Review Article

e-ISSN: 2710-2122, p-ISSN: 2710-2114
2025: Vol 7(s1), pp 1-19. https://doi.org/10.38140/ijer-2025.vol7.s1.01
Interdisciplinary Journal of Education Research

Evaluating the Impact of Professional Development Programmes on Curriculum Design and Implementation for Sustainability Education in High Schools: A Scoping Review

Oluwatoyin A. Ajani[1*]
Samantha Govender[2]

AFFILIATIONS
[1&2]Faculty of Education, University of Zululand, KwaDlangezwa, South Africa.

CORRESPONDENCE
Email: oaajani@gmail.com*

EDITORIAL DATES
Received: 21 August 2024
Revised: 24 February 2025
Accepted: 02 March 2025
Published: 16 April 2025

DOI: 10.38140/ijer-2025.vol7.s1.01

Abstract: This scoping review aims to evaluate the impact of professional development programmes on the curriculum design and implementation of sustainability education in high schools. Reviewing literature published between 2010 and 2025, the study explores how these programmes prepare teachers to integrate sustainability concepts into their teaching practices, thereby promoting sustainable development. A systematic review of existing studies identifies key themes, challenges, and best practices in professional development for sustainability education. The findings reveal that well-designed professional development programmes significantly enhance teachers' knowledge and skills, leading to more comprehensive curriculum design and effective implementation. However, challenges such as inadequate resources, lack of administrative support, and insufficient ongoing training persist. The study highlights the importance of continuous, structured professional development to ensure integration of sustainability education into high school curricula. These insights are intended to guide policymakers, educators, and stakeholders in developing and maintaining effective sustainability education programmes at the secondary level.

Keywords: Professional development, sustainability education, curriculum design, teacher training, secondary education.

1. Introduction

Integrating sustainability education into high school curricula is essential for equipping students with the knowledge, skills, and values necessary to address contemporary environmental, social, and economic challenges. Education for Sustainable Development (ESD) has been recognised globally as a transformative force that fosters critical thinking, informed decision-making, and responsible citizenship (UNESCO, 2017). However, while sustainability education has gained increasing attention in policy and curriculum discussions, its effective implementation relies heavily on adequately prepared and supported teachers. Without targeted professional development (PD), educators may struggle to integrate sustainability concepts effectively across various subjects, thereby limiting the impact of sustainability education. Professional development is widely acknowledged as a fundamental driver of teaching quality and student outcomes (Darling-Hammond et al., 2017; Ajani & Govender, 2023). In the context of sustainability education, PD must be designed to equip teachers with both content knowledge and pedagogical strategies that transcend traditional subject boundaries (Rauch & Steiner, 2013). However, existing PD initiatives often fail to provide the depth of training necessary to enable teachers to embed sustainability principles into their curricula in meaningful and interdisciplinary ways. This gap in professional development presents a significant challenge, as teachers require ongoing training, access to resources, and institutional support to implement sustainability education with confidence.

One of the key barriers to effective sustainability education is the persistence of traditional, discipline-specific teaching approaches. Sustainability education demands a shift towards holistic, inquiry-based, and interdisciplinary pedagogies that encourage problem-solving, systems thinking,

and student engagement with real-world issues (Sterling, 2014; Govender & Ajani, 2021). While professional development programmes have the potential to support this transition, many are criticised for their short duration, lack of subject-specific guidance, and inadequate follow-up support (Fraser et al., 2007). Consequently, teachers often feel ill-equipped to integrate sustainability into their teaching practices, further underscoring the need for more sustained and targeted PD initiatives that provide practical strategies for embedding sustainability education within existing curricula.

Curriculum design plays a crucial role in the effective implementation of sustainability education. Educators must be supported in developing curricula that reflect the interconnectedness of environmental, social, and economic systems while remaining flexible and contextually relevant (Tilbury, 2011; Govender et al., 2023). However, research indicates that many educators lack confidence in designing sustainability-focused curricula, particularly in interdisciplinary contexts (Buchanan et al., 2018). This highlights the need for professional development (PD) programmes that enhance pedagogical expertise and provide guidance on curriculum development aligned with sustainability principles and broader educational objectives.

Institutional support is another critical factor influencing the effectiveness of sustainability education. Educators frequently report that a lack of leadership support and limited access to resources hinder their ability to implement sustainability concepts in their classrooms (Bodzin et al., 2010). School administrators play a pivotal role in fostering an environment that encourages innovation and supports professional learning (Robinson, 2011). Even well-trained and motivated educators may struggle to sustain meaningful changes in their teaching practices without strong institutional backing. Therefore, PD initiatives must address these structural barriers by advocating for policies that promote sustainability education at the institutional level (Ajani & Govender, 2024).

Furthermore, disparities in access to PD opportunities exacerbate inequities in sustainability education. Teachers in under-resourced schools often lack the technological tools and training needed to integrate sustainability effectively into their teaching (Jensen & Schnack, 2006). To bridge this gap, PD programmes should prioritise inclusivity, ensuring that all educators have access to high-quality training regardless of their school's financial and infrastructural constraints. Equitable professional development opportunities are essential for fostering widespread and effective implementation of sustainability education. Despite these challenges, successful models of sustainability-focused PD programmes exist, demonstrating that well-supported educators can effectively integrate sustainability into high school curricula. Initiatives such as the "Eco-Schools" programme provide a structured approach to embedding sustainability in schools through teacher training and institutional collaboration (Barratt Hacking et al., 2010). This study aims to identify best practices, challenges, and key themes that can inform future professional development initiatives by evaluating the effectiveness of such PD programmes. Strengthening PD for sustainability education is essential to ensuring that teachers are well-equipped to inspire and prepare students to become active participants in building a more sustainable future.

Thus, professional development is essential to sustainability education, equipping teachers with the knowledge and skills necessary to design and implement effective curricula (Govender & Ajani, 2021). However, for professional development programmes to be truly effective, they must be tailored to the specific needs of teachers and supported by broader institutional and policy frameworks. Thus, addressing the challenges and leveraging the opportunities identified in this study, policymakers, educators, and stakeholders can collaborate to create a more sustainable future for education. The following research objectives guide:

- To examine how professional development programmes enhance teachers' competencies in integrating sustainability concepts into high school curricula.
- To identify the challenges and barriers that teachers encounter in implementing sustainability education subsequent to their participation in professional development initiatives.

- To explore best practices and strategies for improving professional development programmes to ensure effective curriculum design and the implementation of sustainability education in high schools.

2. Theoretical Frameworks

In this study, two complementary theoretical frameworks, Social Justice Pedagogy and the Diffusion of Innovation Theory, are applied to evaluate the impact of professional development programmes on the curriculum design and implementation of sustainability education in high schools. These frameworks are instrumental in understanding how teachers are equipped to address sustainability issues in their teaching and how innovations, such as sustainability education, are adopted and integrated into school systems.

2.1 Social justice pedagogy in sustainability education

Social Justice Pedagogy emphasises that education should impart knowledge and empower individuals and communities to challenge inequalities and work towards a more just society (Freire, 1970). This approach is particularly relevant in sustainability education, as environmental issues disproportionately affect marginalised communities (Walker, 2012). By integrating social justice principles into sustainability education, students can gain a critical understanding of how environmental challenges—such as climate change, pollution, and resource depletion—are linked to broader socio-economic inequalities. This perspective shifts sustainability education from a neutral, technocratic approach to one that actively engages with systemic injustices, encouraging students to become agents of change in their communities.

To implement this pedagogical approach effectively, professional development programmes must equip teachers with the skills to facilitate critical discussions on sustainability and social justice. Teachers play a crucial role in connecting sustainability concepts to students' lived experiences, making learning more relevant and transformative (Cochran-Smith et al., 2009). However, many existing professional development initiatives fail to address the intersection of sustainability and social justice, instead focusing solely on content delivery (Picower, 2012). By incorporating social justice pedagogy into professional development, teachers can foster a generation of students who not only understand environmental issues but also critically engage with the power structures that contribute to sustainability challenges.

2.2 Diffusion of innovation theory and sustainability education

The Diffusion of Innovation Theory (Rogers, 1962) provides a valuable framework for understanding how new ideas and practices, such as sustainability education, are adopted within educational settings. According to this theory, the adoption of innovations follows a five-stage process: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). In the context of professional development for sustainability education, teachers must be introduced to sustainability concepts and supported throughout the process of integrating them into their teaching. If sustainability education is to be successfully embedded in school curricula, professional development initiatives must address the factors influencing adoption, such as perceived benefits, alignment with existing teaching practices, and ease of implementation.

One of the key insights from the Diffusion of Innovation Theory is the role of peer influence and social networks in facilitating the adoption of new teaching practices. Teachers are more likely to integrate sustainability education into their curricula if their colleagues have successfully implemented it (Straub, 2009). Therefore, professional development programmes should incorporate collaborative learning opportunities, allowing teachers to share best practices and develop supportive professional communities. Additionally, these programmes must address common barriers to adoption, such as a lack of resources, limited administrative support, and competing

educational priorities (Sahin, 2006). By designing professional development initiatives that align with the principles of the Diffusion of Innovation Theory, sustainability education can be more effectively disseminated and sustained across schools.

2.3 Integrating social justice pedagogy and diffusion of innovation theory

The combination of Social Justice Pedagogy and the Diffusion of Innovation Theory offers a comprehensive framework for implementing school sustainability education. While Social Justice Pedagogy ensures that sustainability education is grounded in real-world inequalities and promotes critical engagement, the Diffusion of Innovation Theory provides insights into how new pedagogical practices can be effectively introduced and sustained. By integrating these two perspectives, professional development programmes can be designed to empower teachers with the critical tools needed to address sustainability challenges and support them in overcoming institutional barriers to adoption.

This dual framework highlights the need for professional development initiatives that are both content-rich and strategically structured to encourage long-term adoption. Policymakers and educators must ensure that professional development in sustainability education not only equips teachers with theoretical and practical knowledge but also fosters a school environment that supports the sustained integration of sustainability principles into teaching and learning. Through this approach, sustainability education can become more impactful, ensuring that students are prepared to engage with the complex socio-environmental issues of the 21st century.

3. Literature Review

The increasing emphasis on sustainability education in schools highlights the crucial role of professional development in equipping teachers with the skills to integrate sustainability concepts into their curricula. As sustainability issues continue to dominate global discourse, schools are expected to prepare students to address environmental, social, and economic challenges (Ul Hassan, Murtaza, & Rashid, 2024). However, despite policy directives advocating for Education for Sustainable Development (ESD), teachers often lack the knowledge and confidence to incorporate sustainability education into their teaching practices effectively (Kotze, 2025). This gap underscores the necessity of professional development initiatives that enhance teachers' content knowledge and provide pedagogical strategies to facilitate meaningful learning experiences. Recent studies indicate that professional development programmes significantly shape teachers' capacity to implement sustainability education (Stevens, 2024). Effective professional development must go beyond a one-size-fits-all approach and instead be tailored to the needs of educators within specific socio-cultural and institutional contexts (Stutchbury, Ebubedike, Amos, & Chamberlain, 2025). However, many existing training programmes fail to address teachers' challenges in translating sustainability theory into practice. There is also a growing recognition that professional development should not be confined to periodic workshops but should instead be designed as a sustained, interactive process where teachers continually engage with sustainability concepts through professional learning communities (Shal, Ghamrawi, & Ghamrawi, 2024).

Integrating sustainability education into professional development also requires a rethinking of pedagogical approaches. Traditional teacher training programmes often focus on subject-specific knowledge, neglecting the interdisciplinary nature of sustainability education (Hinostroza-Paredes, 2020). Sustainability education demands a shift towards inquiry-based and experiential learning methodologies, enabling students to explore real-world environmental challenges through problem-solving and critical thinking. However, studies indicate that teachers frequently lack the training to implement such pedagogical innovations effectively (Davids & Waghid, 2020). This limitation suggests an urgent need for professional development frameworks that foster innovative teaching methods while aligning with sustainability principles.

One of the most pressing challenges in teacher professional development for sustainability education is the lack of institutional and administrative support. Research has shown that teachers who receive training in sustainability education often struggle to implement their learning due to unsupportive school policies and limited access to resources (Burger, Bellhaeuser, & Imhof, 2021). Professional development efforts may have limited long-term impact without systemic changes that prioritise sustainability education within school curricula. Furthermore, studies emphasise the importance of mentoring and peer collaboration in professional development, as teachers are more likely to adopt new pedagogical approaches when supported within their professional networks (Admiraal, 2023; Ani, Iketaku & Uzosike, 2021).

Equity in access to professional development also remains a critical issue, particularly in under-resourced schools. Research suggests that disparities in access to professional development opportunities contribute to the unequal implementation of sustainability education, with teachers in disadvantaged areas often receiving inadequate training (Kean, 2023). This challenge is further compounded by limited digital infrastructure, which affects the accessibility of online professional development programmes in some regions (Stutchbury, Chamberlain, & Rodriguez Leon, 2020). Consequently, there is a growing need to develop inclusive and accessible professional development initiatives that cater to the diverse needs of educators in different contexts.

Digital platforms and open-access courses have emerged as a promising approach to addressing these challenges (Stutchbury et al., 2025). Recent research highlights the effectiveness of digital professional development tools, such as Massive Open Online Courses (MOOCs), in reaching a broader range of teachers (Wilcoxen, Bell, & Steiner, 2020). These online platforms provide flexible learning opportunities, allowing teachers to engage with sustainability content at their own pace. However, despite their potential, online professional development initiatives must be designed carefully to ensure engagement, interactivity, and practical application (Ersin & Atay, 2021). Merely providing digital content is insufficient; professional development programmes must incorporate opportunities for teachers to collaborate, reflect, and apply their learning in real-world educational settings.

Another crucial factor in the professional development of sustainability education is the role of mentorship and teacher induction programmes. Studies suggest that early-career teachers often feel ill-equipped to teach sustainability topics due to a lack of formal training in their initial teacher education (Esau & Maarman, 2021). Mentorship programmes can help bridge this gap by pairing novice teachers with experienced mentors who can guide them in integrating sustainability concepts into their teaching (Goldhaber et al., 2022). Moreover, structured mentoring initiatives foster professional agency and confidence, enabling teachers to navigate the challenges of curriculum implementation more effectively (Dreer-Goethe, 2023).

Place-based education is another emerging approach that has shown promise in sustainability education (Padayachee, Maistry, Harris, & Lortan, 2023). Research indicates that students engage more deeply with sustainability topics when they are contextualised within their local environments (Gruenewald, 2003). Professional development programmes that encourage teachers to integrate locally relevant sustainability issues into their curricula can enhance student learning outcomes and foster a sense of environmental responsibility (Zhang et al., 2022). However, the success of place-based education depends on teachers having access to relevant professional development that equips them with the skills to design and implement such curricula effectively.

Despite the challenges, several successful professional development models for sustainability education have emerged. The Eco-Schools programme, implemented in over 60 countries, provides a framework for integrating sustainability into school curricula while offering professional development support for teachers (Henderson & Tilbury, 2004). Similarly, the Green School Network in the United States has developed a professional development model that supports educators in

designing sustainability-focused curricula and fostering environmentally conscious school cultures (Chawla & Cushing, 2007). These initiatives underscore the importance of a holistic approach to professional development, which includes teacher training, institutional support, collaborative learning, and access to resources.

Conversely, the effectiveness of professional development in fostering sustainability education depends on several key factors, including institutional support, pedagogical innovation, equitable access, and ongoing mentorship. Research highlights the need for sustained, collaborative, and contextually relevant professional development to have a meaningful impact on teaching and learning (Shal et al., 2024). Moving forward, policymakers and educational stakeholders must prioritise the integration of sustainability education into professional development initiatives to ensure that teachers are well-equipped to prepare students for the complex environmental challenges of the future.

4. **Research Methodology**

This study adopts a systematic literature review (SLR) methodology to evaluate the impact of professional development programmes on the curriculum design and implementation of sustainability education in high schools. A systematic literature review is a comprehensive, transparent, and replicable method for collecting, critically appraising, and synthesising existing research. This approach ensures a structured analysis of peer-reviewed articles, reports, and case studies that have examined professional development in relation to sustainability education (Petticrew & Roberts, 2006). Given the complex nature of sustainability education and its integration into high school curricula, the SLR is particularly suited to identifying key themes, challenges, and best practices that will guide future research and practice.

The first step in conducting the SLR involved defining straightforward research questions that align with the study's objectives. The primary research questions aim to explore the impact of professional development programmes on the integration of sustainability education into high school curricula. Specifically, this study seeks to address the following:

- How do professional development programmes enhance teachers' competencies in incorporating sustainability concepts into high school curricula?
- What challenges and barriers do teachers encounter when implementing sustainability education after participating in professional development initiatives?
- What best practices and strategies can improve professional development programmes to ensure effective curriculum design and implementation of sustainability education in high schools?

This clarity ensured that the review remained focused and relevant, avoiding unnecessary breadth while enabling an in-depth exploration of pertinent studies (Booth, Papaioannou, & Sutton, 2016). Next, a well-defined search strategy was developed to locate relevant literature, using keywords such as professional development, social justice, curriculum design, sustainable education, and diffusion of innovation. Studies published in English and sourced from peer-reviewed journals, books, and conference proceedings were accessed exclusively from the Scopus and Google Scholar databases. These databases were selected due to their extensive coverage of high-quality, peer-reviewed academic literature and their relevance to the study's focus on sustainability education and professional development. Scopus was chosen for its rigorous indexing of scholarly publications, ensuring credibility and reliability. At the same time, Google Scholar was included to provide broader access to diverse academic sources, including grey literature and interdisciplinary studies. This selective approach ensured a balance between scholarly rigour and comprehensive coverage of the field's most relevant and up-to-date research.

Search terms such as "professional development," "sustainability education," "curriculum design," and "teacher training" were combined with Boolean operators to identify relevant studies. Inclusion

and exclusion criteria were established to guide the selection process. Studies were included if they focused on high school settings, examined professional development programmes, explicitly addressed sustainability education or related concepts, and were published in English-language journals from 2010 to 2025. Thus, the time frame was set between 2010 and 2025 to capture contemporary research and trends in professional development related to sustainability education, given the growing importance of sustainability in educational policy (Kitchenham, 2004; Crocetti, 2015). Studies that did not meet these criteria or were based on tertiary education, unrelated disciplines, or grey literature were excluded from the review. Furthermore, only peer-reviewed studies were considered to ensure the quality and rigour of the analysis. This systematic approach to selecting literature enhanced the credibility and reliability of the findings (Higgins & Green, 2011).

Once the relevant studies were identified, the next stage involved screening and assessing the quality of the research. The screening process was carried out in two phases: title and abstract screening, followed by full-text screening. In this phase, any study that did not meet the inclusion criteria was removed. Studies that were ambiguous or marginally related were discussed and reviewed by two independent reviewers to reduce potential bias (Gough, Oliver, & Thomas, 2017). Quality assessment tools such as the Critical Appraisal Skills Programme (CASP) were employed to evaluate the methodological rigour of each selected study (CASP, 2018). This quality control ensured that only high-quality evidence was synthesised in the review.

The data extraction process was systematic and aimed at identifying key themes, findings, and methodologies employed by each study. Identifying the methodologies was essential to ensure that the selected studies aligned with the research questions, allowing for a rigorous analysis of how professional development programmes influence the integration of sustainability education, the challenges teachers face, and the best practices for improving these initiatives (Paul & Barari, 2022).

A standardised data extraction form was developed to ensure consistency across the extracted information. Key elements extracted included study aims, context, professional development strategies, curriculum implementation, challenges, and outcomes related to sustainability education. This detailed extraction facilitated the subsequent thematic analysis, helping to identify recurring themes and gaps in the existing literature (Arksey & O'Malley, 2005). An initial set of 269 articles was accessed; however, after applying the inclusion and exclusion criteria, this number was refined to a final selection of 77 articles used for the study. These 77 articles were then analysed thematically, following the systematic procedures outlined by Braun and Clarke (2006).

The systematic data synthesis, employing a thematic approach, provided a useful method for identifying patterns across qualitative data and was chosen to highlight commonalities and divergences in how professional development programmes influence sustainability education. Themes such as the role of teacher support, curriculum flexibility, resource availability, and ongoing professional learning emerged as critical factors in the effective implementation of sustainability education (Braun & Clarke, 2006). These themes provided valuable insights into the successes and challenges faced by educators (Table 1 below).

Table 1: *Generated themes from various studies using SLR (Authors).*

Theme	**Key Findings**	**Theoretical Perspective**	**Studies**
Professional Development and Teacher Capacity Building in Sustainability Education	PD enhances teachers' skills and knowledge for sustainability education; hands-on and collaborative PD	Diffusion of Innovation Theory explains PD as a catalyst for adopting sustainability education; Social	Lau & Ahfeldt (2014); Darling-Hammond (2017); Rogers (2003); Stutchbury, Chamberlain, & Rodriguez Leon (2020); Apple (2012); Freire (1970); Borko (2004); Buchanan, Schuck, & Aubusson

	approaches are more effective	Justice Pedagogy ensures inclusive teaching practices	(2018); Stutchbury et al. (2025); Admiraal (2023); Mezirow (2000); Goldhaber et al. (2022) Nicholls (2014); Ul Hassan, Murtaza, & Rashid (2024);
Curriculum Design for Sustainability Education	PD helps teachers design interdisciplinary curricula, but subject-specific silos hinder integration; digital learning platforms can support PD	Social Justice Pedagogy advocates for inclusive curriculum design; Diffusion of Innovation Theory suggests that perceived benefits influence adoption	Stutchbury, Ebubedike, Amos, & Chamberlain (2025); Burger, Bellhaeuser, & Imhof (2021); Tilbury (2011); Freire (1970); Hinostroza-Paredes (2020); Stevens (2024); Rogers (2003); Zhang et al. (2022); Goldhaber et al. (2022); Padayachee, Maistry, Harris, & Lortan (2023); Esau & Maarman (2021); Stutchbury, Chamberlain, & Rodriguez Leon (2020); Crocetti (2015); Admiraal (2023)
Challenges of Resource Availability and Access	Lack of digital tools, teaching materials, and funding in underprivileged schools hinders implementation	Diffusion of Innovation Theory explains infrastructure as a prerequisite for adoption; Social Justice Pedagogy stresses equal access to resources	Jickling & Wals (2008); Henderson & Tilbury (2004); Bodzin, Klein, & Weaver (2010); Rogers (2003); Petticrew & Roberts (2006); Davids & Waghid (2020); Apple (2012); Burger et al. (2021); Gough, Oliver, & Thomas (2017)
The Role of School Leadership and Administrative Support	Schools with leadership buy-in experience stronger implementation; sustainability should be embedded in policies	Diffusion of Innovation Theory states that leadership fosters adoption; Social Justice Pedagogy ensures equitable access	Scott (2013); Robinson (2011); Rogers (2003); Padayachee et al. (2023); Guskey (2002); Freire (1970); Esau & Maarman (2021); Wilcoxen, Bell, & Steiner (2020)
The Impact of Ongoing Professional Learning Communities (PLCs)	PLCs sustain PD impact by fostering peer learning, best practice sharing, and continuous reflection	Diffusion of Innovation Theory describes PLCs as early adopter networks; Social Justice Pedagogy highlights collective learning	Lave & Wenger (1991); Desimone & Garet (2015); Buchanan, Schuck, & Aubusson (2018); Rogers (2003); Stutchbury et al. (2025); Apple (2012); Freire (1970); Darling-Hammond, Hyler, & Gardner (2017); Esau & Maarman (2021); Goldhaber et al. (2022); Robinson (2011); Shal, Ghamrawi, & Ghamrawi (2024); Stutchbury, Chamberlain, & Rodriguez Leon (2020); Burger, Bellhaeuser, & Imhof (2021);

Ani, Iketaku, & Uzosike (2021); Guskey (2002); Moher et al. (2009)

The systematic literature review (SLR) adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological rigour and maintain coherence with the broader study. This approach ensured transparency, replicability, and a structured selection process aligned with the study's objectives (Paul & Barari, 2022). The PRISMA flowchart (as illustrated in the table below) systematically documented the inclusion and exclusion of studies, providing a clear audit trail that enhances the review's credibility (Moher et al., 2009). By integrating these rigorous procedures, the study upheld high standards of reliability and trustworthiness, thereby reinforcing its contribution to evidence-based research in sustainability education and professional development.

The limitations of this study's systematic literature review (SLR) method are acknowledged (Crocetti, 2015). One notable limitation is the reliance on published studies retrieved exclusively from Scopus and Google Scholar databases, which may exclude valuable insights from unpublished works or grey literature that could offer additional perspectives on professional development and sustainability education. Furthermore, the potential for publication bias remains a concern, as studies with positive findings are more likely to be published, potentially skewing the overall results. Nevertheless, the review's rigour and systematic approach help to mitigate these limitations to some extent, ensuring a balanced and comprehensive understanding of the research topic (Petticrew & Roberts, 2006).

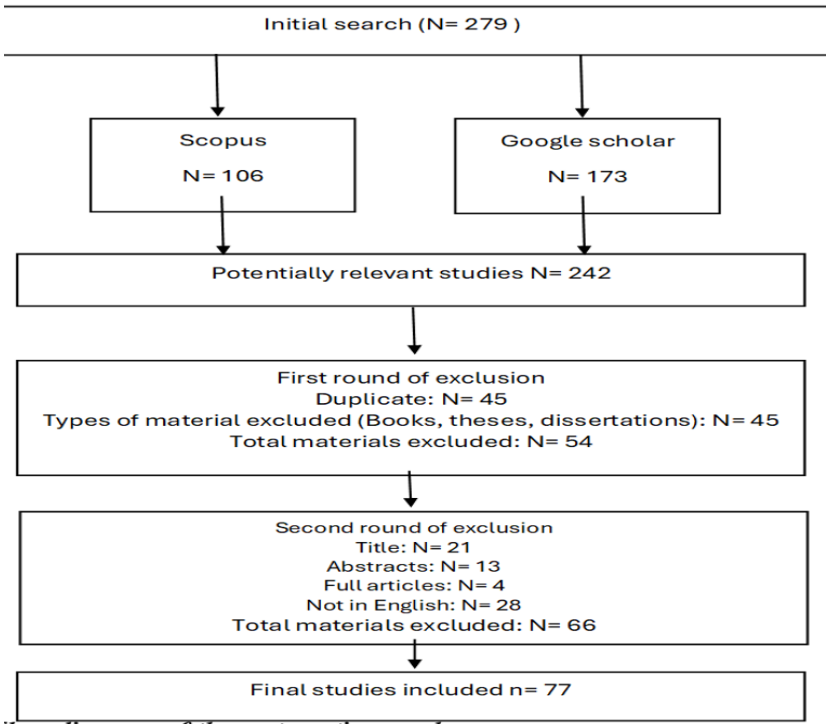

Figure 1: *Flow diagram of the systematic search process*

5. Presentation of Results

The results of this study, derived from a systematic literature review, highlight key themes related to the role of professional development in sustainability education. These themes include teacher capacity building, curriculum design, resource availability, administrative support, and the impact

of professional learning communities in fostering the effective and sustained integration of sustainability concepts into high school curricula.

5.1 Professional development and teacher capacity building in sustainability education

The first theme from the systematic literature review is the critical role that professional development (PD) plays in enhancing teachers' capacities to integrate sustainability education into high school curricula. Professional development programmes are essential for equipping educators with the necessary skills and knowledge to deliver sustainability-focused content effectively (Lau & Ahfeldt, 2014; Darling-Hammond, 2017). Studies reveal that PD programmes aligning with the principles of the Diffusion of Innovation Theory are more successful in embedding sustainable practices in education. This theory explains how innovations, such as sustainability education, are gradually adopted by individuals within an institution, with professional development acting as the catalyst that encourages early adopters and eventually reaches the broader teaching body (Rogers, 2003; Stutchbury, Chamberlain, & Rodriguez Leon, 2020). PD programmes that integrate collaborative learning, hands-on approaches, and real-world applications of sustainability concepts demonstrate greater efficacy (Hinostroza-Paredes, 2020; Stevens, 2024). These programmes foster an environment where teachers feel empowered to bring sustainability education into their classrooms, thus embodying the principles of Social Justice Pedagogy. This pedagogy advocates for inclusivity and equity, ensuring that all students have access to critical knowledge that empowers them to participate in creating a sustainable future (Apple, 2012; Freire, 1970). Teachers who undergo effective professional development become more adept at integrating sustainability in a way that is both accessible and transformative for students (Borko, 2004; Buchanan, Schuck, & Aubusson, 2018).

However, despite these successes, the literature highlights several challenges (Stutchbury et al., 2025; Admiraal, 2023), including a lack of ongoing professional development opportunities and inadequate support from school administrations. Teachers often report that while initial training is helpful, the absence of follow-up sessions or mentoring undermines the long-term impact of PD programmes. Therefore, sustaining teacher engagement with sustainability education requires continuous learning opportunities and systemic support, echoing the principles of both Diffusion of Innovation Theory and Social Justice Pedagogy, which advocate for ongoing development and inclusive teaching practices (Mezirow, 2000; Goldhaber et al., 2022).

5.2 Curriculum design for sustainability education

Curriculum design plays a crucial role in embedding sustainability education within high schools. However, many educators struggle to integrate sustainability principles due to rigid curriculum structures and a lack of institutional support (Nicholls, 2014). Professional development (PD) programmes can equip teachers with the necessary skills to design interdisciplinary curricula that align with sustainability goals (Ul Hassan, Murtaza, & Rashid, 2024). Nevertheless, traditional subject-specific silos often hinder cross-disciplinary collaboration, making it challenging to implement holistic sustainability education (Stutchbury, Ebubedike, Amos, & Chamberlain, 2025). Research suggests that collaborative curriculum design, where teachers work together across disciplines, can enhance the effectiveness of sustainability education by fostering interconnected learning experiences that address environmental, economic, and social justice concerns (Burger, Bellhaeuser, & Imhof, 2021; Tilbury, 2011). The Social Justice Pedagogy framework further underscores the importance of inclusive curriculum design, advocating for sustainable education that empowers students to understand and challenge systemic inequalities (Freire, 1970; Hinostroza-Paredes, 2020). However, many PD initiatives fail to provide teachers with practical tools for integrating sustainability into existing curricula, highlighting the need for targeted support that bridges theory with classroom practice (Stevens, 2024; Rogers, 2003). The Diffusion of Innovation Theory suggests that teachers are more likely to embrace sustainability education if they perceive it as beneficial, practical, and aligned with broader educational objectives (Rogers, 2003; Zhang et al.,

2022). Nonetheless, resistance from school administrations and assessment-driven priorities often hinder the integration of sustainability concepts into curricula (Goldhaber et al., 2022; Padayachee, Maistry, Harris, & Lortan, 2023).

To address these barriers, PD initiatives must train teachers in sustainability content and advocate for institutional support and curriculum flexibility (Esau & Maarman, 2021). Emerging research highlights the potential of digital learning platforms, such as webinars and MOOCs, in providing accessible PD opportunities that promote collaborative curriculum development (Stutchbury, Chamberlain, & Rodriguez Leon, 2020; Stevens, 2024). Additionally, place-based education has been identified as a practical approach for engaging students with sustainability by grounding learning in real-world, local contexts (Crocetti, 2015; Admiraal, 2023). For sustainability education to be fully realised, PD programmes must integrate technological advancements, interdisciplinary collaboration, and institutional advocacy to ensure meaningful and lasting curriculum transformation.

5.3 Challenges of resource availability and access

A recurring theme in the literature is the lack of resources for teachers to integrate sustainability education into their teaching effectively. While professional development can provide teachers with the necessary knowledge and skills, the absence of adequate resources—such as digital tools, teaching materials, and access to real-world sustainability projects—often hinders implementation (Jickling & Wals, 2008; Henderson & Tilbury, 2004). This issue is particularly prevalent in underfunded schools, where sustainability education is viewed as an additional burden rather than a core part of the curriculum (Bodzin, Klein, & Weaver, 2010). The Diffusion of Innovation Theory helps explain why resource availability is a significant barrier to adopting sustainability education. Innovations, such as new teaching methodologies or sustainability concepts, require teacher buy-in and the necessary infrastructure to support them (Rogers, 2003). In environments where resources are scarce, even the most well-intentioned teachers struggle to implement new curricula effectively (Petticrew & Roberts, 2006). This challenge reinforces the need for systemic support at the school and policy levels to ensure that all educators have access to the tools they need to succeed (Davids & Waghid, 2020).

This theme also intersects with Social Justice Pedagogy, which advocates for equitable access to education for all students, regardless of their socio-economic background (Apple, 2012). The unequal distribution of resources in schools means that students in disadvantaged areas are less likely to benefit from sustainability education, perpetuating existing inequalities (Burger et al., 2021). Addressing this requires targeted policy interventions to ensure that all schools have access to the necessary resources to implement sustainability education effectively (Gough, Oliver, & Thomas, 2017).

5.4 The role of school leadership and administrative support

Another key theme is the role of school leadership and administrative support in successfully integrating sustainability education into the curriculum. The literature reveals that schools where leadership actively supports sustainability initiatives are more likely to see sustained changes in teaching practices and curriculum design (Scott, 2013). Leaders who understand the importance of sustainability education and are committed to providing the necessary resources, time, and support for teachers play a critical role in fostering an environment that values sustainability (Robinson, 2011).

This aligns closely with the Diffusion of Innovation Theory, which posits that leadership and administrative buy-in are essential for the successful adoption of new ideas (Rogers, 2003). When school leaders act as early adopters of sustainability education, they create a ripple effect throughout the institution, encouraging other teachers to follow suit (Padayachee et al., 2023). Leadership

support can manifest in various ways, from providing time for professional development to ensuring that sustainability education is embedded in school-wide policies and practices (Guskey, 2002).In the context of Social Justice Pedagogy, school leadership also plays a critical role in ensuring that sustainability education is implemented in a way that promotes equity and inclusion (Freire, 1970; Esau & Maarman, 2021). Leaders must ensure that all students have equal access to sustainability education, regardless of their background or socio-economic status (Wilcoxen, Bell, & Steiner, 2020). This requires a commitment to curriculum reform and resource allocation, ensuring that sustainability education is integral to the school's mission.

5.5 The impact of ongoing professional learning communities

Professional Learning Communities (PLCs) play a vital role in sustaining teachers' engagement with sustainability education by fostering collaborative learning, peer support, and shared problem-solving. Research highlights that teachers who participate in ongoing professional networks are more likely to successfully integrate sustainability concepts into their teaching (Lave & Wenger, 1991; Desimone & Garet, 2015). These communities facilitate continuous reflection, discussions of challenges, and the exchange of best practices, thereby bridging the gap between professional development and practical implementation (Buchanan, Schuck, & Aubusson, 2018). Theoretically, PLCs align with the Diffusion of Innovation Theory, functioning as networks where early adopters spread sustainable teaching practices across institutions (Rogers, 2003; Stutchbury et al., 2025). Additionally, Social Justice Pedagogy underpins the importance of collaborative learning in addressing systemic inequalities, ensuring that all teachers—regardless of school resources—have access to shared knowledge and strategies for inclusive sustainability education (Apple, 2012; Freire, 1970). However, sustaining PLCs remains challenging, particularly in resource-limited schools, where time constraints and administrative barriers hinder teachers' ongoing participation (Darling-Hammond, Hyler, & Gardner, 2017; Esau & Maarman, 2021).

To ensure the long-term viability of PLCs, institutional support is critical. School leadership must prioritise professional collaboration by allocating time, resources, and incentives for teachers to engage in PLCs (Goldhaber et al., 2022; Robinson, 2011). Additionally, digital platforms and virtual learning communities provide an opportunity to expand access to PLCs, allowing educators from diverse backgrounds to engage in sustainability-focused professional learning, regardless of geographical constraints (Shal, Ghamrawi, & Ghamrawi, 2024; Stutchbury, Chamberlain, & Rodriguez Leon, 2020). The integration of sustainability education into initial teacher training is also crucial, ensuring that new educators enter the profession with the necessary skills to engage in collaborative learning and curriculum innovation (Burger, Bellhaeuser, & Imhof, 2021; Ani, Iketaku, & Uzosike, 2021). By embedding PLCs within the broader professional development framework and leveraging digital tools, schools can create a sustainable learning culture that empowers teachers to drive curriculum transformation and effectively embed sustainability education (Guskey, 2002; Moher et al., 2009).

6. Discussion of Findings

The discussion of this study is structured around two key theoretical perspectives: Social Justice Pedagogy and the Diffusion of Innovation Theory. These frameworks offer critical insights into how professional development (PD) initiatives can support the integration of sustainability education into high school curricula. Social Justice Pedagogy underscores the role of education in addressing social and environmental inequalities, advocating for an inclusive approach that empowers students to become agents of change (Freire, 1970). Meanwhile, the Diffusion of Innovation Theory (Rogers, 2003) explains how sustainability education spreads within schools, highlighting the conditions necessary for successful adoption. This discussion integrates insights from the systematic review to explore how these theories illuminate the opportunities and challenges in embedding sustainability education into teaching practices.

Social Justice Pedagogy provides a compelling rationale for prioritising sustainability education in professional development programmes. Sustainability issues, including climate change, resource depletion, and environmental injustice, disproportionately affect marginalised communities (Kotze, 2025). The systematic review identified that professional development initiatives must equip teachers with the knowledge and pedagogical skills to address these classroom inequalities (Hinostroza-Paredes, 2020). For sustainability education to be meaningful, it must go beyond theoretical discussions and engage students in real-world problem-solving that links environmental issues to social and economic disparities (Davids & Waghid, 2020). However, the literature suggests that many PD programmes fail to integrate these critical dimensions, limiting their impact on fostering transformative sustainability education.

As highlighted in the review, a key barrier to sustainability education is the persistent resource inequality among schools. Teachers in underfunded institutions often lack access to the materials and training necessary to incorporate sustainability concepts effectively (Burger, Bellhaeuser, & Imhof, 2021). From a Social Justice Pedagogy perspective, these disparities exacerbate educational inequities, as students from disadvantaged backgrounds are denied opportunities to engage meaningfully with sustainability themes (Kotze, 2025). To address this, professional development initiatives must build teachers' competencies and advocate for systemic changes that provide equitable access to resources, ensuring that all students can benefit from sustainability education (Ul Hassan, Murtaza, & Rashid, 2024).

The Diffusion of Innovation Theory offers a complementary perspective by explaining how sustainability education is adopted within schools. The systematic review revealed that teachers who undergo professional development (PD) programmes often serve as early adopters of sustainability concepts, influencing their colleagues and fostering a culture of innovation (Rogers, 2003). However, the review also highlighted that these efforts often fail to gain traction without institutional support. Schools where leadership actively promotes sustainability initiatives are more likely to see widespread adoption of sustainability education (Fullan, 2007). This aligns with research suggesting that administrators play a crucial role in shaping teachers' willingness and ability to integrate new pedagogical approaches (Goldhaber et al., 2022). Therefore, professional development must extend beyond teachers to include school leaders, ensuring that sustainability education becomes a systemic priority rather than an isolated initiative.

The effectiveness of PD programmes in advancing sustainability education is also contingent on the pedagogical approaches they promote. Sustainability education requires an interdisciplinary approach, yet many PD initiatives remain confined within traditional subject boundaries (Stevens, 2024). The systematic review found that collaborative learning models, such as Professional Learning Communities (PLCs), are particularly effective in enabling teachers to develop interdisciplinary sustainability curricula (Shal, Ghamrawi, & Ghamrawi, 2024). These communities provide a platform for teachers to share strategies, co-develop lesson plans, and reflect on their practice, fostering sustained engagement with sustainability concepts (Lave & Wenger, 1991). From a Social Justice Pedagogy perspective, PLCs also serve as critical spaces where educators can interrogate issues of equity and inclusion, ensuring that sustainability education is relevant and accessible to diverse student populations (Freire, 1970).

Despite the potential of PD to drive sustainability education, broader systemic challenges pose significant obstacles. The literature indicates that neoliberal education policies prioritising standardised testing and short-term performance metrics often undermine efforts to implement flexible, student-centred approaches to sustainability education (Apple, 2012). Teachers frequently report feeling constrained by rigid curriculum structures that leave little room for the interdisciplinary, inquiry-based learning required for sustainability education (Paul & Barari, 2022). Addressing this challenge requires a shift in how professional development is conceptualised—as a

means of enhancing teacher expertise and as a catalyst for broader educational transformation (Davids & Waghid, 2020).

Another challenge identified in the review is the socio-political resistance to sustainability education in specific contexts. Some stakeholders perceive sustainability topics as politically charged, particularly when they challenge dominant economic and environmental narratives (Scott, 2013). The Diffusion of Innovation Theory suggests that overcoming such resistance requires carefully framing sustainability education, emphasising its practical benefits for students' future careers and societal well-being (Rogers, 2003). Professional development programmes must therefore equip teachers with strategies to navigate these socio-political complexities, ensuring that sustainability education remains a constructive and inclusive learning experience (Zhang et al., 2022).

The review further underscores the need for sustained support structures beyond one-off professional development (PD) workshops. Research has consistently shown that ongoing mentoring and collaboration are essential for teachers to successfully integrate new pedagogical approaches (Stutchbury, Ebubedike, Amos, & Chamberlain, 2025). This aligns with findings that mentorship programmes, particularly those grounded in participatory learning models, enhance teachers' ability to navigate the challenges of sustainability education (Ani, Iketaku, & Uzosike, 2021). Without sustained engagement, teachers risk reverting to traditional teaching methods, undermining the long-term impact of PD initiatives (Kean, 2023). Consequently, professional development must be reconceptualised as a continuous process, incorporating peer mentoring, collaborative networks, and digital learning platforms (Stutchbury, Chamberlain, & Rodriguez Leon, 2020).

Integrating sustainability education into high school curricula requires a multidimensional approach that combines professional development with systemic institutional support. Social Justice Pedagogy highlights the importance of ensuring that sustainability education addresses social inequalities, while the Diffusion of Innovation Theory provides insights into the conditions necessary for its successful adoption. For professional development initiatives to be effective, they must enhance teachers' competencies, foster leadership buy-in, promote interdisciplinary collaboration, and offer sustained support mechanisms. By addressing these challenges, sustainability education can move beyond isolated classroom practices to become an integral part of the educational system, equipping students with the knowledge and skills to navigate and address the complex sustainability challenges of the 21st century.

7. Conclusion and Recommendations

Integrating sustainability education into high school curricula is crucial for preparing students to address global environmental and social challenges. This study has demonstrated that well-structured and continuous professional development (PD) programmes significantly enhance teachers' ability to incorporate sustainability concepts into their teaching. However, systemic challenges hinder effective implementation, including inadequate resources, insufficient institutional support, and rigid curriculum structures. By applying Social Justice Pedagogy and the Diffusion of Innovation Theory, the study highlights the need for equity-driven curriculum design and institutional mechanisms that facilitate the adoption of sustainability education. Without addressing these barriers, efforts to embed sustainability education within high schools will remain fragmented and have limited impact.

To overcome these challenges, enhancing PD programmes by ensuring they are ongoing, contextually relevant, and designed to provide theoretical knowledge and practical pedagogical strategies is essential. Teachers need interdisciplinary teaching approaches that integrate sustainability across various subjects while fostering critical thinking and problem-solving skills in students. Additionally, digital technologies should be leveraged with the Technological Pedagogical Content Knowledge (TPACK) model to enhance sustainability education in diverse teaching

contexts. Beyond individual teacher training, school administrators and policymakers must provide institutional support through adequate funding for teaching resources, professional learning communities (PLCs), and curriculum adjustments that incorporate sustainability-related competencies. Schools should foster collaborative cultures, encouraging teachers to share best practices and reflect on innovative teaching methods that effectively integrate sustainability principles.

Collaboration with external stakeholders, including businesses, environmental organisations, and local communities, is also vital in ensuring relevant and impactful sustainability education. These partnerships can offer students real-world learning opportunities through internships, experiential projects, and community-based initiatives, enhancing their understanding of sustainability beyond the classroom. Financial and material support from external organisations can further strengthen the integration of sustainability education in schools. By implementing these measures, sustainability education can become a transformative tool, equipping students with the knowledge, skills, and critical awareness needed to address global sustainability challenges and contribute to a more just and sustainable society.

8. Declarations

Author Contributions: Conceptualisation (O.A.A. & S.G.); Literature review (O.A.A. & S.G.); methodology (O.A.A. & S.G.); software (N/A.); validation (O.A.A. & S.G.); formal analysis (O.A.A. & S.G.); investigation (O.A.A.); data curation (O.A.A.) drafting and preparation (O.A.A. & S.G.); review and editing (O.A.A.); supervision (N/A); project administration (O.A.A. & S.G.); funding acquisition (N/A). All authors have read and approved the published version of the article.

Funding: This research did not receive any external funding.

Acknowledgements: The authors declare no acknowledgement.

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability: This review is based entirely on publicly available data and information sourced from peer-reviewed articles, reports, and other academic publications cited in the manuscript. No new primary data were generated or analysed during this study. Readers may refer to the cited sources for detailed information.

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