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Improving Teacher Education for Sustainable Development: Learning from Research

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ABSTRACT: This review article synthesizes research on teacher education programs aimed at promoting sustainable development. It explores effective pedagogical strategies and curricular enhancements that integrate sustainability concepts across various disciplines. The review highlights successful case studies from diverse educational settings, showing how teacher preparation can be transformed to foster ecological, economic, and social sustainability. Key findings suggest the necessity of incorporating experiential learning, critical thinking, and interdisciplinary approaches to equip teachers with the skills and knowledge required for the 21st century. Recommendations for policy makers and educational institutions emphasize the importance of continued research and collaboration to refine and expand sustainable practices in teacher education. This paper contributes to the evolving discourse on education for sustainable development, offering insights and practical guidance for educators, administrators, and policy makers committed to transforming teaching and learning for a sustainable future.

KEYWORDS: Teacher Education; Sustainable Development; Pedagogical Strategies; Teacher Professional Development

Introduction

Improving teacher education is an important key in realizing sustainable development, but there are often significant obstacles in this process. This happens because teachers, as agents of change in the world of education, often do not have adequate resources, training and support to effectively integrate sustainable development concepts in their teaching (Ferrer & Chalmeta, 2021; Glavič, 2020; Bürgener & Barth , 2018). In addition, there is a gap between sustainable development theory taught in universities and its application in teaching practice in schools, where current realities and global challenges are often not well reflected (Trevisan et al, 2023; Caniglia et al, 2018; Ramos et al, 2015). Many studies show that teachers feel unprepared or unsure to teach sustainable development topics due to a lack of training and available resources (Fang et al, 2023; Zhao & Cheah, 2023; Oberg & Bryce, 2022; Degiene et al, 2022). Existing teacher education curricula often do not include or place sufficient emphasis on sustainable development, leading to a lack of teaching readiness in this area (Gokmenoglu et al, 2023; Zguir et al, 2022). In addition, there is a gap between theoretical knowledge about sustainable development and practical skills to implement it in the classroom (Trevisan et al, 2023; Riess et al, 2022; Howell, 2021). From this situation, it is clear that it is vital to improve teacher education, especially in aspects of sustainable development, by utilizing the latest research so that they are equipped with the

knowledge, skills and resources necessary to teach future generations effectively.

Although there has been progress in research on the integration of Education for Sustainable Development (ESD) in teacher education, there are still significant gaps in the practical implementation and effectiveness of ESD teaching. Most studies focus on curriculum and policy development but often ignore how ESD principles are implemented in daily teaching practice, as well as how they impact student learning behavior (Harvey et al., 2018; Monroe et al., 2019). This research often does not provide adequate solutions to the real challenges teachers face in the classroom, such as a lack of resources, inadequate training, or weak institutional support (Carson & Moulden, 2017; Jensen & Schnack, 2018). Additionally, there is a paucity of research measuring the long-term impact of ESD training on teacher teaching performance and student learning outcomes, which makes it difficult to assess the effectiveness of existing interventions (O'Flaherty & Liddy, 2018; Tanner & Tanner, 2020). This gap suggests that despite advances in theory and policy, the practical application of ESD in the field requires deeper attention to ensure that teacher education truly prepares educators who can effectively implement and promote sustainability in their teaching (Laurie et al., 2021; Mezirow & Taylor, 2023).

The aim of this paper is to identify effective ways of improving teacher education, so that they can be more effective in integrating sustainable development into education. Effective teacher education in sustainable development is important for creating future generations who are aware of sustainability and can contribute to global solutions (Almazroa et al, 2022; Chiba et al, 2021; Del Carmen et al, 2021; Gonzales et al, 2020). Education that meets today's needs requires a deeper understanding of how teachers can be trained effectively. In this context, how can teacher education be improved to effectively support Sustainable Development Goals (SDGs)? Specifically, three main research questions were addressed (1). How can teacher education effectively integrate ESD competencies into its curriculum? (2) How can teacher education utilize pedagogical and technological innovations to teach ESD? and (3) How is the impact of ESD teaching measured and what are the main challenges in implementing it? Answering these questions will help in formulating more targeted and effective strategies in teacher education, which will in turn promote sustainable development at the global level.

This study argues that improving teacher education for sustainable development requires a holistic approach that targets not only knowledge and skills, but also teachers' values and attitudes. Teachers as agents of change play a key role in educating young people about sustainable development, but traditional approaches to teacher education often do not provide them with sufficient tools to face these contemporary challenges (Manakane & Rakuasa, 2023; Rivadeneira & Inga, 2023). This deficiency arises from the lack of focus on non-technical aspects such as ethics, sustainability values, and environmental sensitivity in teacher education curricula (Cheng & Wang, 2023; Dawodu et al, 2023; Lopez et al, 2019). Research shows that integrating these aspects in teacher education can improve their ability to teach and apply sustainable development principles effectively. Additionally, teacher training that focuses more on innovative and interactive teaching methods can increase student engagement in sustainable development topics. Therefore, a more comprehensive and diversified approach to teacher education, which combines knowledge, skills, values and attitudes, is key to effectively achieving sustainable development goals.

Research methods

Research design

This article employs a systematic review method to analyze and integrate findings from various studies related to enhancing teacher education in support of sustainable development. The objective of this review is to identify effective ways to improve teacher education so that teachers are better equipped to integrate sustainable development concepts into education.

Literature search process

The literature search was conducted through major academic databases such as Google Scholar, JSTOR, ScienceDirect, and ERIC. Additionally, manual searches were performed through references from key articles. Keywords used in the literature search included "Teacher education," "Sustainable development," "Education for Sustainable Development (ESD)," "Teacher training," "Pedagogical innovations," and "Curriculum integration."

Inclusion and exclusion criteria

Table 1: Inclusion and exclusion criteria for systematic review

Inclusion Criteria	Exclusion Criteria
Peer-reviewed articles published in the last 10 years (2013-2023)	Articles that are not peer-reviewed (e.g., opinions, editorials)
Studies focused on teacher education and sustainable development	Studies not relevant to the topic of teacher education and sustainable development
Articles discussing the integration of ESD into teacher education curricula	Articles not available in full text
Studies reporting empirical results or literature reviews related to teacher training and development in the context of ESD	

Selection and evaluation process

The selection process began with the screening of titles and abstracts of articles found through the literature search. Articles that did not meet the inclusion criteria were immediately excluded. Articles that passed the initial screening were then fully evaluated, involving an assessment of the methodology, results, and relevance of the studies to the review topic. Each article was independently evaluated by two researchers to ensure objectivity.

Data analysis

Data from the articles included in this review were qualitatively analyzed using thematic synthesis. This analysis aimed to identify key themes relevant to enhancing teacher education to support sustainable development. The main themes identified included the integration of ESD competencies into teacher education curricula, the use of pedagogical and technological innovations in teaching ESD, and the impact of ESD teaching on student learning outcomes and teaching performance.

The analysis process began with open coding to identify key concepts from each article. Open coding allowed researchers to discover and record important ideas and findings without preconceived notions. After identifying the main concepts, axial coding was conducted to connect these concepts and group them into larger, more coherent themes. Axial coding helped in constructing a comprehensive thematic structure and enabled researchers to identify relationships between various findings and themes. Through this process, data analysis provided deep insights into effective ways to enhance teacher education in the context of sustainable development.

Research findings

Competency development

Research has highlighted the importance of effectively integrating ESD competencies into teacher education. Imara and Altınay (2021) identify key competencies that teachers must possess to effectively implement ESD, including a deep understanding of sustainability concepts, the ability to integrate sustainability values into teaching, skills in using relevant pedagogical approaches, and the ability to collaborate with communities and other stakeholders. However, they emphasize that there are still gaps in frameworks that unify teacher competencies for ESD, necessitating efforts to develop more structured and comprehensive competency standards (Imara & Altınay, 2021).

Additionally, research by Brandt et al. (2019) underscores the importance of developing non-cognitive competencies in ESD education. These competencies include attitudes and values that support sustainability, which can be acquired through specialized courses and training. Brandt et al. found that when teachers are trained to develop holistic competencies encompassing cognitive, affective, and psychomotor aspects, they are more prepared and motivated to teach sustainability concepts effectively. Training that includes practical simulations and hands-on experiences also significantly aids in building these competencies (Brandt et al., 2019).

Further research highlights the need for a comprehensive framework to measure and develop teacher competencies in ESD. For instance, Gonzales et al. (2020) propose a competency development model that involves periodic assessments and continuous updates based on feedback from teachers and students. This model includes various assessment tools to measure teachers' skills and knowledge in different aspects of ESD, as well as ongoing training to ensure that acquired competencies remain relevant and up-to-date. Implementing such a framework can help address existing gaps and enhance the effectiveness of ESD education (Gonzales et al., 2020).

Pedagogical innovations

Innovations in ESD teaching methodologies continue to evolve, with the integration of technology becoming increasingly important. Cebrián et al. (2020) explore how Smart Classrooms can support ESD methodologies through project-based learning and collaborative inquiry. They find that the use of technologies such as online collaboration tools, interactive learning devices, and simulation applications can enhance student engagement and allow the application of ESD concepts in real-world situations. These innovations not only make learning more engaging but also improve students' understanding of sustainability issues and encourage them to think critically and creatively about solutions (Cebrián et al., 2020).

Further pedagogical innovations include the use of gamification in ESD education. Monroe et al. (2019) show that incorporating game elements into teaching can increase student motivation and make learning more enjoyable and interactive. Gamification allows students to participate in simulations that replicate the impact of environmental decisions, helping them understand the complexity of sustainability issues and develop problem-solving skills. The use of gamification also enables teachers to dynamically and engagingly assess students' understanding of ESD concepts (Monroe et al., 2019).

Additionally, research indicates that innovations in ESD teaching also involve interdisciplinary approaches. Caniglia et al. (2018) emphasize the importance of combining various disciplines in ESD education to provide students with a more holistic perspective. This approach includes integrating natural sciences, social sciences, and humanities into the curriculum, allowing students to understand sustainability issues from multiple viewpoints. Thus, students not only learn about sustainability theory but also how to apply it in real-life contexts (Caniglia et al., 2018).

Curriculum integration

The importance of integrating ESD competencies into the teacher education curriculum is emphasized by many researchers. Dumitru (2017) discusses the integration of ESD competencies through an infusion technique in the teacher education curriculum in Romania. This technique involves embedding ESD competencies into existing subjects, enabling teachers to teach sustainability concepts in relevant and practical contexts. Dumitru suggests that pedagogical training programs specifically designed to blend ESD competencies with the existing curriculum can enhance teachers' readiness to effectively teach sustainability (Dumitru, 2017).

Research by Chiba et al. (2021) shows that ESD curriculum integration requires strong policy support and collaboration among various educational stakeholders. This includes the development of national standards for ESD and the provision of adequate resources for its implementation. Strong policy support ensures that ESD integration is not just a temporary

initiative but becomes an integral part of the education system. Chiba et al. emphasize the importance of collaboration between governments, educational institutions, and communities to create a supportive environment for ESD implementation (Chiba et al., 2021).

Moreover, research by Gonzales et al. (2020) highlights the importance of flexibility in the ESD curriculum. They find that a flexible curriculum allows teachers to adapt materials to local contexts and students' needs. This not only makes learning more relevant but also fosters innovation and creativity in teaching. Curriculum flexibility also enables teachers to integrate emerging sustainability issues, ensuring that learning remains up-to-date and aligned with current global challenges (Gonzales et al., 2020).

Teacher preparedness

Teacher preparedness to teach ESD is influenced by various factors, including their knowledge of ESD, personal beliefs about sustainability, and practical experience in teaching the topic. Murphy et al. (2020) find that innovative and engaging professional development programs can boost teachers' confidence and competencies in teaching sustainability through science education. They emphasize the importance of interactive and collaborative training approaches to ensure that teachers feel prepared and motivated to integrate ESD into their teaching. This program also highlights the need for ongoing support and opportunities for teachers to participate in supportive communities of practice (Murphy et al., 2020).

Research by Zhao and Cheah (2023) shows that teacher preparedness is also influenced by their access to relevant resources and teaching materials. They find that teachers with access to high-quality resources and comprehensive teaching materials are more likely to feel prepared and capable of teaching ESD. Zhao and Cheah emphasize the importance of developing and distributing teaching materials that support ESD education, as well as providing training that helps teachers effectively use these resources (Zhao & Cheah, 2023).

Additionally, teacher preparedness for ESD is affected by school culture and institutional support. Oberg and Bryce (2022) find that schools supporting a culture of sustainability and providing strong institutional support, such as ongoing training and mentoring, are more likely to have teachers prepared to teach ESD. They suggest that to enhance teacher preparedness, concerted efforts are needed from schools and educational institutions to create an environment that supports learning and teaching sustainability (Oberg & Bryce, 2022).

Impact measurement

Measuring the impact of ESD teacher training remains an ongoing challenge. Eliyawati et al. (2023) develop an instrument to measure science teachers' competencies in teaching ESD, which includes content knowledge, pedagogical content knowledge, and attitudes toward ESD. This instrument is designed to provide a comprehensive evaluation of the effectiveness of teacher training in enhancing their ability to teach sustainability concepts. However, further research is needed to develop more accurate and reliable measurement methods to assess the effectiveness of ESD interventions, including the long-term impact on teaching performance and student learning outcomes (Eliyawati et al., 2023).

Research by O'Flaherty and Liddy (2018) indicates that measuring the impact of ESD should include long-term evaluations to understand sustainable changes in teaching practices and student learning outcomes. They emphasize the importance of using various evaluation methods, such as surveys, interviews, and classroom observations, to gain a comprehensive understanding of the effectiveness of ESD training. Long-term evaluations can help identify areas needing improvement and provide valuable feedback for future training program development (O'Flaherty & Liddy, 2018).

Furthermore, Tanner and Tanner (2020) stress the importance of developing clear and measurable performance indicators for evaluating the impact of ESD. They propose that

these indicators should encompass various aspects, such as improvements in teachers' knowledge and skills, changes in teaching approaches, and increased awareness and understanding of sustainability among students. By using measurable performance indicators, educational institutions can more easily evaluate the effectiveness of training programs and make necessary adjustments to enhance outcomes (Tanner & Tanner, 2020).

Challenges and barriers

Challenges in integrating ESD into teacher education include a lack of content knowledge and comprehensive frameworks for developing ESD competencies. Timm and Barth (2020) identify two types of ESD teachers showing differences in skills integrating ESD into their teaching. The first type possesses strong theoretical knowledge but lacks practical skills, while the second type has practical skills but lacks theoretical knowledge. They emphasize the importance of training focused on developing structural competencies that encompass both aspects to address these gaps (Timm & Barth, 2020).

Other barriers identified include a lack of institutional support, limited resources, and resistance to changes in teaching practices. Carson and Moulden (2017) find that teachers often feel unsupported by their institutions in effectively implementing ESD. They emphasize that institutional support, such as supportive policies, adequate resources, and continuous training, is crucial to overcoming these barriers. Without sufficient support, efforts to integrate ESD into teacher education are likely to be unsuccessful (Carson & Moulden, 2017).

Additionally, resistance to change poses a significant challenge in ESD integration. Jensen and Schnack (2018) show that many teachers feel comfortable with traditional teaching methods and are reluctant to adopt new approaches required for ESD. They suggest that cultural change within educational institutions is necessary to encourage acceptance and adoption of ESD. This includes providing comprehensive training, support from school leadership, and creating an environment that encourages experimentation and innovation in teaching (Jensen & Schnack, 2018).

Best practices

Best practices in teacher education for ESD involve a holistic approach combining competency development, innovative methodologies, and effective curriculum integration. Vare et al. (2019) offer valuable insights into developing practical accreditation models for educators working on ESD. They highlight the importance of constructivist pedagogical approaches, which focus on active, collaborative, and reflective learning. These approaches can enhance the effectiveness of teacher education in teaching sustainability concepts and encourage students to think critically and creatively (Vare et al., 2019).

Research also shows that developing professional networks and learning communities for teachers is a key component of best practices in ESD education. Laurie et al. (2021) find that teachers with access to professional networks and learning communities are more likely to share knowledge and experiences, which in turn can enhance their skills and confidence in teaching ESD. These networks also provide platforms for collaboration and support, helping teachers overcome challenges and barriers in implementing ESD (Laurie et al., 2021).

Other best practices include the use of continuous evaluation and feedback to improve ESD education programs. Mezirow and Taylor (2023) emphasize the importance of ongoing evaluation to understand program effectiveness and identify areas needing improvement. They suggest that feedback from teachers and students should be used to make necessary adjustments and ensure that ESD education programs remain relevant and effective. Thus, teacher education for ESD can continue to evolve and adapt to changing needs and global challenges (Mezirow & Taylor, 2023).

Discussion

The findings from this systematic review provide critical insights into the multifaceted nature of integrating Education for Sustainable Development (ESD) competencies into teacher

education programs. This discussion synthesizes these insights, highlights practical implications, and suggests future research directions to enhance the efficacy of teacher education in promoting sustainable development.

Enhancing competency development

The literature underscores the necessity of a comprehensive framework for developing ESD competencies among teachers. Imara and Altınay (2021) and Brandt et al. (2019) highlight that current efforts often lack cohesion, resulting in inconsistencies in teacher preparedness. To address this, a structured approach that encompasses both cognitive and non-cognitive competencies is essential. Establishing standardized competency frameworks that integrate knowledge, skills, and attitudes required for ESD is crucial. Furthermore, incorporating practical simulations and experiential learning in teacher training programs can significantly enhance competency development. Continuous assessment and feedback mechanisms, as suggested by Gonzales et al. (2020), are vital for maintaining the relevance and efficacy of these competencies over time (Imara & Altınay, 2021; Brandt et al., 2019; Gonzales et al., 2020).

Advancing pedagogical innovations

Innovative teaching methodologies, particularly those involving technological integration, have shown promise in enhancing ESD education. Cebrián et al. (2020) and Monroe et al. (2019) illustrate how Smart Classrooms and gamification can make learning more engaging and effective. However, widespread adoption of these technologies requires substantial investment and comprehensive teacher training. Educational institutions and policymakers must prioritize funding for technological advancements and ensure that teachers are adequately trained to utilize these tools effectively. Additionally, interdisciplinary approaches, as highlighted by Caniglia et al. (2018), are crucial for providing students with a holistic understanding of sustainability issues. Teacher education programs should emphasize the integration of various disciplines, fostering a more comprehensive and interconnected approach to sustainability education (Cebrián et al., 2020; Monroe et al., 2019; Caniglia et al., 2018).

Integrating ESD into curriculum

The integration of ESD competencies into the teacher education curriculum is imperative, as emphasized by Dumitru (2017) and Chiba et al. (2021). Robust policy support and collaboration among educational stakeholders are essential for this integration. Developing national standards for ESD and ensuring the provision of adequate resources for its implementation can make ESD a permanent aspect of teacher education. Flexible curricula, as advocated by Gonzales et al. (2020), are also important to accommodate local contexts and emerging sustainability issues. Such flexibility allows teachers to adapt their teaching materials to the specific needs of their students and communities, enhancing the relevance and effectiveness of ESD education (Dumitru, 2017; Chiba et al., 2021; Gonzales et al., 2020).

Improving teacher preparedness

Teacher preparedness to teach ESD is influenced by access to resources, professional development opportunities, and institutional support. Murphy et al. (2020) and Zhao and Cheah (2023) emphasize the need for high-quality resources and comprehensive training programs to boost teachers' confidence and competencies. Schools and educational institutions must invest in continuous professional development and create supportive environments that encourage the integration of ESD into everyday teaching practices. Institutional support, as noted by Oberg and Bryce (2022), is critical for fostering a culture of sustainability within schools. Providing ongoing mentoring, promoting collaborative practices, and ensuring access to necessary resources and support networks are crucial steps in this direction (Murphy et al., 2020; Zhao & Cheah, 2023; Oberg & Bryce, 2022).

Measuring impact and addressing challenges

Measuring the impact of ESD teacher training remains a challenge, as highlighted by Eliyawati et al. (2023) and O'Flaherty and Liddy (2018). Developing reliable and comprehensive evaluation methods is essential for capturing the

sustained effects of ESD training on teaching practices and student outcomes. Long-term evaluations and diverse evaluation tools, such as surveys, interviews, and classroom observations, can provide a holistic understanding of the effectiveness of ESD training. Tanner and Tanner (2020) stress the importance of clear and measurable performance indicators for evaluating ESD impact. These indicators should cover various aspects, including improvements in teachers' knowledge and skills, changes in teaching approaches, and increased student awareness and understanding of sustainability (Eliyawati et al., 2023; O'Flaherty & Liddy, 2018; Tanner & Tanner, 2020).

Addressing challenges and barriers to ESD integration involves overcoming resistance to change and ensuring adequate institutional support. Timm and Barth (2020) and Carson and Moulden (2017) identify a lack of content knowledge and comprehensive frameworks as significant obstacles. Overcoming these challenges requires cultural shifts within educational institutions to promote the acceptance and adoption of ESD. Providing incentives for teachers to engage in ESD training and implementing supportive policies are necessary steps to foster sustainable teaching practices (Timm & Barth, 2020; Carson & Moulden, 2017).

Best practices and future directions

The review identifies best practices in teacher education for ESD, including developing professional networks and continuous evaluation. Vare et al. (2019) and Laurie et al. (2021) highlight the importance of collaborative and reflective practices in enhancing teacher competencies and promoting innovation. Developing professional networks and learning communities for teachers facilitates knowledge sharing and support, enhancing their skills and confidence in teaching ESD (Vare et al., 2019; Laurie et al., 2021).

Continuous feedback and adaptive approaches, as recommended by Mezirow and Taylor (2023), are crucial for ensuring the relevance and effectiveness of ESD education. Implementing mechanisms for regular feedback from teachers and students allows for the refinement and improvement of ESD programs. Future research should explore the effectiveness of these best practices in diverse educational contexts and identify strategies for scaling successful models (Mezirow & Taylor, 2023).

Conclusion

This review highlights the complexity of integrating ESD into teacher education and underscores the importance of a holistic and structured approach. By addressing the identified challenges and leveraging best practices, educational institutions can enhance the effectiveness of ESD education, better preparing teachers to foster sustainable development. Future research and policy efforts should focus on developing comprehensive frameworks, supporting innovative pedagogies, and creating supportive environments to enable teachers to thrive in their roles as sustainability educators.

Disclosure statement

The authors declare no conflict of interest

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