the workshops strengthened participants' confidence, institutional awareness, and practical engagement with ESD. In contrast, attitudes ($M = 4.59$ to 4.74 , $p = .230$) and behavioural intentions ($M = 4.83$ to 4.74 , $p = .404$) remained consistently high and did not change significantly, indicating a possible ceiling effect and highlighting that the intervention primarily influenced capability and practice rather than underlying motivation. Qualitative findings provide further insight into these changes. Participants' understanding of ESD shifted from fragmented and predominantly environmental interpretations toward more holistic and action-oriented conceptualisations that

integrate knowledge, skills, values, and transformative action. Similarly, the integration of ESD into teaching evolved from implicit and occasional use toward more intentional, structured, and learner-centered pedagogical approaches, including problem-based and collaborative learning. Despite these improvements, persistent structural challenges, such as limited resources, rigid curricula, and large class sizes continued to constrain full implementation. However, participants demonstrated increased capacity to adopt solution-oriented strategies, including the use of digital tools to support ESD integration. The study highlights the importance of sustained professional development in enhancing teacher educators' confidence, pedagogical competence, and practical engagement with ESD. The findings suggest that while short-term interventions can significantly improve perceived behavioural control and teaching practices, long-term and systemic support is necessary to address structural constraints and ensure sustainable implementation. The study contributes to the growing body of research on ESD in higher education by demonstrating the value of capacity-building interventions in bridging the gap between intention and practice, particularly within diverse and resource-constrained contexts.

Keywords: (Five words in alphabetical order) Education for Sustainable Development; higher education; professional development; teacher educators

Introduction

The United Nations (UN) perspective on Education for Sustainable Development (ESD) has become a global priority that aims to addressing environmental, economic, and social challenges facing contemporary societies [43]. In particular, the United Nations Educational, Scientific and Cultural Organization (UNESCO), through the Sustainable Development Goals (SDGs), emphasises the transformative role of education in promoting sustainable futures. This is reflected in SDG 4, which focuses on quality education as a key driver of sustainable development [41, 43]. Similarly, ESD is recognised for its capacity to improve education systems through its core principles, such as learning together, including the whole institution, and respecting diversity. More importantly,

ESD should be understood as an integral part of quality education and lifelong learning. All educational institutions ranging from preschool to tertiary education and including both non-formal and informal education should consider it their responsibility to address sustainable development and to foster the development of key cross-cutting competencies related to sustainability. The development of these competencies is an essential contribution to efforts to achieve the SDGs. [36, pp. 39-40].

Thus, teacher education is fundamental in promoting sustainability through a more holistic approach because teacher educators shape the knowledge, skills, values, and attitudes of student teachers. Although there are solid foundations from both the global and regional levels, the integration of ESD into teacher education remains unbalanced. The European Commission [21] has noted that in Europe, controlled frameworks such as the European Sustainability Competence Framework (GreenComp) have been created to assist the integration of sustainability into curriculum and teacher professional development programmes. While these strategies have provided opportunities for ESD awareness and enabled institutions to support ESD, the challenge of turning policy into consistent classroom practice remains.

Many African countries continue to face systemic challenges that hinder the effective implementation of ESD, including limited resources, inadequate training opportunities, and uneven levels of awareness and institutional support [44]. Recent research further indicates that teacher education systems often lack the capacity and structured professional development needed to incorporate principles of ESD into pedagogy [35], highlighting the need for sustained investment in institutional support and training. Hence, implementing ESD in teacher training programmes is often fragmented, underscoring the importance of considering contextual factors when designing implementation approaches.

Previous research has established teacher educators' preparedness with respect to competencies, beliefs, and practices as critical factors in the successful integration of ESD. While studies consistently report positive attitudes towards sustainability, gaps remain in practical implementation, pedagogical approaches, and confidence in teaching ESD-related content [10, 22]. More recent research confirms that, despite growing awareness, challenges persist in translating ESD into effective teaching practices, due to limited pedagogical training and support [35].

Accordingly, this study aims to examine teacher educators' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD practice behaviour. It further examines their understanding of ESD, the integration into teaching and learning, and the challenges faced in its implementation process. Specifically, this study addresses the following research questions:

1. In what ways do teacher educators' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD practice behaviours change after the workshops?
2. How do teacher educators' understandings and integration of ESD change following the workshops?
3. How do the challenges faced by teacher educators in implementing ESD change following the workshops?

Context of the Study

This study is situated within the broader Future Teacher Education for Sustainable Development (FUTE) project. FUTE seeks to foster the competencies and best practices of teacher educators and student teachers in sustainability. The project is implemented as a three-year partnership between two universities from the Global North and two from the Global South, with the goal of strengthening teacher educators' content knowledge and pedagogical capacity in ESD. The project is organised into three cycles. Cycle 1 consisted of four workshops, each comprising three sessions that combined theoretical input, interactive activities, and practical application tasks and focused on building teacher educators' capacity in ESD, including practical approaches to integrating ESD into university courses. Cycle 2 focused on a mentored course review process to support the inclusion of ESD in the teacher education curriculum, while Cycle 3 extended the project to the broader community through student teachers' ESD-related mini change projects in collaboration with schools and local partners. This paper focuses specifically on Cycle 1, particularly the workshops activities and the impact they have on ESD integration in higher education.

In cycle 1, the workshops introduced teacher educators to the ESD concept, advanced and strengthened teacher educators' conceptual, methodological and pedagogical knowledge and competencies necessary to advance ESD in teacher education in teacher education. The *first workshop* was conducted from September to November 2024. It focused on developing participants' conceptual understanding of ESD, including its principles, alignment with the SDGs, and the integration of interdisciplinary approaches and global citizenship education. The *second workshop*, held from November to December 2024, extended the foundation laid in workshop one. It focused on research-based teacher education and the role of ESD within teacher education research. It emphasised the integration of research into teaching practice and introduced inquiry-oriented pedagogical approaches, such as inquiry-based, problem-based, project-based, collaborative inquiry, and experiential learning, to contribute to the effective implementation of ESD in higher education contexts. The *third workshop* was held in March 2025, and it focused on the contextual and practice-oriented application of ESD through case-based learning. It explored sustainability across disciplines, including physical education, craft science, and home ecology, from diverse international perspectives, while also emphasising digital literacy. Participants engaged in designing contextually relevant learning activities, further supporting the incorporation of sustainability principles into their pedagogical practice. The *fourth and final workshop*, held in May 2025, focused on social justice, sustainability, and agency in teacher education, as well as the integration of ESD into curriculum, assessment, and skills development. It also addressed sustainability in physical education, food systems, and the role of digital learning. The workshops concluded with presentations from NGOs, which provided practical examples of community-based sustainability initiatives and highlighted the importance of linking classroom practices to real-world contexts. Figure 1 illustrates the progression of ESD learning across the FUTE project cycles and the workshop-based intervention.

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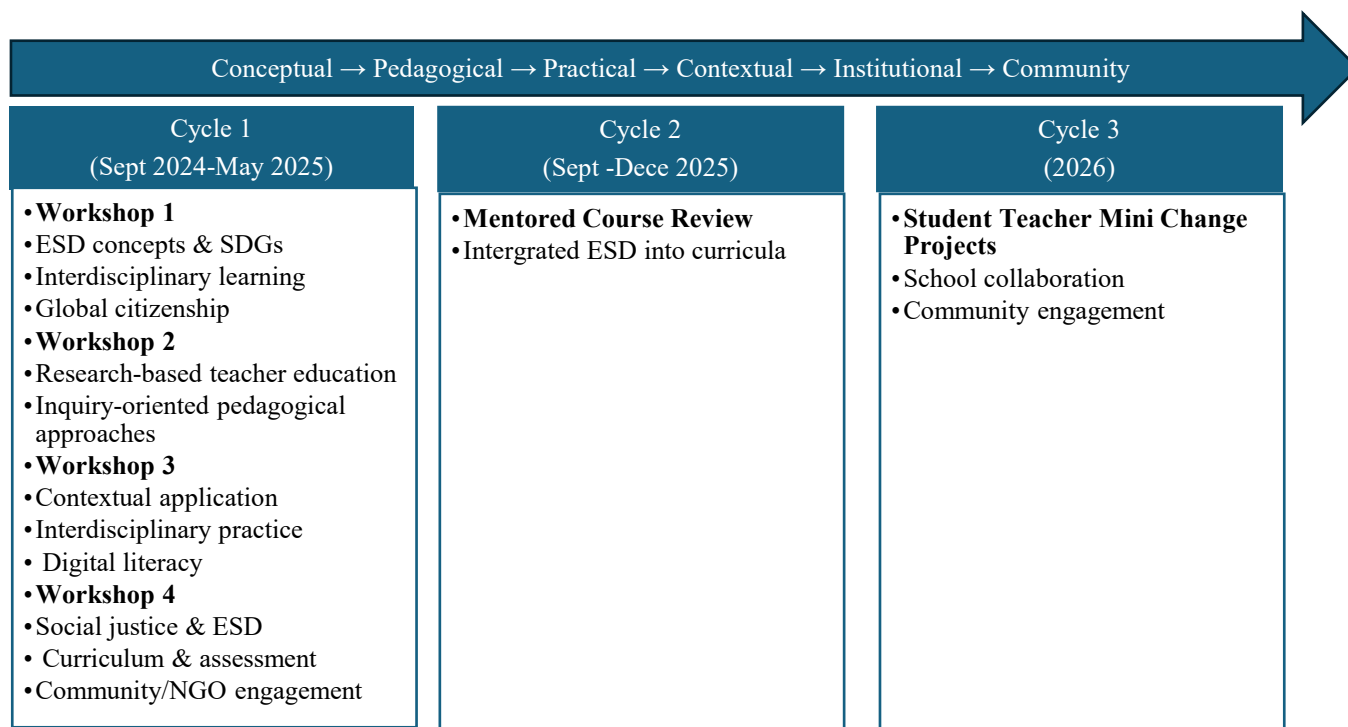


Figure 1. Progression of ESD learning across the FUTE project cycles and the workshop-based intervention.

Within the broader goals of the project, following teacher educators' participation in the workshops described above, this study, conducted in the third year of implementation, examined: (a) changes in teacher educators' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD-related behaviours; (b) changes in their understanding and integration of ESD; and (c) the challenges they encountered in implementing ESD following the workshops.

Theoretical Framework and Literature Review

Theoretical Framework

This study adopted the Theory of Planned Behaviour (TPB) [4]. The TPB assumes that three factors, namely attitudes, subjective norms, and perceived behavioural control, affect behavioural intentions, which also affect behaviour [4, 30]. To consistently perform a behaviour, individuals must possess the behavioural intention to do so. The latter depends on attitudes towards the behaviour. Attitudes towards the behaviour are evaluative dispositions to act or perform a particular behaviour. Behavioural intentions are also a function of subjective norms, which are social expectations regarding the behaviour. Perceived behavioural control refers to one's confidence in performing the behaviour. The TPB has been widely employed in studies of teacher behaviour [30]. Its relevance for predicting educators' ESD-related behaviour makes it useful in this study. Research [3, 5, 26] has utilised the TPB to examine behaviours related to ESD.

Theory of planned behaviour and education for sustainable development

According to the TPB, attitudes, subjective norms, and perceived behavioural control affect sustainability-related behavioural intentions [3]. It has also been used to explain sustainability in the context of inclusive education by addressing SDG 4, where attitudes, perceived behavioural control, subjective norms, and behavioural intention significantly influence inclusive education [5, 31]. In entrepreneurship education, ESD has been found to influence intentions and behaviour through multiple mediators, including attitudes, subjective norms, and perceived behavioural control [26]. Other scholars show that institutional support significantly affects perceived behavioural control while negatively affecting attitudes towards sustainability, and subjective norms negatively affect sustainable entrepreneurial intentions [38].

In environmental education, attitudes, knowledge, subjective norms, and perceived behavioural control, treated as exogenous variables, differently affect pro-environmental intentions and behaviour, where only subjective norms and perceived behavioural control are key predictors [13]. In contrast, in the study exploring the determinants of environmental knowledge-sharing behaviours, subjective norms were not significant predictors [1]. At the workplace, legislation and regulations, acting as external social norms and behavioural controls, have also been linked to graduate students' sustainability-related behavioural attributes, indicating the important role of social context [27]. These earlier studies show mixed findings regarding ESD when examined through the lens of the TPB, indicating the need for further research. Previous studies have operationalised these constructs using context-specific labels, where perceived behavioural control is referred to as confidence, subjective norms as institutional efforts, behavioural intentions as willingness, and behaviour as practice. In this study, however, the constructs are operationalised using their original TPB terminology: attitudes, subjective norms, perceived behavioural control, behavioural intentions, and behaviour.

Education for sustainable development

Sustainable development is a broad concept that encompasses social, economic, and environmental dimensions [23]. The concept originated in 1987, when the UN viewed sustainable development as a principle of organising human development to meet their needs in the long term [46]. In 2015, the UN set out 17 SDGs, whose attainment was projected by the year 2030. The objectives cover all socio-economic aspects with the environment serving as an essential resource in achieving them [34]. To address these objectives, the synergy of human efforts is required and requires diverse multidisciplinary competencies. Education was considered the most strategic tool in promoting the attainment of the SDGs by improving human capacity to address the economic, environmental, and social issues [46]. ESD provides knowledge, skills, and values pertinent to global citizenship and the development of individuals who can support and uphold sustainable societal practices [23]. ESD studies have emphasised the different dimensions of human abilities to address environmental, social, and economic issues sustainably. Different attributes include attitudes [34, 37, 46], beliefs [23], knowledge, values [37, 46], sustainable consumption [24, 34], self-efficacy, and locus of control [34]. The role of institutions and, consequently, their expectations on educators have also begun receiving attention [45]. Most of these attributes align with the constructs described in the TPB, that is, attitudes, confidence or perceived behavioural control, and behavioural intentions [30], which we adopt in this study.

Importance of ESD and Its Integration

ESD is viewed as a tool for achieving sustainable development. Educators at all levels are change agents in society [33]. Through ESD, educators can develop knowledge, skills, values, and attitudes, empowering them to participate effectively in sustainable development [46]. ESD strengthens versatility, critical systems thinking, active participation, collaboration, and responsibility, both as individuals and in collaborative teams, to promote sustainability [28]. It is a process that challenges routine pedagogies and promotes transformative practices that address the needs of the current and future societies. It is a kind of education that goes beyond content to include the process and outcomes of sustainability [39]. ESD is a process of empowering learners with essential knowledge, awareness, skills, and competencies for working and living in ways that safeguard the economic, environmental, and social well-being of current and future generations. [34]. ESD for future teachers is important for future classroom teachers, subject teachers, and educational leaders responsible for resource provision, motivation, and setting expectations that act as sources of subjective norms [23, 45].

Integrating ESD in teacher education is important because it exposes future teachers to sustainability initiatives, social challenges, and public debates related to the SDGs [16]. ESD cultivates positive attitudes toward sustainability and strengthens perceived behavioural control by enhancing learners' confidence to adopt sustainable practices in their everyday lives and reducing perceived barriers to action [3]. By fostering positive attitudes, social norms, self-efficacy, and the relationship between intention and behaviour, ESD helps prepare future professionals with the knowledge and competencies required to effectively promote and implement sustainable practices in education [12, 29].

Development of ESD and Challenges

Educational interventions of limited duration do not significantly impact educators' sustained intentions and actions in ESD; therefore, professional development should be designed as long-term training [26]. A semester-long course for preservice teachers is reported to change their attitudes towards sustainability [34]. A hybrid course involving preservice teachers is also reported to change their attitudes, self-efficacy, beliefs, and locus of control alongside sustainable consumption behaviours [33]. This process requires focused teaching methods that are relevant to the development of these skills. A review of teaching methods has found that ESD literature is aligned with constructivist perspectives, where self-regulated and self-directed learning approaches are advocated, while few studies see the need

for active guidance by the teacher, alongside the cognitivist perspective [37]. In decentralised education systems like Sweden, educators have more freedom regarding ESD practices, while in centralised educational systems like Japan, there is more emphasis on ESD-integrated curriculum content [23]. Thus, in some contexts, educators might have autonomy to decide how to integrate ESD, while in others, they may be under pressure to integrate ESD in accordance with curriculum guidelines, both of which require diverse instructional competencies. This suggests that ESD is also relevant to teacher educators. Generally, educators at all levels and their institutions have been charged with the responsibility to promote and implement ESD [37]. Teacher educators must be prepared and motivated to play a leading role in promoting sustainability.

Although ESD in teacher education is strategic, as it prepares future teachers for sustainability, most teacher education institutions lack the curriculum content needed to develop these competencies [33]. Also, intervention efforts, although very useful, raise concerns about long-term retention and scalability [3]. Some opposing workplace influences constrain behaviour consistent with sustainability [27]. In the workplace, therefore, there must be mechanisms for reinforcement and institutional support to sustain behavioural changes. The current study examines the impact of a series of in-house and online workshops and mentorship activities, conducted over several months, on teacher educators' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD-related behaviours

Methodology

This study is part of the three-year FUTE project (2024–2026). The methodological focus, however, is specifically on the workshops as an intervention used to examine changes in teacher educators' ESD-related knowledge, perceptions, and practices. The intervention consisted of four workshops conducted between September 2024 and May 2025 (see Figure 1). The workshops progressed from developing conceptual understanding of ESD and its alignment with the SDGs, to introducing research-based and inquiry-oriented pedagogies, and finally to supporting the practical and context-specific application of ESD. The final workshop also emphasised social justice, curriculum development, assessment, and community engagement. The workshops aimed to strengthen teacher educators' understanding, pedagogical capacity, and ability to implement ESD.

Study Context

This study was conducted within the FUTE project (2024–2026), which aims to strengthen ESD in teacher education across Europe and Africa. The project brings together four partner institutions: the University of Namibia, the University of Eastern Finland, the University of Turku, and the Dar es Salaam University College of Education, providing a multi-institutional context for examining teacher educators' ESD-related knowledge, perceptions, and practices.

Approach and Design

This study utilised a mixed-methods approach to examine participants' ESD-related perceptions, intentions, and practices, alongside their understanding, the integration of ESD into teaching, and perceived implementation challenges. Mixed-methods research integrates both quantitative and qualitative data to achieve a more comprehensive understanding of a research problem [14, 17]. In this study, quantitative data were used to assess changes in teacher educators' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and behaviour before and after the workshops, while qualitative data captured their understanding of ESD, its integration into teaching, and implementation challenges. This approach enabled both statistical analysis and a deeper contextual interpretation [17]. The study employed a pre- and post-survey design; the pre-survey was administered at the start of Cycle 1, and the post-survey at the end of Cycle 1 (see Figure 1). Only matched responses from participants who completed both surveys were included in the analysis. The surveys were identical and included closed-ended questions for quantitative analysis and open-ended questions to explore participants' perspectives. Data were gathered through the Webropol online survey system, with links shared via email and the project's WhatsApp groups.

Participants

The pre-survey included 54 respondents, while the post-survey included 37 respondents. To enable paired comparisons over time, only teacher educators who completed both the pre- and post-surveys were included in the analysis. This resulted in a matched sample of 24 participants (48 responses in total), allowing changes between the two measurement points to be examined reliably. Participants were drawn from Schools of Education at partner institutions within the FUTE project, providing diverse perspectives on ESD. Ethical approval for this study was obtained from the participating institutions where required, including the University of Namibia (Approval No. HPC06/2025) and the

Dar es Salaam University College of Education (Approval No. AB3/12(B)). Although the broader FUTE project involves four higher education institutions, data for the present study were collected from only three partner institutions, as no participants were recruited from the University of Turku. At the University of Eastern Finland, a formal ethical review was not required because the study did not meet the University's criteria for ethical review. Participation was voluntary, informed consent was obtained from all participants prior to data collection, and all responses were collected anonymously and treated confidentially throughout the study. A convenience sampling approach was used due to participant accessibility within the project context [19]. Of these, 11 (46%) were female and 13 (54%) were male, aged between 30 and 64 years, and all were university teaching staff. While a larger number of participants took part in each survey separately, analysing only matched responses ensured consistency and enabled a direct comparison of participants' understanding between the beginning and the end of the study. This approach is consistent with pre- and post-test designs that focus on within-participant change [48].

Data collection methods and procedures

Data were collected using pre- and post-surveys. The pre-survey assessed participants' attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD-related practices, as well as their understanding of ESD, its integration into teaching, and associated challenges. Participants then engaged in 12 ESD-related sessions organised into four workshops (September 2024–May 2025), aimed at strengthening their understanding and pedagogical approaches. A post-survey was subsequently administered to assess changes in ESD-related perceptions and practices. Figure 2 presents an overview of the data collection process, including the administration of pre- and post-surveys and participation in the workshops intervention. Both surveys included closed- and open-ended questions. Closed-ended items used a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). This scale was used to measure constructs, including attitudes, subjective norms, perceived behavioural control, behavioural intentions, and ESD practice behaviour. Open-ended questions captured participants' understanding of ESD, its integration into teaching, and the challenges faced in implementing ESD in education. The survey instruments were adapted from validated tools in ESD research [7, 40] to ensure alignment with established ESD frameworks and enhance the validity of the measures.

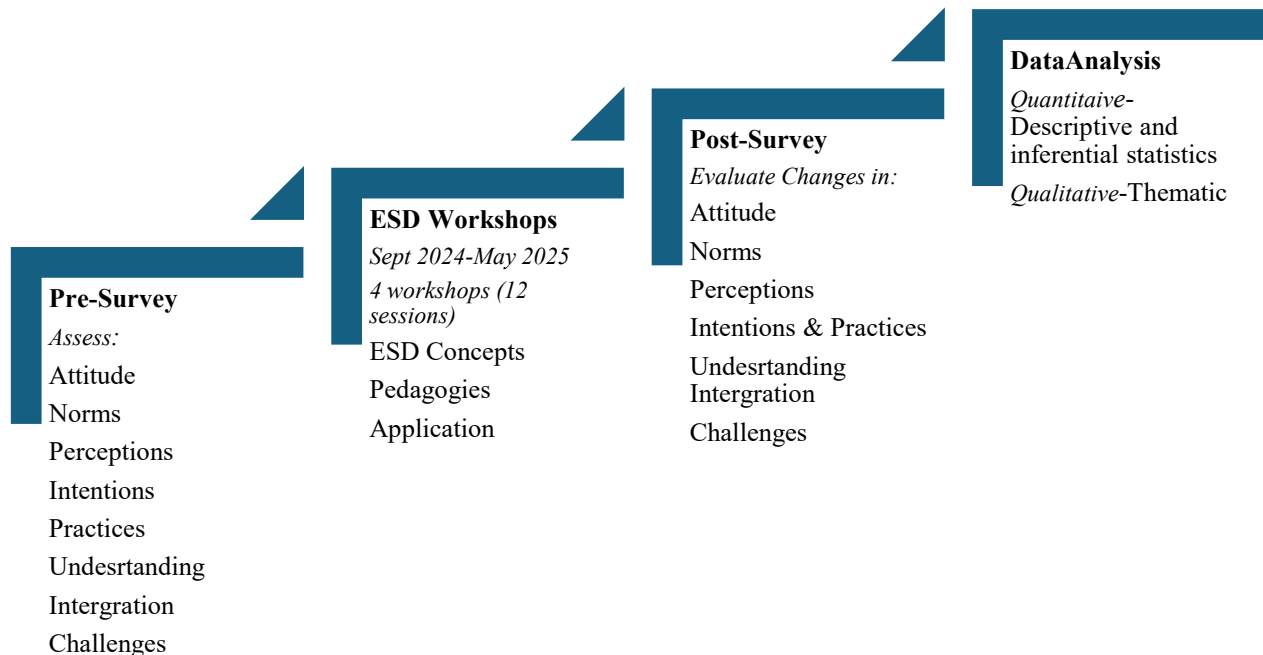


Figure 2. Data collection procedure

Participation in the study was voluntary, and all participants gave electronic informed consent before completing the surveys. Ethical approval was obtained from the participating universities where required. In all cases, key ethical principles, including confidentiality, anonymity, informed consent, and appropriate data management, were strictly upheld throughout the study.

Several strategies were employed to minimise potential sources of bias throughout the study. The survey instrument was reviewed by independent experts who were not involved in the research, ensuring that items were clearly worded and free from ambiguity or leading language. Since participants came from diverse cultural and institutional contexts across Europe and Africa, the survey language was kept neutral, simple, and inclusive, taking cultural and gender considerations into account. Data were collected through the Webropol online survey system, with links distributed via email and project WhatsApp groups. Responses were recorded automatically, meaning that the research team had no direct contact with or influence over participants during data collection. Participation was entirely voluntary, and participants were assured of confidentiality and anonymity before completing the surveys. These measures ensured that participants could respond freely and honestly. Finally, quantitative and qualitative data were triangulated through joint displays and narrative integration. This allowed for the identification of convergent patterns across both data types, providing a more transparent and holistic interpretation of the findings.

Data analysis

Quantitative data analysis was conducted using IBM SPSS Statistics. Construct means were calculated using the MEAN.n function, which averages non-missing items while requiring a minimum number of valid responses. This proration approach provides reliable estimates despite modest item missingness [47]. Descriptive statistics were first used to compare pre- and post-workshops scores and identify patterns of change across the five constructs: attitude, subjective norms, perceived behavioural control, behavioural intentions, and behaviour. Statistical significance was assessed through inferential analyses based on mean difference scores, calculated as the difference between post-test and pre-test scores for each construct. A preliminary assessment of normality using a skewness and kurtosis threshold of ± 2 [25] suggested approximate normality for all constructs except for attitude. However, this approach may be insufficient for small samples ($n < 50$) [24]. Therefore, with $n = 24$ in this study, normality was re-assessed using the Shapiro–Wilk test ($p > .05$). The data met the assumption of normality only for perceived behavioural control ($p = .371$) and behaviour ($p = .780$), and these were subsequently analysed using paired-samples *t*-tests. In contrast, attitude ($p < .001$), subjective norms ($p = .023$), and behavioural intentions ($p < .001$) significantly deviated from normality (see Table 1) and were analysed using the Wilcoxon signed–rank test. Effect sizes were interpreted using [32] benchmarks. Cohen’s *d* was reported for the *t*-tests ($0.2 = \text{small}$, $0.5 = \text{medium}$, $0.8 = \text{large}$), while the *r* effect size was used for the Wilcoxon tests ($0.1 = \text{small}$, $0.3 = \text{medium}$, $0.5 = \text{large}$) in line with each construct’s Shapiro–Wilk-based normality assessment. These quantitative analyses were used to assess how the workshops contributed to changes in teacher educators’ ESD-related competencies, including attitudes, perceived behavioural control, and reported practices, thereby highlighting key areas of development as well as constructs that showed limited change.

Table 1: Normality and Statistical Tests Used for Each Construct ($n = 24$)

Preliminary Normality Assessment Using Skewness and Kurtosis				Shapiro–Wilk Normality Test		
Construct	Skewness	Kurtosis	Normality Assumption	Shapiro–Wilk <i>p</i> -value	Distribution	Statistical Test Used
Attitude	2.121	5.734	Violated	< .001	Non-Normal	Wilcoxon Signed-Rank Test
Subjective Norms	1.144	1.502	Met	.023	Non-Normal	Wilcoxon Signed-Rank Test
Perceived Behavioural Control	0.464	-0.199	Met	.371	Normal	Paired-samples <i>t</i> -test
Behavioural Intentions	0.154	1.268	Met	< .001	Non-Normal	Wilcoxon Signed-Rank Test
Behaviour	-0.443	1.120	Met	.780	Normal	Paired-samples <i>t</i> -test

Note. $p < .05$.

The qualitative data obtained from open-ended survey questions were examined through thematic analysis following [8, 9]. A hybrid deductive-inductive approach was employed. After familiarising ourselves with the data, we identified segments and assigned them codes guided by three key dimensions: understanding of ESD, integration of ESD in teaching, and challenges in implementation, while allowing new insights to emerge from the data. Codes were grouped into thematic categories representing recurring patterns across participants' responses, and pre- and post-survey data were compared to identify shifts following the intervention. Categories were then developed into themes, which were used to present the data. The qualitative dimensions were aligned with the quantitative data to provide explanatory insight. Improved understanding of ESD helped explain increases in perceived behavioural control, while changes in integration practices reflected the observed improvements in ESD-related teaching behaviour. Reported challenges provided insight into persistent structural constraints affecting the implementation of ESD, highlighting key barriers despite observed improvements in other areas. These findings contribute to understanding both the enabling factors and the challenges associated with advancing ESD in teacher education contexts. Data were integrated through joint displays and narrative triangulation to identify convergence and explanatory relationships between qualitative and quantitative data. The integrated analysis provided a comprehensive account of how ESD-related competencies develop and what challenges remain in practice.

Results

Changes in ESD-Related Constructs Following the Workshops

Descriptive and inferential analyses of the pre- and post-survey data indicate changes across five constructs related to ESD integration: attitudes, perceived behavioural control, subjective norms, behavioural intentions, and behaviour related to ESD practices. At baseline, participants reported moderate levels of confidence, institutional support, and practice, alongside positive attitudes and behavioural intentions towards ESD. Following the workshops, improvements were observed across most constructs, particularly in perceived behavioural control, subjective norms, and ESD teaching practices. Inferential analyses confirmed that these increases were statistically significant for perceived behavioural control, subjective norms, and practice, while changes in attitudes and behavioural intentions were not statistically significant. These results suggest that the workshops primarily strengthened educators' confidence and practical implementation of ESD rather than their underlying attitudes or intentions, indicating a shift from intention to practice. This shift represents a key contribution to ESD by demonstrating how targeted interventions can translate existing positive attitudes into observable teaching practices, while also highlighting persistent challenges in influencing deeply rooted intentions. This pattern reflects an important divergence between intention and behaviour, as reflected in the improvements in perceived behavioural control and contextual support observed in the study. Table 2 shows the pre- and post-workshops means, standard deviations, and findings of the inferential statistical tests for each construct.

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Table 2. Changes in Teacher Educators' ESD Constructs Before and After the Workshops ($n = 24$)

Construct	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Difference Δ (Post – Pre)	Test Statistic	p-value	Effect Size	Interpretation
Non-parametric (Wilcoxon Signed-Rank Test)							
Attitude	4.59 (.52)	4.74 (.42)	+ .15	$Z = -1.20$	.230	$r = .25$	Not Significant (small-medium)
Subjective Norms	3.17 (.65)	3.59 (.53)	+ .42	$Z = -2.73$	.006	$r = .56$	Significant (large)
Behavioural Intentions	4.83 (.33)	4.74 (.51)	- .09	$Z = -.83$	.404	$r = .17$	Not Significant (small)
Parametric (Paired t-test)							
Perceived Behavioural Control	3.55 (.84)	4.18 (.43)	+ .63	$t(23) = -3.95$	< .001	$d = .81$	Significant (large)
Behaviour	3.40 (.68)	3.69 (.44)	+ .29	$t(23) = -2.40$	.025	$d = .49$	Significant (medium)

Note. $p < .05$. Effect sizes are reported as Cohen's d for parametric tests and r for non-parametric tests.

Attitudes Toward ESD

Participants demonstrated very positive attitudes toward ESD in both the pre- and post-surveys. At baseline, attitudes toward integrating ESD into teaching were already very positive ($M = 4.59$, $SD = .52$). Participants strongly agreed that ESD should be an important component of the curriculum ($M = 4.62$) and recognised its benefits for student development ($M = 4.65$). Following the workshops, attitudes remained strongly positive and increased slightly ($M = 4.74$, $SD = .42$), indicating a small positive change ($\Delta = +0.15$). A Wilcoxon signed-rank test indicated that this increase was not statistically significant, $Z = -1.20$, $p = .230$. Nevertheless, the small-to-medium effect size ($r = .25$) suggests a modest positive shift in attitudes from pre- to post-test. This indicates that, although participants' attitudes improved slightly after the workshops, the change was not strong or consistent enough across the group to reach statistical significance. A supplementary sign test confirmed the absence of a statistically significant change ($p = .607$). Participants continued to express strong agreement that ESD should be integrated into curricula ($M = 4.79$) and that it contributes positively to students' learning and development ($M = 4.83$). These findings suggest that participants already held highly favourable attitudes toward ESD prior to the workshops, leaving limited scope for measurable improvement. The small observed increase, together with the non-significant result, points to a likely ceiling effect, where already high baseline attitudes constrained the extent of detectable change. This helps explain the absence of statistically significant change despite the already high baseline attitudes, thereby resolving the apparent inconsistency between high baseline values and limited observed change.

Subjective Norms

Perceptions of institutional support for ESD showed a notable increase from the pre-survey ($M = 3.17$, $SD = .65$) to the post-survey ($M = 3.59$, $SD = .53$), indicating a moderate positive change ($\Delta = +.42$). A Wilcoxon signed-rank test indicated that this increase was statistically significant, $Z = -2.73$, $p = .006$, with a large effect size ($r = .56$). This indicates a substantial and consistent improvement in participants' perceptions of institutional support for ESD following the workshops. At baseline, participants perceived moderate institutional support, with responses reflecting neutral or moderately positive views regarding leadership support and the incorporation of sustainability issues into teaching. Notably, lower mean scores were observed for the integration of global issues into the curriculum ($M = 1.01$) and the availability of teaching materials for ESD ($M = 2.54$), indicating participants' perceived limitations in

curriculum integration and resource availability. Following the workshops, participants reported stronger perceptions of institutional engagement with ESD, with higher scores for the incorporation of sustainability issues into university curricula ($M = 4.04$) and for institutional leadership promoting ESD initiatives ($M = 3.96$). The statistically significant increase, together with the large effect size, suggests that the workshops had a meaningful impact on participants' perceptions of institutional support, reflecting a shift from moderate to more positive evaluations of institutional support for sustainability education.

Perceived Behavioural Control

Perceived behavioural control for implementing ESD increased notably from the pre-survey ($M = 3.55$, $SD = .84$) to the post-survey ($M = 4.18$, $SD = .43$), reflecting a substantial positive change ($\Delta = +0.63$). A paired-samples t-test revealed that this increase was statistically significant, $t(23) = -3.95$, $p < .001$, with a large effect size ($d = 0.81$). This suggests a strong and meaningful improvement in participants' perceived ability to implement ESD in their teaching. In the pre-survey, participants reported moderate levels of perceived behavioural control, particularly in integrating sustainable development into curriculum objectives ($M = 3.79$) and implementing ESD initiatives ($M = 3.75$). Lower scores were observed for evaluating ESD projects ($M = 3.08$) and addressing political aspects of sustainable development ($M = 3.25$), indicating areas of lower confidence. Following the workshops, participants reported higher levels of perceived behavioural control across several areas, including implementing ESD ($M = 4.33$), addressing social aspects of sustainable development ($M = 4.42$), and integrating sustainability objectives into curricular guidelines ($M = 4.21$). The statistically significant increase, together with the large effect size, indicates that the workshops had a strong influence on enhancing teacher educators' confidence and capacity to implement and manage ESD-related teaching activities.

Behavioural Intentions

Teacher educators' intentions to engage with ESD were extremely high in both the pre- and post-surveys. At baseline, behavioural intentions were very strong ($M = 4.83$, $SD = .33$). Participants expressed strong interest in integrating ESD into their teaching ($M = 4.79$), as well as in developing expertise in sustainability education and participating in professional development (both $M = 4.88$). In the post-survey, intentions remained consistently high ($M = 4.74$, $SD = .51$), although a slight decrease was observed ($\Delta = -0.09$). A Wilcoxon signed-rank test indicated that this change was not statistically significant, $Z = -0.83$, $p = .404$, with a small effect size ($r = .17$). This suggests that participants' behavioural intentions remained stable over time, with no meaningful overall change following the workshops. Participants continued to express strong intentions to integrate ESD into their teaching and to further develop their knowledge and skills. The slight decrease in mean scores, although not statistically significant, may reflect a more realistic appraisal of the effort and complexity involved in implementing ESD after engaging with the workshops content. This finding helps explain the apparent contradiction between consistently high intentions and the limited change observed over time, suggesting that participants' responses became more reflective of practical implementation realities.

ESD Behaviour

Participants reported moderate levels of ESD-related teaching practices in the pre-survey ($M = 3.40$, $SD = .68$). While many indicated that they sometimes integrated sustainability issues into their teaching ($M = 3.58$), lower scores were observed for evaluating the effectiveness of ESD teaching ($M = 2.67$) and the availability of teaching materials ($M = 2.71$), suggesting limitations in the systematic implementation of ESD. Following the workshops, reported teaching practices increased to a mean score of 3.69 ($SD = .44$), reflecting a positive change ($\Delta = +0.29$). A paired-samples t-test indicated that this increase was statistically significant, $t(23) = -2.40$, $p = .025$, with a medium effect size ($d = 0.49$). This indicates a meaningful improvement in participants' ESD-related teaching practices after the intervention. Participants reported greater integration of sustainability topics into their teaching ($M = 4.13$) and increased use of digital tools to support sustainable teaching practices ($M = 4.00$). These findings suggest that the workshops contributed to strengthening the practical application of ESD, moving participants from occasional use towards more consistent and structured implementation in their teaching.

Changes in Participants' Understanding of ESD, Its Integration into Teaching, and Perceived Challenges Following the Workshops

The open-ended responses from the pre- and post-surveys were analysed thematically to identify patterns in participants' perceptions and experiences of ESD. The analysis focused on three areas: participants' understanding of ESD, the integration of ESD into teaching, and the challenges associated with its implementation. A comparison of the pre- and post-survey responses showed notable shifts in teacher educators' conceptualisations of ESD, their

reported pedagogical approaches, and their perceptions of the factors enabling or constraining ESD integration. These qualitative findings complement the quantitative results by providing deeper insight into how and why changes occurred following the workshops. Together, these findings advance understanding of ESD by illustrating how changes in knowledge, pedagogical practice, and contextual constraints interact in shaping the implementation of ESD in teacher education.

Understanding of Education for Sustainable Development

Participants' understanding of ESD varied considerably in the pre-survey responses. Some participants indicated little or no prior knowledge of the concept, with one respondent stating, *"I have no idea... ESD is a new concept to me."* Others demonstrated a limited understanding, primarily associating ESD with environmental protection and sustainable resource use, for example describing it as "education focused on facilitating understanding of sustainable use of available resources for the benefit of current and future generations." In contrast, post-survey responses reflected a more comprehensive and holistic understanding of ESD. Participants increasingly conceptualised ESD as an approach that prepares learners to acquire the knowledge, skills, values, and attitudes required to respond to sustainability challenges. For instance, one participant described ESD as *"empowering individuals to make informed decisions and take responsible actions for sustainable environments for current and future generations,"* while another emphasised its integrative nature, noting that it *"focuses on promoting and integrating sustainable development in teaching and learning activities."*

These qualitative findings align with the statistically significant increase in perceived behavioural control observed in the quantitative results, which improved from $M = 3.55$ ($SD = .84$) to $M = 4.18$ ($SD = .43$), $t(23) = -3.95$, $p < .001$. The shift from fragmented to more coherent and multidimensional understandings of ESD suggests that enhanced conceptual clarity may have contributed to participants' increased confidence in implementing ESD. This is further reflected in higher post-intervention scores for implementing ESD ($M = 4.33$) and addressing social aspects of sustainable development ($M = 4.42$). This improved understanding is also confirmed in the significant increase in ESD-related teaching practices, suggesting that enhanced conceptual clarity, together with increased confidence, translated into more active implementation. The findings indicate that the workshops supported a transition from limited awareness to a more integrated and action-oriented understanding of ESD, which, in turn, reinforced participants' confidence and practice. This development highlights an important contribution to ESD, showing that enhanced conceptual understanding can act as a foundation for strengthening both confidence and implementation.

Integration of ESD into Teaching

In the pre-survey responses, participants reported integrating sustainability issues into their teaching primarily through contextual examples and real-life applications. For instance, a participant noted, *"I always refer to real-life situations and challenges that people encounter."* Others described using project-based learning and community engagement activities; however, several participants expressed uncertainty about whether their practices explicitly reflected ESD principles. This suggests that integration was largely implicit and not systematically aligned with ESD frameworks. In contrast, post-survey responses demonstrated more intentional and structured integration of ESD into teaching. Participants described adopting learner-centred pedagogies, including problem-based learning and collaborative approaches. One respondent explained that ESD integration involves *"problem-based learning and projects that address local sustainability issues,"* while another noted designing assignments that *"reflect real-world scenarios and sustainability issues."* These responses indicate a shift towards more deliberate and pedagogically grounded implementation of ESD.

These qualitative findings align with the statistically significant increase in ESD-related teaching practices observed in the quantitative results, which improved from $M = 3.40$ ($SD = .68$) to $M = 3.69$ ($SD = .44$), $t(23) = -2.40$, $p = .025$, with a medium effect size ($d = 0.49$). This suggests that the shift from implicit to more structured integration was not only perceptual but also reflected in measurable changes in practice. While pre-survey responses reflected occasional integration ($M = 3.58$) and lower engagement in evaluating ESD teaching ($M = 2.67$) and coordinating cross-curricular approaches ($M = 2.79$), post-survey responses indicated more consistent and systematic practices. This is further supported by higher post-survey scores for integrating sustainability topics ($M = 4.13$) and the use of digital tools ($M = 4.00$). The findings suggest that the workshops facilitated a transition from implicit and fragmented approaches to more intentional, structured, and practice-oriented integration of ESD into teaching. These findings contribute to ESD research and practice by demonstrating how professional development can support a shift from implicit to more systematic and pedagogically grounded integration of sustainability concepts.

Challenges in Integrating Education for Sustainable Development

Participants identified several challenges related to integrating ESD into teaching. In the pre-survey responses, the most common barriers included limited knowledge of ESD, lack of resources, rigid curricula, and large class sizes. For example, one participant noted that *“the curriculum is packed, leaving little room to effectively engage with sustainability issues,”* while another highlighted that *“there are not enough teaching materials to support sustainability topics.”* These responses indicate that both knowledge-related and structural constraints limited the effective implementation of ESD at baseline. Although these challenges remained evident in the post-survey responses, participants increasingly proposed strategies for addressing them. For instance, one respondent suggested that *“the use of technology may substitute some resources and facilitate ESD integration.”* This shift towards more solution-oriented responses suggests that the workshops enhanced participants’ ability to navigate existing constraints, even if those constraints were not fully removed.

These qualitative findings align with the quantitative results. Significant improvements in subjective norms (representing perceptions of institutional support) ($Z = -2.73, p = .006, r = .56$) suggest that participants perceived greater institutional engagement with ESD, which may have helped mitigate some structural challenges. Similarly, the significant increase in ESD-related teaching practices, $t(23) = -2.40, p = .025, d = .49$, indicates that participants were able to implement ESD more actively despite ongoing constraints. In addition, the substantial improvement in perceived behavioural control, $t(23) = -3.95, p < .001, d = .81$, suggests that participants developed greater confidence in managing and adapting to these challenges. While structural and resource-related barriers persisted, the findings indicate that the workshops strengthened participants’ capacity to respond to these challenges more proactively. Both results suggest that the workshops supported not only increased engagement with ESD but also a shift from constraint-focused to more solution-oriented approaches in addressing implementation challenges. These findings highlight that, although individual capacity can improve, structural and institutional constraints remain key challenges in the effective and sustained implementation of ESD. This underlines a key tension between increased individual capacity and persistent structural constraints, helping to explain why improvements in practice do not fully eliminate implementation challenges.

Synthesis of Quantitative and Qualitative Findings

The integration of quantitative and qualitative results offers a comprehensive understanding of the workshops’ impact. Quantitative results showed significant improvements in teacher educators’ perceived behavioural control, subjective norms, and ESD teaching practices, while attitudes and behavioural intentions remained consistently high with no significant change. The qualitative findings complement these results by offering explanatory insights into both the observed changes and areas of stability. Across the three qualitative dimensions, understanding of ESD, integration into teaching, and implementation challenges, participants demonstrated a shift from fragmented or limited interpretations of ESD towards more holistic and action-oriented conceptualisations that emphasised knowledge, skills, values, and practice. This enhanced understanding was reflected in more intentional and structured pedagogical approaches, including learner-centred methods and real-world applications, which helps explain the significant improvements in perceived behavioural control and ESD-related teaching practices identified in the quantitative analysis. However, both datasets consistently highlight the persistence of structural challenges, including limited resources, large class sizes, and institutional constraints. While participants became more solution-oriented in addressing these barriers, such constraints continue to influence the extent of ESD implementation. The findings suggest that the workshops primarily strengthened participants’ conceptual understanding, confidence, and pedagogical readiness for ESD, enabling improvements in practice, while broader institutional factors continue to shape the sustainability and scalability of implementation. The findings further advance understanding of ESD by demonstrating that, while targeted interventions can strengthen educators’ knowledge, confidence, and teaching practices, the effectiveness of such initiatives depends largely on the institutional and structural conditions in which educators operate. At the same time, the findings help reconcile the apparent contradiction between stable attitudes and intentions and improved practices, showing that behavioural change in ESD is strongly influenced by capability and contextual factors rather than intention alone.

Discussion

This section provides a discussion of the study findings concerning teacher educators’ levels of attitudes, subjective norms, perceived behavioural control, behavioural intentions and behaviours in ESD. It further discusses teacher educators’ understanding of ESD, integration of ESD into teaching, and the challenges they face in implementing ESD within their courses. Findings revealed that although participants reported moderate levels of perceived behavioural control, subjective norms, and behaviour at baseline, these constructs improved significantly following their

participation in the four workshops. The findings indicate that the workshops did not primarily create positive attitudes towards ESD, as these were already high at baseline. Nonetheless, they strengthened participants' conceptual understanding, confidence, and pedagogical practice. At the same time, entrenched structural barriers, such as limited resources, overcrowded classrooms, and uneven institutional support, continued to shape the extent of ESD implementation in teacher training programmes. This suggests that ESD capacity-building interventions can boost teacher educators' confidence and practical engagement with ESD, even when attitudes and intentions are already well established. It also suggests that ESD professional development should move beyond awareness-raising and instead focus on strengthening practical capabilities and contextual support, highlighting the importance of designing interventions that directly target implementation rather than attitudes alone. These findings contribute to ESD by demonstrating how targeted professional development can translate existing positive dispositions into improved teaching practice, while also highlighting persistent structural challenges that continue to shape implementation.

The results of this study support the TPB, which postulates that behaviour is shaped not solely by attitudes and intentions but also influenced by perceived behavioural control and social context. In this study, significant improvements in perceived behavioural control and subjective norms were associated with increased ESD-related teaching practices. In line with [23], teachers with higher levels of ESD competence are more likely to adopt sustainable practices and promote these among their student teachers who will support their learners in engaging in sustainability practices within their schools and beyond. However, [26] argue that educational interventions of limited duration do not significantly influence educators' intentions and actions in ESD. Thus, interventions should be designed as sustained, long-term initiatives. This suggests that participants in this study should continue to receive ESD workshops to achieve meaningful long-term impact. These findings raise important concerns about the sustainability of short-term ESD interventions. While they may enhance educators' knowledge and confidence, their long-term impact on intentions and teaching practices is likely to depend on ongoing professional development and supportive institutional environments.

Notably, behavioural intentions did not change significantly, despite improvements in ESD practice behaviour. Within the framework of the TPB, behavioural intention reflects motivation to act in favour of ESD [3]. However, ESD related behaviour is jointly determined by intention and perceived behavioural control [13]. Our results in this study therefore indicate that improving teacher educators' capability and contextual support may be more critical for behavioural change than attempting to influence already high levels of intention. These findings offer empirical evidence in support of the TPB by demonstrating that behavioural change can occur without corresponding changes in intention, particularly when perceived behavioural control and contextual support are strengthened. This finding is also consistent with previous ESD research, which shows that competence development and institutional support are stronger predictors of teaching practice than attitudes alone [7]. Our findings further highlight the importance of capability and enabling conditions in narrowing the gap between intention and practice, a phenomenon widely recognised in the TPB, where behavioural intentions do not necessarily translate into actual behaviour. Similar patterns have been observed in sustainability research, where intentions often fail to result in corresponding behavioural outcomes [11,18]. Furthermore, [20] demonstrate that ESD-related behaviour is shaped by the interaction of attitudes, social norms, and perceived behavioural control rather than intention alone, reinforcing the existing and persistent gap between intention and behaviour. These findings collectively advance understanding of ESD by showing that strengthening capability and contextual support is central to promoting behavioural change, and help resolve the apparent contradiction between stable intentions and improved practices observed in this study.

The findings further demonstrated that participants' understanding of ESD evolved from narrow, environmentally focused interpretations to more holistic and action-oriented conceptualisations that include knowledge, skills, values, and transformative action. This enhanced understanding helps explain the observed increase in perceived behavioural control, as participants became more confident in implementing ESD in their teaching. In line with [2], educators with a broader understanding of ESD principles are more likely to put their knowledge into practice. This finding is also supported by studies showing that conceptual clarity is a key mechanism for improving teaching practice in ESD [36]. This growing discussion in the literature presents an important contribution to the field, highlighting the role of conceptual understanding as a foundation for translating ESD knowledge into effective pedagogical practice.

Teacher educators are central to the successful incorporation of ESD within curricula, and their competencies, beliefs, and practices are critical for meaningful implementation [6]. In terms of pedagogical practice, participants initially reported integrating ESD through isolated activities such as real-life examples and project-based learning, often without explicit alignment to ESD principles. Following the workshops, participants described more intentional and structured approaches, including learner-centred, problem-based, and collaborative pedagogies. These approaches are widely recognised as effective for fostering sustainability competencies [41, 42]. The significant improvement in ESD-

related teaching practices observed in the quantitative data confirms that these pedagogical shifts were not only conceptual but also translated into measurable behavioural change. This supports findings by [28], who argue that participatory and collaborative approaches enhance critical thinking, agency, and sustainability-oriented action. These findings contribute to ESD by demonstrating how shifts in pedagogical approaches can support the development of sustainability competencies in teacher education.

Despite these improvements, structural and contextual challenges remained significant barriers to ESD implementation. Participants consistently reported limited resources, rigid curricula, and large class sizes as key constraints. While the intervention did not eliminate these challenges, it enabled participants to adopt a more solution-oriented approach, for example by using digital tools to compensate for resource limitations. This suggests that professional development can strengthen educators' capacity to navigate existing constraints rather than remove them entirely. Similar structural and contextual challenges have been widely documented in ESD implementation, with research emphasising the importance of building educators' adaptive and reflective capacities to work productively within such limitations [44]. These results reinforce the understanding that structural and institutional barriers remain central challenges in the effective implementation of ESD, even when individual competencies improve.

The findings indicate that ESD interventions are most effective when they focus on strengthening educators' understanding, confidence, and pedagogical competence, while also addressing institutional and structural factors that support sustained implementation. Although the workshops contributed to improvements in confidence and practice, persistent structural constraints limited the full implementation of ESD, suggesting that participants were not always able to implement ESD successfully. This highlights the need for sustained ESD capacity building to support teacher educators in understanding the complexity of sustainability issues and their interconnections [29]. As suggested by [26], short-term interventions such as the workshops provided in this study may have limited impact on ESD-related intentions and behaviour. This emphasises the importance of sustained and context-sensitive professional development in ESD. It further emphasises the need for sustained capacity development, institutional backing, and alignment of policies to enable teacher educators to fully integrate ESD into their teaching practice. Our study advances understanding of ESD by showing that while professional development can strengthen educators' knowledge, confidence, and practice, the success of ESD initiatives ultimately depends on the interplay between individual capacity and broader institutional support.

Conclusion

Before concluding, we acknowledge several potential biases that might have implications for the conclusions. The study relied on self-reported data, which may be subject to social desirability bias, particularly given that participants were drawn from the same project community. To mitigate this, participation was voluntary and anonymity was assured, encouraging honest responses. The small, matched sample of 24 participants, while appropriate for a pre- and post-survey design within a bounded project context, limits the generalisability of the findings. Conclusions are therefore drawn with caution and positioned as context-specific rather than universally applicable. To strengthen the trustworthiness of interpretations, quantitative and qualitative results were cross-referenced through triangulation. This approach enabled a more comprehensive and contextually grounded understanding of the data, where qualitative insights explained and complemented the statistical findings. Where results appeared contradictory or unexpected, possible explanations are offered based on the theoretical framework and existing literature rather than drawing definitive conclusions. These measures support the credibility and transparency of the study's conclusions, while recognising that future research with larger and more diverse samples is needed to validate and extend the findings beyond the current project context.

Despite the limitations outlined above, this study examined a workshop-based professional development intervention on teacher educators' engagement with ESD, focusing on key constructs derived from the TPB, alongside participants' understanding, pedagogical integration, and perceived implementation challenges. The findings indicate that while teacher educators already held highly positive attitudes and strong behavioural intentions towards ESD, the workshops primarily contributed to significant improvements in perceived behavioural control, subjective norms, and ESD-related teaching practices. This suggests that the intervention strengthened participants' confidence, contextual awareness, and practical implementation of ESD rather than their underlying intentions. Therefore, our findings contribute to ESD by demonstrating how professional development interventions can move educators from strong intentions to more consistent and effective practice. Importantly, the results highlight that behavioural change can occur without corresponding changes in intention, reinforcing the importance of capability and enabling conditions in translating intention into practice. These findings advance understanding of professional development for ESD in

teacher education by demonstrating that targeted capacity-building interventions are more effective in promoting ESD implementation than efforts aimed at changing attitudes or intentions that are already well established. Specifically, interventions that strengthen teacher educators' confidence and perceived institutional support appear to be the more critical drivers of meaningful and sustained ESD practice.

This study further demonstrated that participants' understanding of ESD evolved from narrow and fragmented interpretations towards more holistic and action-oriented conceptualisations. This enhanced conceptual clarity was reflected in more intentional and structured pedagogical approaches, including learner-centred, problem-based, and collaborative methods. The findings point to the critical importance of professional development in supporting not only knowledge acquisition but also pedagogical transformation in ESD. They present an important contribution to ESD, highlighting conceptual understanding as a key driver of effective implementation. Despite these positive developments, structural and contextual challenges, including limited resources, rigid curricula, and large class sizes, continued to constrain the full implementation of ESD. While the workshops enabled participants to adopt more solution-oriented approaches, these findings highlight the need for sustained and systemic support. These results also emphasise that structural and institutional barriers remain central challenges in the effective and sustained implementation of ESD. Consistent with [29] and [26], continuous capacity building is essential to enable teacher educators to engage with the complexity and interconnectedness of sustainability issues.

The findings additionally suggest that ESD interventions are most effective when they move beyond raising awareness and instead focus on strengthening educators' competence, confidence, and pedagogical practice, while simultaneously addressing institutional and structural conditions. This highlights the dual focus required in ESD, strengthening individual competencies while addressing contextual constraints. Higher education institutions therefore play a pivotal role in embedding ESD within curricula, supporting ongoing professional development, and creating enabling environments for sustainable teaching and learning [15]. This study's results thus advance understanding of ESD by showing that meaningful change is achieved through the interaction of improved individual capacity, pedagogical development, and supportive institutional conditions, while persistent structural challenges continue to shape the extent of implementation. Finally, future research should examine the long-term effects of such interventions and evaluate how institutional contexts influence the sustainability of ESD practices. Further studies could also investigate discipline-specific approaches to ESD integration and identify strategies for overcoming structural barriers within different higher education settings. In particular, longitudinal research is needed to examine whether observed changes in practice are sustained over time and how institutional conditions evolve to support or constrain long-term ESD implementation.

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