CHAPTER SIX

Education for Sustainable Development and Its Implication for the Preparation of Pre-service Mathematics Teachers

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Abstract: This chapter explores the integration of Education for Sustainable Development (ESD) into mathematics teacher education programmes. It highlights the fundamental principles of ESD and examines the potential benefits and challenges of incorporating these principles into mathematics education. The chapter methodically synthesises key themes related to ESD principles, such as an interdisciplinary approach, critical thinking and problem-solving, active participation, values and ethics, sustainable consumption, and holistic understanding. Furthermore, it identifies various pedagogical strategies that can facilitate the integration of ESD into mathematics teacher education programmes and discusses their significance. The chapter argues that integrating ESD into mathematics teacher education can enhance mathematics teacher educators' ability to foster critical thinking and problem-solving skills among pre-service mathematics teachers. It also reveals that while there are significant opportunities for enriching the mathematics curriculum through ESD, challenges such as limited resources, lack of training, and resistance to change within educational institutions persist. The chapter emphasises the need for collaborative efforts among educators, policymakers, and institutions to overcome these obstacles. Additionally, it contributes to the existing body of knowledge by providing valuable insights for mathematics teacher educators and stakeholders interested in promoting sustainable practices within mathematics curricula. Thus, by addressing both the challenges and opportunities associated with ESD integration, this chapter serves as a foundational resource for future research and practice in the field.

Keywords: Challenges and opportunities, education for sustainable development, integration, mathematics teachers, teacher preparation.

1. Introduction

Education for Sustainable Development (ESD) has become an essential paradigm for incorporating sustainability into educational practices across several disciplines. The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2018) refers to ESD as a comprehensive educational approach that enables individuals to make informed decisions and undertake responsible activities for environmental sustainability, economic viability, and social equity. ESD is a developing framework aimed at providing individuals with the knowledge, skills, attitudes, and values essential for fostering a sustainable future. It underscores the interconnection of environmental, social, and economic facets of sustainability and seeks to cultivate critical thinking, problem-solving, and proactive strategies to address current global

issues (Sharma, 2023; Assefa, 2024). The framework prioritises critical thinking, problem-solving, and interactive learning, urging learners to comprehend intricate interrelations within social, economic, and environmental systems (Taylor, 2014; Rieckmann, 2018; Agbedahin, 2019). Thus, as the globe confronts challenges including climate change, biodiversity decline, and social injustice, ESD has gained prominence in educational discussions and practices.

In mathematics education, ESD seeks to contextualise mathematical concepts within real-world sustainability issues, rendering mathematics relevant and practical to students' lives and future professions. However, research on the impact of ESD in mathematics teacher preparation is still in its nascent stages, highlighting the need for empirical studies that examine best practices and effective models. In mathematics education, ESD aims to prepare pre-service mathematics teachers with the knowledge, skills, and attitudes essential for promoting a sustainable future through their pedagogical practices.Therefore, the integration of ESD into mathematics education stems from the understanding that mathematics serves not just as a collection of abstract ideas but also as a means to tackle real-world challenges, such as environmental sustainability, social equity, and economic viability (UNESCO, 2014). For instance, studies (Renert, 2011; Li & Tsai, 2022) contend that mathematics educators should be prepared to cultivate critical thinking and problem-solving abilities that enable students to address sustainability issues. However, this necessitates a change in teacher development programmes to incorporate ESD concepts and practices. Furthermore, the integration of ESD in mathematics teacher education requires a re-evaluation of assessment techniques. Traditional assessment methods in teacher preparation programmes often prioritise memorisation and procedural skills, which may inadequately represent students' understanding of sustainability concepts or their ability to apply mathematical reasoning in real-world situations (Olawale, 2022; Olawale & Hendricks, 2023). Thus, this chapter explores the concepts of ESD, its key principles, how it could be integrated into mathematics teacher education programmes, as well as its challenges and opportunities.

2. The Concept of Education for Sustainable Development

ESD has become a crucial concept in discussions about sustainable practices and policies, especially regarding global environmental issues. ESD is characterised as a comprehensive educational approach that incorporates sustainability principles into teaching and learning, with the objective of enabling individuals to make informed choices and engage in responsible actions for environmental integrity, economic viability, and social equity (UNESCO, 2014; Agbedahin, 2019). As such, literature on ESD encompasses various facets, including theoretical frameworks such as the model of competence and systems theory (De Haan, 2010; Kopnina & Meijers, 2014; Handtke, Richter-Beuschel, & Bögeholz, 2022), instructional practices such as experiential learning and inquiry-based learning (Kostoulas-Makrakis, 2010; Sinakou, Donche, & Van Petegem, 2022; Sinakou, Donche, & Van Petegem, 2024), and empirical studies that highlight its significance and implications for educational systems worldwide (Mochizuki & Fadeeva,

2010; Ssossé, Wagner, & Hopper, 2021; Mutongoza, Olawale, & Mncube, 2023). Similarly, the transformative learning theory, postulated by Mezirow (1995; 2018), is a foundational paradigm underpinning Education for Sustainable Development (ESD). This concept posits that learning necessitates critical reflection, enabling individuals to scrutinise their assumptions and ideas. In the context of ESD, transformative learning encourages learners to tackle complex sustainability issues, improving critical thinking and fostering a sense of agency (Rieckmann, 2018).

Extensive research has also demonstrated the effectiveness of transformative learning in ESD environments, suggesting that it enhances learners' capacity to address sustainability challenges (Sterling, 2011; Leal Filho et al., 2018; Alam, 2022). Thus, given that pedagogical approaches to ESD are diverse and often customised to specific settings, strategies such as inquiry-based learning, experiential learning, problem-based learning, and project-based learning are frequently acknowledged as effective methodologies that promote active engagement and problem-solving skills in students (Murphy, Smith, Mallon, & Redman, 2020; Daramola et al., 2024; Funa, Roleda, & Prudente, 2024; Cebrián, Palau, & Mogas, 2020; Siphukhanyo & Olawale, 2024). These techniques align with the principles of constructivism, which emphasise the importance of learners constructing their understanding through interaction with their environment. Therefore, Wals and Corcoran (2012) and Daramola et al. (2024) emphasise the significance of experiential learning in enhancing comprehension of sustainability challenges by enabling learners to link theoretical knowledge with practical implementations. Furthermore, the role of educators in advancing Education for Sustainable Development (ESD) is a vital area of investigation within the ESD conceptualisation, as educators are tasked with imparting knowledge and motivating students to adopt sustainable behaviours. For instance, Nikolic, Milutinovic, Nedanovski, and Mrnjaus (2017) assert that professional development programmes for educators can enhance their understanding of ESD and improve their teaching methodologies.

Integrating ESD into teacher training programmes is essential for equipping future educators with the necessary skills and knowledge to effectively impart sustainability principles (Nikolic, Milutinovic, Nedanovski, & Mrnjaus, 2017; Leicht, Combes, Byun, & Agbedahin, 2018). Empirical studies have shown a positive impact of ESD on student achievement, enhancing students' environmental awareness, critical thinking skills, and sense of responsibility toward sustainability (Nousheen, Zai, Waseem, & Khan, 2020; Ernst & Monroe, 2004; O'Flaherty& Liddy, 2018). Furthermore, ESD has been linked to increased motivation and engagement among students, as it often involves practical, real-world projects that resonate with their interests and values (Andersson, Jagers, Lindskog, & Martinsson, 2013; Stössel, Baumann, & Wegner, 2021; Muñoz-García & Villena-Martínez, 2021). However, despite the growing recognition of ESD, challenges remain in its implementation across many educational contexts.

3. **Key Principles of Education for Sustainable Development**

Education for Sustainable Development (ESD) has become a crucial foundation for addressing the intricate relationships among the environmental, social, and economic aspects of sustainability. The fundamental concepts of ESD focus on cultivating critical thinking, encouraging active engagement, and developing a comprehensive understanding of sustainability challenges (UNESCO, 2014). Table 1 below presents the fundamental concepts of ESD, integrating insights from diverse academic contributions and policy documents.

Table 1: Key Principles of Education for Sustainable Development

Key Principles	Aims
Interdisciplinary Approach	ESD promotes an interdisciplinary perspective that integrates knowledge from various fields, including science, social studies, economics, and ethics (Howlett, Ferreira, & Blomfield, 2016; Annan-Diab & Molinari, 2017; Risopoulos-Pichler, Daghofer, & Steiner, 2020). This approach helps learners grasp the complexities of sustainability issues and the multifaceted solutions needed to address them.
Critical Thinking and Problem-Solving	ESD encourages learners to think critically about the challenges facing society and to develop problem-solving skills (Tilbury, 2011; Leicht et al., 2018). It fosters the ability to analyse situations, evaluate options, and make informed decisions that consider the long-term implications of actions.
Active Participation	ESD - 91 -aption- 91 -in the importance of active participation in learning processes. Students are encouraged to engage in discussions, collaborate with peers, and take part in community initiatives (Wals & Corcoran, 2012; Huckle & Wals, 2015; Olsson, Gericke, & Chang Rundgren, 2016). This participatory approach not only enhances learning outcomes but also empowers individuals to become agents of change within their communities.
Values and Ethics	ESD promotes the development of values and ethics that support sustainable living (Cebrián & Junyent, 2015; Olsson, Gericke, & Chang Rundgren, 2016). It encourages learners to reflect on their beliefs and attitudes towards the environment, society, and future generations, thereby fostering a sense of stewardship and responsibility.
Sustainable consumption	ESD promotes responsible and mindful consumption patterns that contribute to environmental sustainability, social equity, and economic viability (Jackson, 2005; Thøgersen & Zhou, 2012; Rieckmann, 2018). It fosters awareness and knowledge, encourages behavioural change, and - 91 -aption- 91 -in systems thinking, cultural sensitivity, and future-oriented thinking.
Local and Global Perspectives/Holistic Understanding	ESD - 91 -aption- 91 -in the significance of both local and global contexts in understanding sustainability (UNESCO, 2014; Rieckmann, 2018). It encourages learners to appreciate the diversity of cultures, traditions, and practices, while also - 91 -aption- 91 -ing the interconnected nature of global challenges.

The interdisciplinary approach is essential to ESD, as it acknowledges that sustainability concerns are complex and cannot be sufficiently addressed through a single disciplinary perspective. For instance, studies such as Wiek, Xiong, Brundiers, and Van der Leeuw (2014); Howlett, Ferreira, and Blomfield (2016); Annan-Diab and Molinari (2017); and Risopoulos-Pichler, Daghofer, and Steiner (2020) assert that multidisciplinary education enables learners to

synthesise knowledge from diverse disciplines, enhancing the critical thinking and problem-solving abilities vital for addressing sustainability issues. Thus, Sterling (2011) emphasises that ESD must surpass conventional topic boundaries to foster a holistic understanding of ecological, social, and economic interdependencies. Furthermore, an interdisciplinary approach fosters collaboration among various stakeholders, including educators, students, and community members. Leal Filho et al. (2018) highlight that collaborative learning environments promote the exchange of ideas and experiences, thereby augmenting the collective potential to tackle sustainability challenges. By amalgamating disciplines such as environmental science, economics, and social studies, ESD can foster a more sophisticated comprehension of sustainability essential for effective intervention.

Another fundamental principle of ESD is the enhancement of critical thinking and problem-solving abilities. Tilbury (2011) asserts that ESD equips learners to critically analyse and assess information, facilitating informed decision-making regarding sustainability issues. The ability for critical reflection is vital in a swiftly evolving environment where misinformation can readily spread. Leicht et al. (2018) assert that promoting critical thinking improves individual decision-making and aids in collective efforts toward achieving sustainable development goals (SDGs).

Active engagement is another fundamental principle of ESD. According to Wals and Corcoran (2012), ESD promotes the active engagement of learners in their communities and environments. This interactive method is essential for fostering a sense of agency in learners, allowing them to engage in sustainable practices and policies. Similarly, values and ethics are crucial in influencing the attitudes and behaviours required for sustainable existence. Thus, integrating ethical considerations into ESD is vital for cultivating a sense of responsibility toward the environment and society. According to Huckle and Wals (2015), ESD must involve learners in ethical contemplation over the consequences of their decisions and actions, fostering a values-oriented perspective on sustainability. UNESCO (2014) emphasises the necessity of incorporating values such as respect for nature, social justice, and intergenerational parity into educational systems. These principles not only influence individual conduct but also establish collective cultural standards that support sustainable behaviours. Moreover, incorporating ethical viewpoints in ESD may enable learners to critically evaluate the consequences of their consumption behaviours and promote more sustainable options (Cebrián & Junyent, 2015; Olsson, Gericke, & Chang Rundgren, 2016).

Sustainable consumption is also an essential aspect of ESD, as it pertains to the influence of individual and group decisions on environmental and social systems. The notion encompasses various practices, such as resource conservation and ethical shopping. For instance, Jackson (2005) asserts that fostering sustainable consumption necessitates an understanding of the fundamental social and economic frameworks that drive unsustainable practices. Hence, educational initiatives centred on sustainable consumption seek to provide learners with the knowledge and skills needed to make informed choices about their consumption behaviours

(Jackson, 2005; Rieckmann, 2018). Thøgersen and Zhou (2012) demonstrate that educational initiatives highlighting the environmental and social ramifications of consumption can markedly affect consumer behaviour. Thus, by cultivating a culture of sustainability, ESD may motivate individuals to embrace actions that reduce their ecological footprint and support overarching sustainability objectives. Lastly, a holistic understanding is also critical in ESD, as it recognises the interconnectedness of environmental, social, and economic systems. According to UNESCO's (2014) Global Action Programme on ESD, a holistic approach to education equips learners with the ability to understand the complex relationships between human activities and ecological health. This perspective aligns with the findings of Rieckmann (2018), who argues that interdisciplinary education is essential for addressing the multifaceted nature of sustainability challenges. Thus, by integrating diverse disciplines, educators can provide learners with a comprehensive understanding of sustainability issues, fostering a more profound commitment to sustainable practices. Therefore, ESD should not simply be an educational programme but a transformative strategy that enables individuals and communities to significantly contribute to sustainable development.

4. Integration of ESD into the Preparation of Pre-service Teachers

The integration of ESD into the preparation of pre-service mathematics teachers is a vital endeavour that has the potential to transform mathematics education. Equipping future educators with the means to address sustainability concerns through mathematical inquiry will cultivate a generation of learners who are both proficient in mathematics and committed to fostering a more sustainable world (Li & Tsai, 2022). However, the successful implementation of ESD in pre-service mathematics teacher education programmes requires a shift in educational practices and policies. This entails integrating sustainability principles into curricula, teaching methods, and school governance. Table 2 below presents several strategies that can facilitate the effective incorporation of ESD into mathematics teacher education programmes.

Table 2: approaches to incorporating ESD in Mathematics Teacher Education Programmes

Strategies	Suggestion for implementation/Integration
Curriculum Development	Educational institutions should revise curricula to include ESD-related content across subjects (Davis & Krajcik, 2005; Bögeholz, Böhm, Eggert, & Barkmann, 2014; Edwards, 2019). This can be achieved by integrating themes such as climate change, social justice, and sustainable economics into existing courses or by developing new interdisciplinary programmes focused on sustainability.
Teacher Training	Educators play a crucial role in facilitating ESD. Professional development programmes should equip teachers with the knowledge and skills needed to teach sustainability concepts effectively (Visser, 2010; Tomas, Girgenti, & Jackson, 2017). Training should emphasise experiential learning, critical pedagogy, and the use of innovative teaching methods.
Community Engagement	Schools should actively engage with local communities to foster partnerships that enhance ESD (Gutstein & Peterson, 2005; Furman, 2012; Valenzuela, 2016; Bennett, 2021). Collaborating with community organisations, businesses, and local governments can provide students with real-world experiences and opportunities for service learning.

Assessment and Evaluation	Measuring the impact of ESD initiatives is essential for continuous improvement (Gulikers, Bastiaens, Kirschner, & Kester, 2008; Gulikers, Biemans, Wesselink, & van der Wel, 2013). Educational institutions should develop assessment frameworks that evaluate not only academic knowledge but also the development of skills, attitudes, and behaviours related to sustainability (Gulikers et al., 2008; 2013).
Policy Support	Governments and educational authorities must create supportive policies that promote ESD at all levels of education (Sterling, 2011; Leal Filho et al., 2018; Kanandjebo, 2024). This includes allocating resources for ESD initiatives, providing incentives for schools to implement sustainable practices, and fostering collaboration among stakeholders.

The urgency of integrating Education for Sustainable Development (ESD) into mathematics teacher training programmes is emphasised by the United Nations' Sustainable Development Goals (SDGs), especially Goal 4, which stresses the importance of providing inclusive and equitable quality education and fostering lifelong learning opportunities for all (United Nations, 2015; United Nations Educational, Scientific and Cultural Organization (UNESCO), 2017). The SDGs offer a comprehensive framework for tackling the complex issues of sustainability, with education acknowledged as an essential facilitator of this initiative. Thus, mathematics teacher education programmes possess a distinct potential to advance the attainment of the SDGs by incorporating sustainability approaches into their training. These strategies collectively facilitate the effective integration of ESD into mathematics teacher education programmes, thereby fostering a generation of educators equipped to address sustainability issues in their teaching.

Curriculum development is a fundamental approach for integrating Education for Sustainable Development (ESD) into mathematics teacher training. For instance, Tilbury (2011) asserts that a well-organised curriculum integrating sustainability principles can augment the applicability of mathematical concepts to real-world issues. In addition, UNESCO (2017) reinforces this viewpoint, highlighting the necessity for a curriculum that encompasses mathematical theories while situating them within sustainable frameworks. Therefore, effective curriculum development must employ multidisciplinary approaches (Bögeholz, 2006; Bögeholz, Böhm, Eggert, & Barkmann, 2014; Edwards, 2019), connecting mathematics with environmental science, social equality, and economic viability to promote a comprehensive understanding of sustainability. Furthermore, the curriculum must be flexible and attuned to local circumstances, as emphasised by Davis and Krajcik (2005) and Barraza et al. (2017), who contend that localised curriculum content can improve student engagement and relevance. Thus, by incorporating project-based learning and problem-solving activities centred on environmental challenges, mathematics teacher education programmes can enhance critical thinking and analytical skills in future educators through real-life scenarios (Barraza et al., 2017).

It is also vital to reiterate that the effectiveness of ESD integration is significantly dependent on the calibre of teacher training programmes. Studies demonstrate that professional development programmes must provide mathematics educators with essential pedagogical competencies to teach sustainability principles effectively (Cohen & Hill, 2000; Malm, 2009; Cebrián & Junyent, 2015). This encompasses instruction in integrative pedagogical techniques, cooperative learning,

and the application of technology to enhance Education for Sustainable Development (ESD) (Daramola et al., 2024). As such, studies such as Fraser, Kennedy, Reid, and McKinney (2007) and McKeown and Hopkins (2007) assert that continuous professional development is essential for educators to stay abreast of sustainability matters and pedagogical advancements. Moreover, teacher training programmes ought to prioritise reflective practice, allowing educators to critically evaluate their pedagogical approaches and the effects of their instruction on student learning in relation to sustainability (Visser, 2010; Tomas, Girgenti, & Jackson, 2017). This reflective methodology prompts educators to modify their practices to incorporate ESD concepts into their mathematics teaching more effectively, promoting a culture of ongoing enhancement and adaptability to new sustainability issues (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009).

Furthermore, community engagement is an essential technique for improving Education for Sustainable Development (ESD) in mathematics teacher education programmes. Interacting with local communities enables teacher candidates to comprehend the socio-cultural aspects of sustainability and the role of mathematics in tackling community-specific issues (Furman, 2012). For instance, Vare and Scott (2007) assert that collaborations between educational institutions and community organisations can enhance experiential learning opportunities, enabling future educators to apply mathematical principles to real-world sustainability challenges. Furthermore, community engagement cultivates a sense of social responsibility among teacher candidates, motivating them to perceive themselves as active contributors to the promotion of sustainable practices within their communities (Valenzuela, 2016; Bennett, 2021). This participation may manifest in several ways, including service-learning initiatives, community-based research, and partnerships with local stakeholders. Therefore, integrating community viewpoints into mathematics education enables teacher candidates to cultivate a more sophisticated comprehension of the challenges associated with sustainability (Gutstein & Peterson, 2005; Olawale, Mncube, & Harber, 2021).

Effective assessment and evaluation systems are also crucial for gauging the impact of ESD integration in mathematics teacher education. According to Volante and Fazio (2007) and Fischer et al. (2022), conventional assessment techniques may insufficiently reflect the comprehensive understanding and application of sustainability principles among teacher candidates. Consequently, alternative assessment methods, like performance-based assessments, portfolios, and reflective diaries, ought to be utilised to examine the incorporation of ESD principles (Gulikers, Bastiaens, Kirschner, & Kester, 2008; Gulikers, Biemans, Wesselink, & van der Wel, 2013; Mncube, Ndondo, & Olawale, 2022). Moreover, formative assessments offer continuous feedback to teacher candidates, allowing them to recognise areas needing enhancement and modify their teaching methodologies accordingly (Mncube, Ndondo, & Olawale, 2022). It is therefore essential to design assessment standards that directly reflect sustainability competencies. This entails assessing candidates' competencies in integrating

sustainability concerns into their lesson design, pedagogical approaches, and classroom management (Voss, Kunter, & Baumert, 2011; Mncube, Ndondo, & Olawale, 2022).

Lastly, policy support is essential for the incorporation of ESD into mathematics teacher education programmes. For instance, The Global Action Programme on ESD advocates for legislative frameworks that foster the development of curricula, teacher training, and evaluation methods that advance sustainability (UNESCO, 2014). Similarly, studies such as Vare and Scott (2007), Sterling (2011), and Leal Filho et al. (2018) assert that collaboration between educational institutions and policymakers is crucial for establishing conducive settings for the integration of ESD. Research demonstrates that policies promoting innovative teaching methods and allocating funding for ESD projects can substantially improve the quality of mathematics teacher education (Rico, Agirre-Basurko, Ruiz-González, Palacios-Agundez, & Zuazagoitia, 2021; Kanandjebo, 2024). Furthermore, cultivating a sustainability culture at educational institutions can be accomplished through policy initiatives that encourage sustainable activities, including resource conservation and waste minimisation (Adams, Martin, & Boom, 2018).

5. Challenges and Opportunities of ESD in Maths Teacher Education Programmes

Despite the key principles and approaches that support the integration of ESD into mathematics teacher education, several challenges impede this process. According to Laurett and do Paço (2019), a major obstacle is the existing curricular framework, which frequently emphasises content understanding rather than teaching methods that integrate sustainability. As such, mathematics teacher educators may feel restricted by standardised curricula that lack the flexibility necessary to properly integrate ESD concepts. Tilbury (2011) also adds that barriers such as financial limitations, insufficient teacher training, and rigid curricula hinder the effective integration of ESD principles. Similarly, another difficulty is the absence of professional development opportunities for mathematics educators to acquire the requisite skills and expertise for teaching ESD principles. According to Darling-Hammond (1989), Stevenson (2007), and Bakker, Cai, & Zenger (2021), numerous teacher preparation programmes insufficiently equip prospective educators to tackle sustainability concerns via mathematics, resulting in a deficiency in their pedagogical topic understanding. The gap is further intensified by the restricted availability of tools and materials that directly link mathematics with sustainability issues (Kanandjebo, 2024). In addition, there is sometimes a mismatch between academic knowledge and practical implementation (Kopnina & Meijers, 2014). Thus, many mathematics educators may grasp the benefits of ESD but struggle to implement it in their classrooms owing to a lack of confidence or expertise. This mismatch underlines the need for more robust support mechanisms within teacher preparation programmes that enable experimentation and reflection on ESD practices.

Despite the challenges, ample opportunity exists for the incorporation of ESD into mathematics teacher education programmes. A viable strategy involves the integration of interdisciplinary projects that link mathematics with environmental and social concerns. Studies indicate that project-based learning can improve student engagement and comprehension of mathematical concepts and sustainability (Fini, Awadallah, Parast, & Abu-Lebdeh, 2018; Nguyen, Nguyen, Thai, Truong, & Nguyen, 2024). Mathematics educators can develop collaborative projects that tackle real-world issues, fostering significant learning experiences that connect with students' lives. Furthermore, the incorporation of technology in mathematics instruction offers a chance to improve ESD practices (Oladele et al., 2023).The use of digital tools can enhance data analysis and modelling, allowing students to statistically investigate intricate sustainability challenges. For instance, Barwell (2013) argued that utilising statistical tools to examine environmental data enables students to comprehend the mathematical foundations of sustainability metrics, thus enhancing their awareness of mathematics' role in tackling global concerns. In addition, professional development programmes centred on ESD can enable mathematics educators to integrate sustainability into their instructional methodologies (Darling-Hammond, 1989;Stevenson, 2007; Bakker, Cai, & Zenger, 2021). Thus, through workshops and training sessions that focus on practical techniques for incorporating ESD concepts into mathematics curricula, teachers' confidence and competence can be improved (Boeve-de Pauw, Olsson, Berglund, & Gericke, 2022). Lastly, establishing communities of practice among mathematics educators can enhance knowledge exchange and collaboration, fostering a culture of sustainability in mathematics education.

6. Conclusion and Recommendation

This chapter explores the concepts of ESD, its key principles, the integration of ESD in mathematics teacher education programmes, and its challenges and opportunities. It elucidates the essential principles of ESD, highlighting its multidisciplinary nature, the development of critical thinking and problem-solving abilities, and the encouragement of active engagement, values, and ethics. By integrating these themes, it is clear that ESD enhances the mathematics curriculum while aligning it with urgent global environmental concerns. Consequently, the prospective advantages of integrating ESD into mathematics teacher education are numerous. Educators knowledgeable in ESD principles can cultivate a cohort of pre-service teachers who are both skilled in mathematical concepts and proficient in applying these concepts to real-world challenges. This comprehensive understanding is essential for equipping future educators to motivate their pupils towards sustainable habits.

Nevertheless, the chapter underscores considerable challenges, such as resource constraints, inadequate training, and institutional resistance to change, which hinder the effective integration of ESD. To navigate these challenges, collaborative efforts among educators, policymakers, and educational institutions are imperative. By fostering a shared commitment to sustainability in

education, stakeholders can create an environment conducive to the successful implementation of ESD principles.

This chapter contributes to the existing body of knowledge by providing a comprehensive overview of ESD integration strategies, serving as a foundational resource for future research and practice. It therefore recommends that mathematics teacher education programmes formulate instructional practices that cultivate critical thinking and problem-solving abilities, empowering future educators to assist students in quantitatively examining and tackling sustainability issues. Similarly, engagement with interdisciplinary fields can augment the relevance of mathematical concepts in sustainability situations, thus enhancing the learning experience. The chapter also recommends integrating practical learning approaches to offer hands-on experiences in which mathematics is utilised for sustainability initiatives, fostering engagement and enhancing comprehension. Furthermore, ongoing professional development for mathematics teacher educators must incorporate ESD training to ensure they are adequately prepared to teach these interconnected ideas effectively. Moreover, empirical research is needed to evaluate the effectiveness of existing ESD-integrated mathematics curricula. Lastly, longitudinal studies that track the impact of ESD-focused teacher training on student outcomes in mathematics and sustainability literacy should be conducted to provide valuable insights into best practices and areas for improvement.

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