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Enhancing teacher competencies in ESD: A framework for professional development

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ABSTRACT

Education for Sustainable Development (ESD) equips students with the knowledge and skills to address global sustainability challenges. However, the effectiveness of ESD largely depends on the competencies of teachers. This article aims to develop a comprehensive framework for improving teachers' competencies in ESD. This research uses a qualitative approach, literature review, qualitative content analysis, secondary case study, and conceptual design methods. The framework identifies essential competencies, including critical thinking, problem-solving, and ethical decision-making, that educators must possess to integrate sustainability principles into their teaching practices effectively. Additionally, the paper explores professional development strategies that can support teachers in acquiring these competencies, such as continuous training, collaborative learning, and experiential education. The findings suggest that a holistic approach to professional development is necessary to empower teachers and enable them to foster a sustainability-oriented mindset in their students. By implementing this framework, educational institutions can contribute to preparing future generations to engage actively in sustainability efforts. This study highlights the importance of teacher competencies in ESD and provides actionable recommendations for policymakers and educational leaders to enhance teacher training programs and promote sustainability education in schools.

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ABSTRAK

Pendidikan untuk Pembangunan Berkelanjutan (ESD) memainkan peran penting dalam membekali siswa dengan pengetahuan dan keterampilan yang diperlukan untuk menghadapi tantangan keberlanjutan global. Namun, efektivitas ESD sangat bergantung pada kompetensi guru. Artikel ini bertujuan untuk mengembangkan kerangka kerja komprehensif untuk meningkatkan kompetensi guru dalam ESD. Penelitian ini menggunakan pendekatan kualitatif dengan metode tinjauan literatur, metode analisis konten kualitatif, studi kasus sekunder, dan metode desain konseptual. Kerangka kerja ini mengidentifikasi kompetensi penting, termasuk berpikir kritis, pemecahan masalah, dan pengambilan keputusan etis, yang harus dimiliki pendidik untuk secara efektif mengintegrasikan prinsip-prinsip keberlanjutan ke dalam praktik pengajaran mereka. Selain itu, artikel ini mengeksplorasi strategi pengembangan profesional yang dapat mendukung guru dalam memperoleh kompetensi tersebut, seperti pelatihan berkelanjutan, pembelajaran kolaboratif, dan pendidikan berbasis pengalaman. Temuan menunjukkan bahwa pendekatan holistik terhadap pengembangan profesional sangat diperlukan untuk memberdayakan guru dan memungkinkan mereka untuk membina pola pikir yang berorientasi pada keberlanjutan di antara siswa mereka. Dengan menerapkan kerangka ini, lembaga pendidikan dapat berkontribusi dalam mempersiapkan generasi mendatang untuk secara aktif terlibat dalam upaya keberlanjutan. Studi ini tidak hanya menyoroti pentingnya kompetensi guru dalam ESD tetapi juga memberikan rekomendasi yang dapat diterapkan bagi pembuat kebijakan dan pemimpin pendidikan untuk meningkatkan program pelatihan guru dan mempromosikan pendidikan keberlanjutan di sekolah.

Kata Kunci: kompetensi guru; pengembangan profesional; pendidikan berkelanjutan; pendidikan untuk pembangunan berkelanjutan

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INTRODUCTION

Education for Sustainable Development (ESD) plays an increasingly significant role in addressing global challenges such as climate change, social inequality, and environmental crises. In this context, ESD transfers knowledge related to sustainability and develops skills, values, and attitudes that support concrete actions toward a more sustainable world. Teachers have an important role as agents of change who can shape the younger generation's mindset through a pedagogical approach that integrates sustainability principles into teaching and learning activities (Nguyen et al., 2020). In the context of Education for Sustainable Development (ESD), this role becomes even more significant, given the urgency to build critical awareness of global challenges such as climate change, social justice, and the preservation of natural resources. With pedagogical approaches integrating sustainability principles, teachers can encourage students to think systemically, understand the interconnectedness between humans and the environment, and take responsible action in their daily lives. Through active learning strategies, such as case studies, community-based projects, and reflective discussions, teachers help students internalize sustainability concepts. This approach allows students to understand the theory and practice it in a real context.

The Sustainable Development Goals (SDGs) set out in 2015 by the United Nations encompass 17 global goals designed to address the environmental, social, and economic challenges facing the world today. The SDGs emphasize the importance of education as a critical foundation for achieving sustainability. SDG 4, “Quality Education,” specifically calls for inclusive and quality education for all, promoting lifelong learning opportunities (see: https://www.unesco.org/en/sustainable-development/education). However, quality education cannot be separated from the broader context of sustainability. In addition, SDGs play a vital role in fostering sustainability awareness among students. This helps them understand the interconnectedness of social, economic, and environmental issues and encourages them to think critically about sustainability challenges (Shulla et al., 2020).

One of the biggest challenges in implementing ESD in schools is the lack of teacher competency and readiness. Many teachers do not yet deeply understand sustainability issues and how to integrate them into their curriculum. Teacher education often underemphasizes the importance of sustainability, leading to an urgent need to develop professional development programs that can strengthen teacher capacity in supporting the sustainability agenda (Kohli, 2019). One of the biggest challenges in implementing ESD in schools is the lack of teacher competence and preparedness. Many teachers do not profoundly understand sustainability issues and how to integrate them into their curriculum. Teacher education often underemphasizes the importance of sustainability, so there is an urgent need to develop professional development programs that can strengthen teachers' capacity to support the sustainability agenda (Kohli, 2019). A study by UNESCO found that only 36% of teachers worldwide felt they had received adequate training on education for sustainable development. Teachers often feel they lack the resources or strategies to teach sustainability effectively, including limited conceptual knowledge, lack of relevant teaching materials, and lack of time to incorporate sustainability into an already crowded curriculum (Kohli, 2019).

Teachers in Qatar also face these barriers when implementing the Sustainable Development Goals (SDGs) framework in education (Hamwy et al., 2023). Many teachers feel inadequately equipped with in-depth knowledge of the SDGs and how to integrate them into their curriculum. The availability of resources, including relevant teaching materials and professional training, is a significant barrier. Rigid education policies and pressure to achieve conventional academic results often make integrating the SDGs in learning difficult. Teachers face challenges in adapting the SDGs framework to Qatar's local values and cultural norms. Teacher professional development in the context of education for sustainable development

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on teachers' professional action competence (PAC). Teachers involved in ESD-based training are better equipped to address sustainability issues with an interdisciplinary approach. Teachers show a better understanding of how to integrate sustainability into various subjects.

This article proposes a professional development framework to improve teachers' competencies in teaching Education for Sustainable Development. By identifying critical elements of ESD and incorporating aspects of the Sustainable Development Goals (SDGs) formulated by the United Nations (UN). These critical elements of ESD 2030 include three dimensions: cognitive learning dimension, social and emotional learning dimension, and behavioral learning dimension (see: https://www.unesco.org/en/sustainable-development/education). First, cognitive learning emphasizes understanding sustainability challenges and their complex interrelationships, exploring disruptive ideas and alternative solutions. Second, social and emotional learning is needed to develop core values and attitudes for sustainability, foster empathy and compassion for others and the planet, and motivate people to lead change. Third, the behavioral learning dimension is about practical action for sustainable transformation in the personal, social, and political spheres.

These three dimensions are the basis for developing key teacher competencies in teaching ESD. The key teacher competencies include critical thinking, problem-solving, ethical decision-making, and sustainability-oriented pedagogical skills. Therefore, this article aims to provide practical and theoretical guidance that educational institutions can adopt to improve the effectiveness of sustainable learning. Educators worldwide have the opportunity to develop the capacity to drive societal transformation for a sustainable future. Training institutions for educators systematically integrate ESD (see: https://www.unesco.org/en/sustainable-development/education).

Through the implementation of this professional development framework, it is hoped that teachers will be better prepared to teach the principles of the SDGs, which cover aspects such as poverty eradication, quality education, gender equality, climate action, and life on land and water. The SDGs provide a clear direction for global education, and by equipping teachers with the skills and knowledge needed to achieve these goals, education systems can play a critical role in advancing sustainable development.

Quality education must include knowledge about sustainability and the skills needed to address future challenges. Teaching the SDGs in schools provides an understanding of global issues and equips students with the capacity to think critically, solve complex problems, and act responsibly (Westheimer, 2020; Assefa, 2024). However, to achieve this, teachers must have adequate competence in ESD to instill sustainability values in everyday learning.

Despite the global recognition of the importance of ESD and the SDGs, there are several challenges in improving teacher competency in this area. One of the main challenges is the limited resources available for teacher training and professional development. Many education systems do not provide comprehensive training on ESD, so teachers often feel ill-equipped to integrate sustainability issues into their curricula. For example, in the national education system, although environmental values are integrated through programs such as *Adiwiyata*, implementation has not been thorough (Adawiah, 2019; Aeni et al., 2020). These challenges include lacking resources, specialized teacher training, and clear guidance on incorporating sustainability into daily lessons. In addition, in many developed countries, the main focus of education is often on academic achievement as measured by international standards, such as PISA. This makes it challenging to integrate ESD as sustainability is often considered an additional topic and not included in the primary assessment. In the US, although initiatives such as the *Green Schools Alliance* and *Next Generation Science Standards* (NGSS) are beginning to integrate sustainability, many teachers feel underprepared to implement it due to the lack of specialized training in ESD (Glavič, 2020).

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Another challenge is teachers' lack of a deep understanding of the SDGs. Some teachers may see the SDGs as separate from their daily practice, and they find it difficult to understand how the goals can be applied locally. Therefore, it is essential to develop professional development programs that provide information about the SDGs and help teachers understand how they can teach these principles in a way that is relevant to their students.

The professional development framework proposed in this article aims to address the above challenges by providing a comprehensive and structured approach to improving teacher competencies in ESD and the SDGs. The framework consists of several critical elements designed to ensure teachers have the knowledge, skills, and attitudes to teach sustainability effectively. These key elements include knowledge of the SDGs and sustainability issues, pedagogical skills for ESD, critical reflection and attitude development, collaboration and networking, and continuous evaluation and improvement (Glavič, 2020).

By adopting this professional development framework, the global education system will be better able to support the achievement of the SDGs, especially in the context of SDG 4 (quality education) and SDG 13 (climate action) (see: https://www.unesco.org/en/sustainable-development/education). Teachers who are competent in ESD will not only be able to teach the technical skills needed to address sustainability challenges but will also play a leadership role in inspiring young people to become agents of change.

Applying this framework also has implications for education policy in various countries. Policymakers should support teachers' continuous professional development by providing adequate resources and encouraging the integration of ESD and SDGs into national curricula. In addition, developing policies that focus on education for sustainability can also help create learning environments that support students in developing the critical, creative, and collaborative thinking skills needed for a more sustainable future.

Education for Sustainable Development (ESD) plays a critical role in realizing a better future, with teachers at the forefront of this effort. Education significantly impacts achieving the Sustainable Development Goals (SDGs) by catalyzing change in many aspects of life. Through quality education, poverty can be reduced, social inequalities minimized, public health improved, and innovation and sustainable economic development encouraged. However, a more integrated approach is needed to address global challenges such as climate change, social injustice, and environmental degradation, of which ESD is a key element. To teach sustainability effectively, teachers must have the right competencies, which can be developed through a structured professional development program grounded in the SDGs. This article identifies the competency needs of teachers in implementing ESD and proposes a professional development framework that focuses on integrating sustainability values and principles into the learning process. With a holistic approach, this framework aims to empower teachers as agents of change, support the achievement of the SDGs, and prepare future generations to face increasingly complex global challenges. The urgency of ESD lies in its ability to equip individuals not only to adapt to change but also to drive transformation towards a more inclusive, equitable, and sustainable world.

LITERATURE REVIEW

Definition and Importance of Education for Sustainable Development (ESD)

Education for Sustainable Development (ESD) is an educational approach that aims to empower individuals with the knowledge, skills, attitudes, and values needed to contribute to sustainable development at the local and global levels. ESD focuses not only on environmental issues but also includes sustainability's social, economic, and cultural dimensions. This education emphasizes the importance of critical thinking, problem-solving, and the ability to take responsible actions toward the sustainability of society and the environment in the future.

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Education for Sustainable Development (ESD) is a transformative learning process that equips individuals with the knowledge, skills, values, and attitudes necessary to contribute to sustainable development. It empowers individuals to make informed decisions and take responsible action for environmental integrity, economic viability, and a just society for present and future generations while respecting cultural diversity. Moreover, ESD is an integral part of quality education and is critical to achieving the 17 Sustainable Development Goals (SDGs) (Zguir et al., 2021; Cebrián et al., 2020). Effective education for sustainable development is outlined in the 2030 Agenda, particularly concerning the SDGs, especially Goal 4 (Quality Education) and Target 4.7, which emphasize the importance of education in promoting sustainable development (Shulla et al., 2020). By integrating ESD into the curriculum, educational institutions can help achieve the broader goals of the 2030 Agenda for Sustainable Development (Shulla et al., 2020; Pegalajar-Palomino et al., 2021; Kioupi & Voulvoulis, 2019). Teachers should be equipped with new pedagogical tools and approaches to teach the SDGs holistically, covering issues such as climate change, social justice, and sustainable management of natural resources.

ESD is essential for developing key competencies such as critical thinking, problem-solving, and collaborative skills. ESD competencies include systemic thinking, ethical decision-making, and collaboration to address global challenges related to sustainability (Cebrián et al., 2020). These competencies are essential for individuals to engage in sustainable practices and contribute to sustainable development in their personal and professional lives (Cebrián et al., 2020; Sinakou et al., 2019). In this regard, teachers play an essential role in shaping students' understanding of sustainability and teaching them the skills to address issues and contribute globally.

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Professional development is essential for teachers to strengthen these competencies so that they can become effective agents of change. Within this framework of teacher professional development, its importance lies in its ability to transfer knowledge and develop pro-sustainability attitudes and behaviors among students. In this regard, ESD links educational goals to achieving the SDGs, creating a systemic framework that enables teachers to develop complex and interdisciplinary thinking skills and encourages action on the ground (Kioupi & Voulvoulis, 2019). For example, students can study the linkages between climate change, energy consumption, and community well-being through problem-based learning projects while seeking local solutions relevant to their context.

Thus, ESD is essential in training future teachers, who are the primary agents of change and transition toward societal sustainability. Practical teacher training in ESD ensures educators can integrate sustainability principles into their teaching practices (Shulla et al., 2020; Riess et al., 2022). The importance of ESD in developing teacher competencies lies in transferring knowledge about sustainability and strengthening pedagogical abilities to support the social transformation needed to face global challenges. Teachers need to be trained to become facilitators who can inspire change, lead action-based learning projects, and encourage student participation in the global sustainability movement.

Teacher Competence in ESD

The concept of teacher competency in Education for Sustainable Development (ESD) is multifaceted. It involves various skills, knowledge, and attitudes required to integrate sustainability principles into

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educational practice effectively. Teacher competency in ESD refers to a set of specific professional skills, knowledge, and attitudes that educators need to teach and promote the principles of sustainable development effectively. These competencies are essential to foster the development of sustainability competencies among students, a key objective of the 2030 Agenda for Sustainable Development (Cebrián et al., 2020).

1. Knowledge of SDGs and Sustainability Issues

   Professional development programs should include in-depth training on the SDGs and global and local sustainability issues. Teachers need a deep understanding of sustainability content and pedagogical strategies to teach this content effectively (Riess et al., 2022). This includes Content Knowledge (CK) and Pedagogical Content Knowledge (PCK), i.e., the ability to integrate ESD into existing curricula and adapt teaching methods to foster sustainability competencies (Brandt et al., 2019; Timm & Barth, 2020). Teachers also need to understand how the SDGs are relevant to education and how they can integrate them into the curriculum. For example, teachers can be taught how to link SDG 13 on climate action to science lessons or how to integrate SDG 5 on gender equality into civics.

2. Pedagogical Skills for ESD

   Developing pedagogical skills is essential to ensure teachers can teach sustainability concepts engagingly and effectively (Riess et al., 2022). This includes using project-based, collaborative, and place-based learning, which can help students actively engage with sustainability issues.

   Pedagogical skills for Education for Sustainable Development (ESD) are a set of abilities, knowledge, attitudes, and strategies teachers possess to design, implement, and evaluate learning processes that support sustainability. These skills include the ability to integrate sustainable development values, principles, and goals into curricula and teaching practices, using participatory and transformative approaches that promote critical thinking, environmental awareness, and social responsibility (Albareda-Tiana et al., 2019; Riess et al., 2022; Brandt et al., 2022). These skills also involve facilitating collaboration, empowering students as agents of change, and adapting learning to local and global contexts by utilizing technology and interdisciplinary approaches (AlAfnan & Dishari, 2024; Hussain et al., 2024). Thus, pedagogical skills for ESD enable teachers to create transformative learning that contributes to achieving sustainable development goals (Bascopé et al., 2019).

   Teachers should possess pedagogical skills for Education for Sustainable Development (ESD), including the ability to integrate innovative pedagogical approaches, mastery of professional action competencies, and application of constructivist approaches in learning. Teachers should have in-depth knowledge of the concept of sustainability and how it relates to the SDGs, as well as skills to encourage students' critical and reflective thinking through participatory methods such as project-based learning and cross-disciplinary collaboration (Albareda-Tiana et al., 2019; Bascopé et al., 2019; Riess et al., 2022). In addition, they need to develop attitudes of empathy, responsibility, and critical awareness of global challenges, as well as skills to facilitate constructive discussions in sustainability (Brandt et al., 2022). Digital technologies and constructivism-based approaches are essential to connect students with relevant issues locally and globally (AlAfnan & Dishari, 2024; Hussain et al., 2024). These competencies enable teachers to create transformative learning, empowering students to become agents of change who contribute to sustainable development.

3. Critical Reflection and Attitude Development

   Professional development programs should also encourage teachers to reflect critically on their role as educators for sustainability. Teachers must understand the importance of proactively addressing

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sustainability challenges and developing values supporting positive action for change. This includes implementing ESD across various subjects, including professional knowledge, beliefs, motivational orientations, and self-regulation (Lohmann et al., 2021). In addition, teachers must be willing to support and implement ESD actively. This involves a commitment to sustainability and a positive attitude to integrating ESD into their teaching practice (Imara & Altınay, 2021; Brandt et al., 2019).

4. Collaboration and Networking

Collaboration and networking competencies for teaching Education for Sustainable Development (ESD) are essential for teachers to create transformative learning and support sustainability goals. Teachers need to develop the skills of working in professional networks that enable them to share knowledge, experiences, and resources to strengthen their teaching practices (Prenger et al., 2021). In addition, utilizing social media and online platforms can enhance teachers' ability to reach out to a broader community, facilitate cross-cultural collaboration, and support continuous learning, especially in situations such as the COVID-19 pandemic (Cavus et al., 2021). In the context of technology-enabled learning, collaboration with artificial intelligence (AI) is also essential to create more effective and adaptive learning experiences, where teachers can work with AI to design learning relevant to students' needs (Kim et al., 2022). Furthermore, collaboration between teachers, students, and local communities in educational networks can help establish universities or educational institutions as change centers to support global sustainability (Zamora-Polo & Sánchez-Martín, 2019). Teachers can integrate sustainability values into learning more holistically and contextually with this competency.

5. Continuous Evaluation and Improvement

The framework also includes elements of continuous evaluation and improvement, where teachers are encouraged to continually evaluate the effectiveness of their practice in teaching ESD. Continuous evaluation and improvement in teaching Education for Sustainable Development (ESD) is crucial to ensure the effectiveness of sustainability learning programs. Evaluating teachers' self-efficacy in ESD shows that increasing their confidence through theory-based training can improve their ability to implement ESD practices in the classroom (Handtke et al., 2022). In addition, sustainability education for prospective teachers significantly changes their attitudes toward sustainable development issues, affecting their intention to implement ESD in teaching practices (Nousheen et al., 2020; Stössel et al., 2021). Data mining-based strategies can also be used to analyze and improve teachers' competencies in ESD by providing deeper insights into their professional needs (Weng et al., 2020). On the other hand, approaches such as service learning in STEM courses have proven effective in integrating sustainability values into the curriculum through experiential learning, which is relevant to real-life contexts (Martín-Sánchez et al., 2022). Evaluation of these methods often faces challenges, such as determining appropriate indicators of success, but research shows that data-driven approaches and active participation can overcome these barriers (Ssossé et al., 2021). By continuously evaluating and adopting innovative strategies, ESD teaching can be continuously improved to achieve a more significant impact on students and society.

Continuous evaluation and improvement in teaching Education for Sustainable Development (ESD) also requires student evaluation, personal reflection, and feedback from peers and the broader education community. Student evaluations allow teachers to understand the extent to which learners receive and understand ESD learning. At the same time, personal reflection helps teachers evaluate the effectiveness of the pedagogical approaches they use in the context of ESD (Handtke et al., 2022). Feedback from colleagues and the education community can enrich insights and provide new perspectives on relevant learning approaches, especially in identifying weaknesses and opportunities

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for innovation (Ssossé et al., 2021). This collaborative approach also supports implementing service learning-based strategies, where community involvement provides added value in connecting learning to real life (Martín-Sánchez et al., 2022). By integrating these various evaluation sources, teachers can continuously improve the quality of ESD learning dynamically and contextually.

Key Competencies Required to Teach ESD

Teaching in the context of Education for Sustainable Development (ESD) requires mastery of several key competencies that enable teachers to guide students in understanding, addressing, and solving global sustainability challenges. These competencies include critical thinking, problem-solving, ethical decision-making, and sustainability-oriented pedagogical skills (Lozano et al., 2019). At the tertiary level, competencies for sustainability education involve in-depth knowledge of sustainability issues, the ability to analyze their impacts, and skills to integrate sustainability principles into various disciplines (Bianchi, 2020; Wilhelm et al., 2019). Sustainability-focused education requires pedagogical approaches that incorporate competency-based learning and active learning, encouraging students to collaborate to solve real challenges (Evans, 2019). With these competencies, teachers can support students in developing the skills necessary to take responsible action toward social, economic, and environmental sustainability and contribute to solutions to global challenges (Sady et al., 2019).

1. Critical Thinking

   Critical thinking is one of the key competencies required in ESD. Teachers are expected to be able to encourage students to not only accept information as it is but also to question, analyze, and evaluate the information they receive. Critical thinking in ESD refers to the ability of teachers and students to question, analyze, and deeply understand sustainability issues (Felix, 2023). Critical thinking in ESD involves understanding the interconnectedness of global issues, such as climate change, social inequality, and environmental degradation, and their impacts on human life and ecosystems. Critical thinking is essential to understanding and dealing with the complexity and uncertainty of sustainability issues. With critical thinking skills, students can identify problems, understand multiple perspectives, and develop solutions based on careful analysis of social, economic, and environmental consequences (Cebrián et al., 2020).

2. Problem-Solving

   Problem-solving is at the heart of the action-based approach taught in ESD. Competence in problem-solving involves the ability to formulate sustainability problems and generate innovative and sustainable solutions effectively. In the context of ESD, teachers are expected to teach basic concepts related to sustainability and guide students through a problem-solving process that involves identifying critical issues, exploring potential solutions, and evaluating the impact of various action options (Riess et al., 2022). Teachers should guide students in understanding the problem and finding creative solutions that can be implemented in real life. This helps students actively find solutions to sustainability issues through scientific methods and interdisciplinary approaches. This problem-solving is often done through collaborative work, where students work in groups to find holistic and sustainable solutions. Problem-solving skills are essential in ESD because sustainability involves complex and multidimensional issues that require integrative and sustainable solutions (Riess et al., 2022). The problem-solving process also encourages students to think systemically, recognizing the interconnectedness of natural and human systems and how local solutions can impact the global context (Zguir et al., 2021).

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3. Ethical Decision Making

   Ethical decision-making in the context of Education for Sustainable Development (ESD) refers to making choices compatible with moral principles and sustainability values, particularly in educational and leadership settings. A study emphasizes that ethical decision-making is essential for creating a "moral compass" in leadership, which involves ethical approaches such as virtue-based or deontological perspectives to guide actions that support sustainability and responsible leadership in educational contexts (Holst, 2023).

   Ethical decision-making is a competency related to students' ability to make choices considering the moral and ethical impacts on others, future generations, and the environment. Teachers should be able to guide students in identifying ethical dilemmas related to sustainability issues, such as social justice, access to resources, and human rights, and encourage them to make fair and responsible decisions. Ethical decision-making is essential because sustainability involves economic and environmental considerations and questions of social justice and human well-being (Hariram et al., 2023; Haughton, 2021). ESD teaching needs to help students develop a solid moral framework to navigate these dilemmas carefully and wisely.

4. Sustainability-Oriented Pedagogical Skills

   In addition to individual competencies in critical thinking, problem-solving, and ethical decision-making, teachers also need specific pedagogical skills to teach ESD effectively. These include creating collaborative, interdisciplinary, and participatory learning environments that enable students to actively engage in learning about sustainability. Action-oriented pedagogy is particularly effective in ESD because it encourages students to learn through direct experience and critical reflection on sustainability issues (Sinakou et al., 2019). These pedagogical skills also involve integrating multiple disciplines in sustainability teaching, as sustainability issues often encompass multiple dimensions, such as ecology, economics, sociology, and politics. In addition, building "professional action competence" is essential for teachers teaching ESD. This competence involves the ability to integrate knowledge, skills, and values in sustainability teaching, as well as the ability to continuously learn and adapt to the latest developments in the field of sustainability (Brandt et al., 2022).

METHODS

This article will focus on a qualitative approach, as this study aims to develop a framework through a literature review and exploration of professional development strategies (Susanto et al., 2024). The following research methods can be used: literature review, qualitative content analysis, secondary case study, and conceptual design methods.

Literature Review

This article conducts a qualitative review of the existing literature. This method involves identifying, evaluating, and synthesizing studies relevant to teacher competency development in ESD (Siddaway et al., 2019). This review helps build a comprehensive framework based on previous research findings. The steps are:

1. Using the academic database of Google Scholar to identify relevant articles and research reports on ESD, teacher competencies, and professional development.
2. Establish criteria for filtering relevant literature.

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3. Analyze key themes and concepts from the literature to identify ESD competencies needed by teachers and effective professional development strategies.
4. Organize and synthesize findings into categories that form the basis of a professional development framework.

Qualitative Content Analysis

Once the literature has been collected, content analysis can be used to identify key patterns or themes related to teacher competency in ESD and successful professional development strategies (Kleinheksel et al., 2020). This analysis uses thematic coding methods to identify key themes such as critical thinking, problem-solving, ethical decision-making, collaborative learning, and experiential education. Then, these themes will be connected to teacher competency development outcomes and ESD practices. Coding offers several significant advantages, including the ability to derive deep, comprehensive, and holistic insights from data, making informed decision-making easier. In addition, coding allows data to be more easily accessed and retrieved through efficient algorithms while simplifying sorting and organizing data with precise automation. Thus, coding helps increase productivity and accuracy in data management, supporting various research analyses and decision-making needs (Skjott & Korsgaard, 2019).

Secondary Case Study

Case studies are in-depth investigations of phenomena related to real-life contexts (Schoch, 2020). This article could draw on secondary case studies from the existing literature to illustrate how professional development strategies have been successfully implemented in different educational contexts. These case studies could come from reports of teacher training programs or evaluations of ESD implementation in specific schools, i.e., selecting case studies from the literature that discuss the implementation of ESD training for teachers in different geographical and cultural contexts. Then, the results and impacts of these case studies will be analyzed to see if the approaches could be applied in a broader context.

Conceptual Design Method

Part of this research involved developing a conceptual framework based on the findings of the literature review (Varpio et al., 2020). This method helped build a clear, structured framework for ESD teacher competency development. Steps:

1. Integrating findings: Integrate the literature review results into a conceptual framework that describes the key elements of teacher competency and the required professional development approaches.
2. Framework validation: Ensure the framework is logical and applicable by comparing it with empirical studies and best practices in the field.

RESULTS AND DISCUSSION

In this section, we will discuss research results that focus on the literature review on Education for Sustainable Development (ESD) and its implications for developing teaching competencies among educators. This review involves several vital analyses that provide deeper insights into the development of ESD globally and its impact on educational practices. First, we will analyze the number of articles published on ESD each year, which provides an overview of the research development trends and key foci in this field. Secondly, we will discuss the content analysis of these articles to identify the main themes, methods used, and challenges faced in teaching ESD.

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In addition, we will explore the general background of documents reviewed by the country, which includes an overview of relevant policies, curriculum documents, and initiatives from different countries related to ESD implementation. This allows us to understand how different countries integrate sustainability principles in their education systems and the differences and similarities in the approaches taken. We will also examine case studies of ESD implementation in several countries to explore how ESD is applied in different cultural contexts and education systems and the challenges and successes faced.

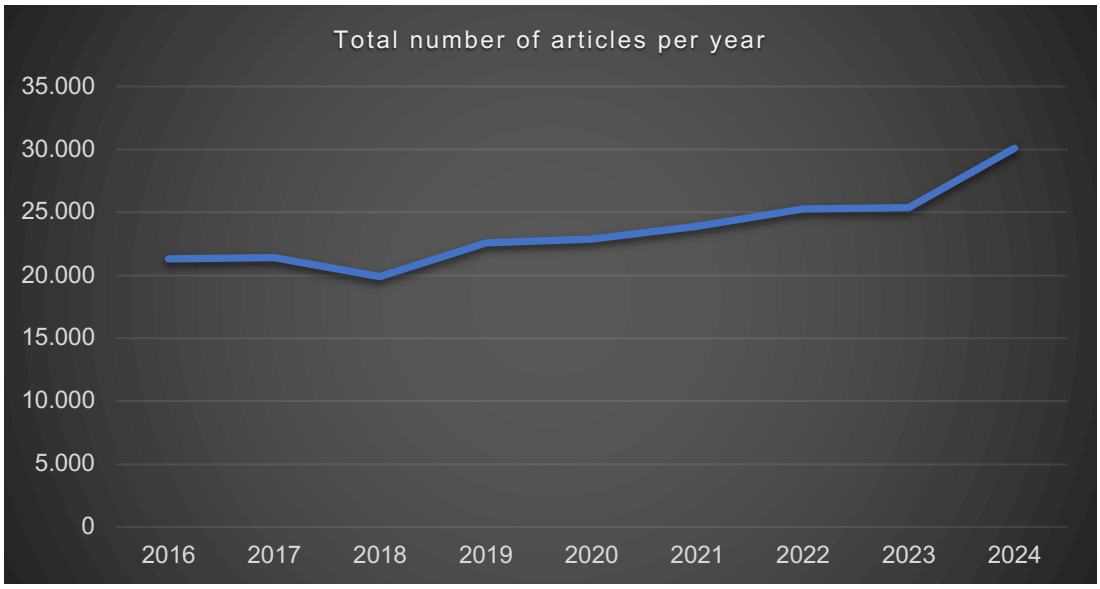

Figure 1. Graph of Articles on ESD Published in The Last 9 Years From 2016-2024
Source: Google Scholar Database 2024

The diagram shows the development of the number of articles published related to education for sustainability from 2016 to 2024. In the early period between 2016 and 2018, the number of articles published appears to be relatively stable, with minimal fluctuations. This suggests that interest in this topic may not have peaked yet, and many researchers are still exploring various aspects of education for sustainability.

However, starting in 2019, there has been a significant upward trend. The number of articles per year has begun to show more consistent growth, reflecting the growing attention to education issues for sustainability and the importance of developing teacher competencies in this context. This increase may be driven by greater global awareness of sustainability challenges, such as climate change, and the need to prepare future generations to face these challenges.

In 2023, the number of articles peaked, with more than 30,000 articles published. This continued increase indicates that education for sustainability is increasingly relevant and a significant focus among academics and practitioners. Furthermore, the predictions for 2024 indicate that this trend will continue, along with more significant efforts to improve teacher competencies and implement professional development strategies in education for sustainability. The existence of this diagram reflects a surge in interest and research contributions in the field of education for sustainability, which is further strengthened by the urgent need to prepare educators to face the challenges that exist in today's world.

General Background of Documents Reviewed by Country

Education for sustainability has become a major concern in many parts of the world. Emphasis is placed on the importance of building appropriate teacher competencies to teach sustainability concepts to

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students. These studies reflect different approaches according to each country's specific needs and challenges.

Table 1. Country Background of ESD Articles

Code	Country of origin	Author and Article Title
A1	Spanish	**Albareda-Tiana, S., García-González, E., Jiménez-Fontana, R., & Solís-Espallargas, C.** (2019). Implementing pedagogical approaches for ESD in initial teacher training at Spanish Universities. *Sustainability, 11*(18), 4927. https://doi.org/10.3390/su11184927
A2	Croatia	**Anđić, D.** (2020). Continuing professional development of teachers in education for sustainable development-case study of the Republic of Croatia. *Teacher Development, 24*(2), 143-164. https://doi.org/10.1080/13664530.2020.1719877
A3	Chile	**Bascopé, M., Perasso, P., & Reiss, K.** (2019). Systematic review of education for sustainable development at an early stage: Cornerstones and pedagogical approaches for teacher professional development. *Sustainability, 11*(3), 719. https://doi.org/10.3390/SU11030719
A4	German	**Brandt, J., Barth, M., Hale, A., & Merritt, E.** (2022). Developing ESD-specific professional action competence for teachers: Knowledge, skills, and attitudes in implementing ESD at the school level. *Environmental Education Research, 28*(8), 1691-1729. https://doi.org/10.1080/13504622.2022.2064973
A5	Ireland	**Murphy, C., Smith, G., Mallon, B., & Redman, E.** (2020). Teaching about sustainability through inquiry-based science in Irish primary classrooms: The impact of a professional development program on teacher self-efficacy, competence and pedagogy. *Environmental Education Research, 26*(9), 1112-1136.https://doi.org/10.1080/13504622.2020.1776843
A6	Vietnamese	**Thao, N., Kieu, T., Schruefer, G., Nguyen, N., Nguyen, Y., Thong, N., Yen, N., Ha, T., Phuong, D., Hai, T., Cuc, N., & Hanh, N.** (2022). Teachers' competencies in education for sustainable development in the context of Vietnam. *International Journal of Sustainability in Higher Education, 23*(1), 163-180. https://doi.org/10.1108/ijshe-08-2021-0349
A7	Taiwan	**Weng, S., Liu, Y., Dai, J., & Chuang, Y.** (2020). A novel improvement strategy of competency for Education for Sustainable Development (ESD) of University Teachers Based on Data Mining. *Sustainability, 12*(7), 2679. https://doi.org/10.3390/su12072679

Source: Google Scholar Database 2024

Table 1 shows the country regions that conducted research related to Teacher Competence for ESD. These countries are from Europe (A1, A2, A4, A5), Asia (A6, A7), and America (A3). A study conducted in Spain discusses the implementation of pedagogical approaches to ESD in initial teacher training at Spanish universities (Albareda-Tiana et al., 2019). This study shows the importance of integrating ESD in teacher education to ensure that future teachers have adequate skills and knowledge to address sustainability issues. In Spain, education for sustainability is an important part of the curriculum reform, which aims to create an education system that supports environmental and social sustainability.

Chile also highlighted the importance of integrating ESD in the professional development of teachers at an early stage of education (Bascopé et al., 2019). In Chile, there is a solid push to make education a tool to raise awareness of sustainability from an early age. This shows the commitment of Latin American countries to the development of sustainability competencies among teachers.

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Ireland emphasizes the development of professional programs to improve teachers' skills in using inquiry-based learning approaches when teaching sustainability issues in primary schools (Murphy et al., 2020). Ireland has sought to strengthen teachers' pedagogical competencies through training focused on approaches that support sustainability, hoping to inspire students to think critically about environmental issues.

In Germany, developing specific professional action competencies for ESD in teachers is important (Brandt et al., 2022). This study focused on the application of knowledge, skills, and attitudes in implementing ESD in schools. With its proactive educational policy background, Germany has supported the development of these competencies through various training and professional development initiatives for teachers.

A study conducted in Taiwan showed the use of data mining strategies to identify and improve ESD competencies among university teachers. Taiwan uses technology and data to map and develop relevant competencies in sustainability education, demonstrating an evidence-based approach to integrating ESD (Weng et al., 2020).

Continuing professional development for ESD teachers in Croatia, focusing on ESD in higher education, is essential to ensure teachers acquire relevant knowledge and skills to advance sustainability in the educational community (Anđić, 2020). Like several countries in Eastern Europe, Croatia sees education as a tool to strengthen national commitment to sustainability.

A study in Vietnam reviewed teacher competencies in education for sustainability in a developing country. In Vietnam, ESD is important not only for formal education but also for the country's economic and social development (Thao et al., 2022). This study emphasizes the importance of developing teacher competencies in ESD so that students can actively participate in the sustainability of their communities.

From the above studies, it is clear that the approach to ESD and teacher competency development is strongly influenced by the geographical context, educational policies, and specific challenges each country faces. In Europe, there is a strong focus on using innovative pedagogical methods and professional development through international collaboration (Brandt et al., 2019). In Asia, such as in Taiwan and Vietnam, there is an emphasis on using technology and developing critical thinking skills to support sustainability (Weng et al., 2020; Thao et al., 2022). The background documents reviewed show that local factors, including national education policies, resource availability, and the specific needs of each community, influence ESD development efforts worldwide. The integration of ESD in teacher education is a strategic step taken by various countries to better address global sustainability challenges through strengthening critical thinking skills, problem-solving, ethical decision-making, sustainability-oriented pedagogical skills, and holistic and contextual teacher professional development strategies (Brandt et al., 2022; Bascopé et al., 2019).

Content Analysis

Based on the results of the content analysis, the thematic coding method was used to identify patterns and main themes related to teacher competency in ESD and successful professional development strategies. In particular, from various studies, the definition of the best components and approaches for teacher professional development frameworks for ESD can be obtained. The themes used are critical thinking skills (CT), problem-solving (PS), ethical decision-making (DM), sustainability-oriented pedagogical skills (PSs), and professional development strategies (PDS).

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Table 2. Article Content Analysis

Code	Year	Author and Article Title
CT1, DM1, PDS4	2022	**Brandt, J., Barth, M., Hale, A., & Merritt, E.** Developing ESD-specific professional action competence for teachers: Knowledge, skills, and attitudes in implementing ESD at the school level. *Environmental Education Research, 28*, 1691 - 1729. https://doi.org/10.1080/13504622.2022.2064973
CT2	2023	**Chaaban, Y., Du, X., Lundberg, A., & Abu-Tineh, A**. Education stakeholders' viewpoints about an ESD competency framework: Q methodology research. *Sustainability, 15*(3), 1787. https://doi.org/10.3390/su15031787
CT3	2022	**Liu, H., Sheng, J., & Zhao, L. (2022).** Innovation of teaching tools during robot programming learning to promote middle school students' critical thinking. *Sustainability, 14*(11), 6625. https://doi.org/10.3390/su14116625
CT4	2019	**Lorencová, H., Jarošová, E., Avgitidou, S., & Dimitriadou, C.** Critical thinking practices in teacher education programs: a systematic review. *Studies in Higher Education, 44,* 844-859. https://doi.org/10.1080/03075079.2019.1586331
CT5	2023	**Felix, S**. Critical thinking (Dis) positions in education for sustainable development—A positioning theory perspective. *Education Sciences*, 13(7), 666. https://doi.org/10.3390/educsci13070666
PS1	2022	**Chaikovska, H.** Formation of ESD competencies in teachers of primary classes in the process of professional training. *The Scientific Issues of Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Pedagogy, 1*(1), 72-80. https://doi.org/10.25128/2415-3605.22.1.9
PS2, DM2	2023	**Eliyawati, E., Widodo, A., Kaniawati, I., & Fujii, H.** The development and validation of an instrument for assessing science teacher competency to teach ESD. *Sustainability, 15*(4), 3276. https://doi.org/10.3390/su15043276
PS3	2023	**Ozpinar, I., & Arslan, S.** Teacher-based evaluation of students' problem solving skills. *International Journal of Psychology and Educational Studies, 10*(2), 543-560. https://doi.org/10.52380/ijpes.2023.10.2.1160.
PS4	2020	**Son, J., & Lee, M**. Exploring the relationship between preservice teachers' conceptions of problem solving and their problem-solving performances. *International Journal of Science and Mathematics Education, 19*, 129-150. https://doi.org/10.1007/s10763-019-10045-w
PS5	2023	**Ubaidillah, M., Marwoto, P., Wiyanto, W., & Subali, B**. Problem solving and decision-making skills for ESD: A bibliometric analysis. *International Journal of Cognitive Research in Science, Engineering and Education, 11*(3), 401-415. https://doi.org/10.23947/2334-8496-2023-11-3-401-415
PS6, DM3, PDS8	2020	**Weng, S., Liu, Y., Dai, J., & Chuang, Y.** A novel improvement strategy of competency for Education for Sustainable Development (ESD) of university teachers based on data mining. *Sustainability, 12*(7), 2679. https://doi.org/10.3390/su12072679
DM4, PSs3, PDS3	2019	**Brandt, J., Bürgener, L., Barth, M., & Redman, A.** Becoming a competent teacher in education for sustainable development. *International Journal of Sustainability in Higher Education, 20*(4), 630-653. https://doi.org/10.1108/IJSHE-10-2018-0183
DM5	2021	**Reeves, B.** Assessing ethical capability: A framework for supporting teacher judgment of student proficiency. *The Australian Educational Researcher, 49*, 779-804. https://doi.org/10.1007/S13384-021-00442-Y
DM6	2020	**Timm, J., & Barth, M**. Making education for sustainable development happen in elementary schools: the role of teachers. *Environmental Education Research, 27*, 50-66. https://doi.org/10.1080/13504622.2020.1813256
PSs1	2019	**Albareda-Tiana, S., García-González, E., Jiménez-Fontana, R., & Solís-Espallargas, C.** Implementing Pedagogical Approaches for ESD in Initial Teacher Training at Spanish Universities. *Sustainability, 11*(18), 4927. https://doi.org/10.3390/su11184927

Code	Year	Author and Article Title
PSs2, PDS2	2019	**Bascopé, M., Perasso, P., & Reiss, K.** Systematic review of education for sustainable development at an early stage: Cornerstones and pedagogical approaches for teacher professional development. *Sustainability, 11*(3), 719 https://doi.org/10.3390/SU11030719
PS4	2020	**Cebrián, G., Junyent, M., & Mulà, I.** Competencies in education for sustainable development: Emerging teaching and research developments. *Sustainability, 12*, 579. https://doi.org/10.3390/su12020579
PSs5, PDS5	2021	**Imara, K., & Altınay, F.** Integrating education for sustainable development competencies in teacher education. *Sustainability, 13*(22), 12555. https://doi.org/10.3390/su132212555
PSs6	2020	**Murphy, C., Smith, G., Mallon, B., & Redman, E.** Teaching about sustainability through inquiry-based science in Irish primary classrooms: The impact of a professional development program on teacher self-efficacy, competence and pedagogy. *Environmental Education Research, 26*, 1112-1136. https://doi.org/10.1080/13504622.2020.1776843
PDS1	2020	**Anđić, D.** Continuing professional development of teachers in education for sustainable development-case study of the Republic of Croatia. *Teacher Development, 24*, 143-164. https://doi.org/10.1080/13664530.2020.1719877
PDS6	2021	**Lohmann, J., Breithecker, J., Ohl, U., Giess-Stüber, P., & Brandl-Bredenbeck, H.** Teachers' Professional Action Competence in Education for Sustainable Development: A Systematic Review from the Perspective of Physical Education. *Sustainability, 13*(23), 13343. https://doi.org/10.3390/su132313343
PDS7	2022	**Thao, N., Kieu, T., Schruefer, G., Nguyen, N., Nguyen, Y., Thong, N., Yen, N., Ha, T., Phuong, D., Hai, T., Cuc, N., & Hanh, N.** Teachers' competencies in education for sustainable development in the context of Vietnam. *International Journal of Sustainability in Higher Education, 23*(7), 1730-1748. https://doi.org/10.1108/IJSHE-08-2021-0349

Source: Google Scholar Database 2024

Professional Development Framework

From the references in **Table 2**, a professional development framework was created to improve teacher competencies for ESD. The framework includes the identification of teacher competencies, professional development structures that support ESD competencies, a holistic approach to developing ESD competencies, and policy recommendations to support the implementation of the framework.

1. Identification of Teacher Competencies for ESD

a. Critical thinking

Critical thinking competence is essential for teachers in implementing Education for Sustainable Development (ESD) to face the complex challenges of achieving sustainable development goals (Taimur & Sattar., 2020). In the context of sustainable education, teachers are required to not only master the learning content but also facilitate critical thinking skills in their students. Developing critical thinking in teachers is an essential step in transforming higher education towards sustainability (Felix, 2023). They emphasize that critical thinking enables teachers to evaluate and reflect on their pedagogical practices and identify sustainable solutions to existing issues. This competence is very relevant to the perspective of sustainability education, where teachers are expected to think reflectively and assess the implications of their actions on the environment and society.

In addition, various stakeholders have important perspectives on building an ESD competency framework for teachers. According to their research, teachers with critical thinking skills can encourage student engagement in in-depth and reflective discussions on global issues and sustainable problem solving (Chaaban et al., 2023). This ability is essential to equip students with the knowledge and skills to face future sustainability challenges.

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Their systematic review of critical thinking practices in teacher education programs stated that the application of learning strategies that focus on developing critical thinking skills has proven effective in improving prospective teachers' analytical and reflective abilities (Lorencová et al., 2019). Using this technique in teacher education can contribute to forming more substantial ESD competencies (Lorencová et al., 2019). Teachers with critical thinking skills can better analyze information, evaluate multiple perspectives, and make informed decisions in the context of continuing education.

Innovation in teaching tools, such as robotic programming, can improve students' critical thinking skills. This experience is relevant in teacher education because the development of technology and innovation skills supports sustainability-based teaching (Liu et al., 2022). Teachers with critical thinking and technology skills can use various tools to optimize ESD teaching.

It is important to develop ESD-specific professional action competencies in teachers, which include the knowledge, skills, and attitudes needed to implement ESD in schools. Critical thinking skills enable teachers to develop relevant curricula and methods and support student-centered learning (Brandt et al., 2022).

b. Solution to Problem

Problem-solving skills are crucial in teacher competencies for Education for Sustainable Development (ESD), as teachers must guide students in facing complex sustainability challenges. Problem-solving involves the ability to identify, analyze, and find solutions to problems, which becomes increasingly relevant in the context of ESD because the challenges faced are global and multidimensional.

Forming ESD competencies in primary school teachers requires developing problem-solving skills from the early stages of professional training. Teachers need to master effective problem-solving techniques and strategies in order to teach students to think critically and innovatively in facing sustainability challenges (Chaikovska, 2022). This shows that problem-solving competencies are not just individual skills but also crucial for building students' capacity to understand and respond to sustainability issues.

There is a significant relationship between preservice teachers' understanding of problem solving and their ability to solve problems directly. This study shows that teachers with a strong concept of the problem-solving process tend to be more effective in solving complex problems. Thus, to be an effective teacher in the context of ESD, teachers need to have a deep understanding of how the problem-solving process can be applied in various educational situations (Son & Lee, 2020).

Some identified strategies for improving university teachers' ESD competencies, including problem-solving, using a data mining approach. This study demonstrates the importance of leveraging technology and data to understand teachers' ESD competencies, including analyzing and finding innovative solutions to existing problems. This emphasizes the importance of a data-driven approach in evaluating and developing teachers' problem-solving competencies (Weng et al., 2020).

Teachers' problem-solving abilities are also closely related to evaluating students' skills. Teachers' evaluation of students' problem-solving skills can help them identify areas where students need further guidance. Teachers with good problem-solving competencies can provide more appropriate and effective feedback, ultimately improving students' problem-solving skills in the context of sustainability (Özpınar & Arslan, 2023).

A study conducted a bibliometric analysis of problem-solving and decision-making skills in ESD. The authors emphasized that these skills are essential for identifying short-term solutions and developing sustainable solutions that can have long-term impacts. Teachers must be equipped with these skills to integrate long-term thinking into their teaching, which aligns with ESD principles (Ubaidillah et al., 2023).

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The development of problem-solving competencies in teachers for ESD also needs to be validated with appropriate instruments. They developed an instrument to assess teacher competencies in ESD, including problem-solving skills. This study shows the importance of valid assessment tools in ensuring teachers have the competencies to teach students in a sustainability context (Eliyawati et al., 2023).

c. *Making Ethical Decisions*

The ability to make ethical decisions is one of the essential aspects of teacher competence in Education for Sustainable Development (ESD) because teachers need to consider various ethical perspectives in dealing with dilemmas related to sustainability. Ethical decisions in the context of ESD refer to the ability of teachers to evaluate the impact of their actions on the environment, society, and economy and to ensure that the decisions they make align with the principles of sustainable development.

Innovative data-driven approaches can improve ESD competencies in university teachers, including ethical decision-making skills. Data mining identifies competency aspects that need improvement and provides insights into how teachers can better assess the ethical implications of their educational decisions. In the context of ESD, teachers need to understand the impact of their pedagogical choices to ensure that they create learning environments that support sustainability (Weng et al., 2020).

Professional competency development for teachers in ESD includes knowledge, skills, and attitudes related to implementing continuing education at the school level. A critical aspect of this competency is the ability to make ethical decisions in complex situations that often do not have clear solutions. Teachers must consider various factors, including student well-being, environmental impact, and prevailing social values when making decisions in their teaching (Brandt et al., 2022).

A framework is relevant to helping teachers assess students' ethical skills and enhance their ethical competence in ESD. Teachers' ability to guide students in understanding and addressing ethical dilemmas is vital in developing students' understanding of broader sustainability issues. Using this approach, teachers can provide opportunities for students to engage in discussion and reflection on ethical issues, essential to sustainable learning (Reeves, 2021).

The role of teachers in implementing ESD in elementary schools, especially in the context of making decisions, is essential to support sustainability. Teachers must be able to identify ethical dilemmas in everyday learning and make decisions that support a balance between the needs of students, society, and the environment. This includes choices in designing learning activities that focus not only on academic achievement but also on instilling sustainability values (Timm & Barth, 2020).

Some important points of being a competent teacher in ESD include the ability to make fair and sustainable decisions. Teachers must be able to weigh the impacts of their choices and ensure that their decisions reflect sustainability values, such as social justice and environmental responsibility. This ability is essential to ensure that their education can encourage students to become concerned citizens and actively engage in sustainability issues (Brandt et al., 2019).

Some studies developed and validated an instrument to assess science teachers' competencies in teaching ESD, including the ability to make ethical decisions. They emphasized that assessing these competencies is essential to ensure that teachers not only master the learning content but also consider the impact of the teaching methods used in sustainability (Eliyawati et al., 2023).

d. *Sustainability Oriented Pedagogical Skills*

Sustainability-oriented pedagogical skills are a crucial component in developing teacher competencies for ESD. Sustainability-supporting education focuses on knowledge of sustainability issues and

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developing pedagogical skills that enable teachers to implement innovative and relevant teaching methods in support of sustainability.

Implementing pedagogical approaches to ESD in initial teacher training at Spanish Universities aims to equip prospective teachers with the skills necessary to deliver ESD content effectively. They found that integrating approaches such as project-based and collaborative learning was very effective in improving teachers' pedagogical skills related to sustainability (Albareda-Tiana et al., 2019).

Some identified competencies are essential in education for sustainability, including pedagogical skills that support active and transformative learning. Teachers are expected to facilitate learning processes that promote students' critical and reflective thinking, essential in developing sustainability awareness. This approach also includes collaboration with students in designing solutions to sustainability issues relevant to their lives (Cebrián et al., 2020).

The integration of ESD competencies in teacher education can strengthen teachers' pedagogical skills in teaching about sustainability. They argue that interdisciplinary learning and active learning experiences should be part of teacher competency development to encourage students' engagement in sustainability issues and create meaningful learning experiences (Imara & Altınay, 2021).

In the early stages of education for sustainability, professional training of teachers is essential to provide educators with the necessary foundations for teaching sustainability. They emphasized the importance of using pedagogical approaches that include active student engagement, real-world problem solving, and critical reflection as part of sustainability teaching (Bascopé et al., 2019).

A professional development program focused on inquiry-based teaching of sustainability in primary school classrooms in Ireland improved teachers' self-efficacy, competence, and pedagogical skills. Inquiry-based teaching allows teachers to engage students more deeply with the learning material through hands-on experiments and investigations, enhancing students' understanding of sustainability concepts and their applications in everyday life (Murphy et al., 2020).

Becoming a competent teacher in ESD requires the skills to use various teaching methods that support sustainability. These methods include collaborative teaching, case studies, and transdisciplinary approaches, all of which aim to develop students' understanding of the complexities of sustainability and encourage them to think critically and holistically about the issues at hand (Brandt et al., 2019).

2. Professional Development Structures that Support ESD Competencies

a. *Professional development strategies*

Professional development strategies for teacher competency and education in ESD ensure educators have the skills, knowledge, and attitudes needed to integrate sustainability issues into the learning process. This effort can be done through various professional development programs that focus on strengthening teacher competency in implementing ESD.

b. *Continuous Training*

Long-term training for teachers in ESD is essential to deepening their understanding of sustainability principles. A study emphasized that specific professional action competencies for ESD include the knowledge, skills, and attitudes necessary for effective implementation at the school level (Brandt et al., 2022). Without continuous training, teachers may not have a deep understanding of how to integrate sustainability into their curriculum, which can limit the effectiveness of their teaching (Bascopé et al., 2019). Professional action competencies in ESD should include integrating sustainability education into

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broader teaching contexts, including through interdisciplinary and collaborative approaches relevant to students' daily lives (Lohmann et al., 2021). The approach emphasizes the development of pedagogical competencies, such as the ability to teach sustainability issues in an interdisciplinary manner and the use of teaching methods that inspire students to take action on sustainability challenges (Brandt et al., 2022). Therefore, long-term training can help strengthen teachers' knowledge base, enabling them to become key drivers in sustainability education.

The strategy for improving ESD competency for university lecturers at the higher education level is based on data mining. This approach aims to identify the specific needs of each teacher or lecturer in ESD teaching and then develop a customized development program. This strategy can help improve the effectiveness of training programs by focusing on areas of competency that are still lacking (Weng et al., 2020).

c. *Collaborative Learning*

Collaborative learning between teachers also plays a crucial role in developing ESD competencies. Through collaboration, teachers can share best practices, teaching strategies, and resources that support the integration of ESD into their curriculum. Involvement in collaborative learning communities allows teachers to support each other and strengthen their skills in ESD teaching (Chaaban et al., 2023). Collaborative learning enhances individual skills and builds a supportive educational culture in implementing sustainability principles in the school environment.

Teacher professional training at the early stages of sustainability education is essential. Their systematic review shows that pedagogical approaches such as project-based learning, collaborative learning, and reflective approaches are essential for teacher professional development. This training ensures that teachers have a foundation of relevant pedagogical skills to teach ESD effectively (Bascopé et al., 2019).

d. *Experience-Based Education*

In addition, experiential learning is essential in helping teachers integrate sustainability principles into their teaching practices. Experiential learning methods allow teachers to learn through hands-on practice, which can enhance the understanding and application of ESD. Using innovative teaching tools in experiential learning can enhance students' critical thinking skills, essential components of ESD (Liu et al., 2022). By providing teachers with hands-on experience in implementing ESD, they can be more confident in teaching the concepts to their students.

In the context of integrating ESD competencies into teacher education, the importance of developing teacher training programs that promote the integration of ESD competencies into educational practices is emphasized. Interdisciplinary learning and active learning experiences should be at the heart of teacher competency development to facilitate effective sustainability teaching (Imara & Altınay, 2021). The goal is for teachers to become competent in ESD through professional development. Effective professional development strategies include increasing teachers' awareness of the complexity of sustainability issues and the ability to use various teaching methods that support students' holistic understanding of sustainability challenges (Brandt et al., 2019).

3. Secondary Case Study

The case study on teachers' continuing professional development in Croatia found that continuing training is essential to ensure that teachers stay updated with the latest developments in ESD. The

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study highlights the need for policies that support continuing training for teachers in the context of ESD and provide adequate resources to improve their competencies in sustainability education (Anđić, 2020).

The positive impact of a professional development program focused on inquiry-based teaching of sustainability in primary school classrooms in Ireland. The program not only increased teachers' self-efficacy and competence in teaching sustainability but also increased their ability to adapt innovative and relevant teaching methods (Murphy et al., 2020).

Teacher competencies in ESD in Vietnam include pedagogical skills, knowledge of sustainability, and the ability to create a supportive learning environment. These are crucial elements that need to be strengthened through teacher professional development. Professional training programs should also be designed to meet local and specific needs, such as the social and cultural contexts that influence the implementation of ESD in schools (Thao et al., 2022).

4. Conceptual Design: The Relationship Between Teacher Competency Components and Professional Development Strategies for ESD

The interrelationships between variables, namely critical thinking skills, problem-solving, ethical decision-making, sustainability-oriented pedagogical skills, and teacher professional development strategies for ESD, support each other and form a solid foundation for education for sustainable development (ESD). The relationships between these variables can be understood as follows:

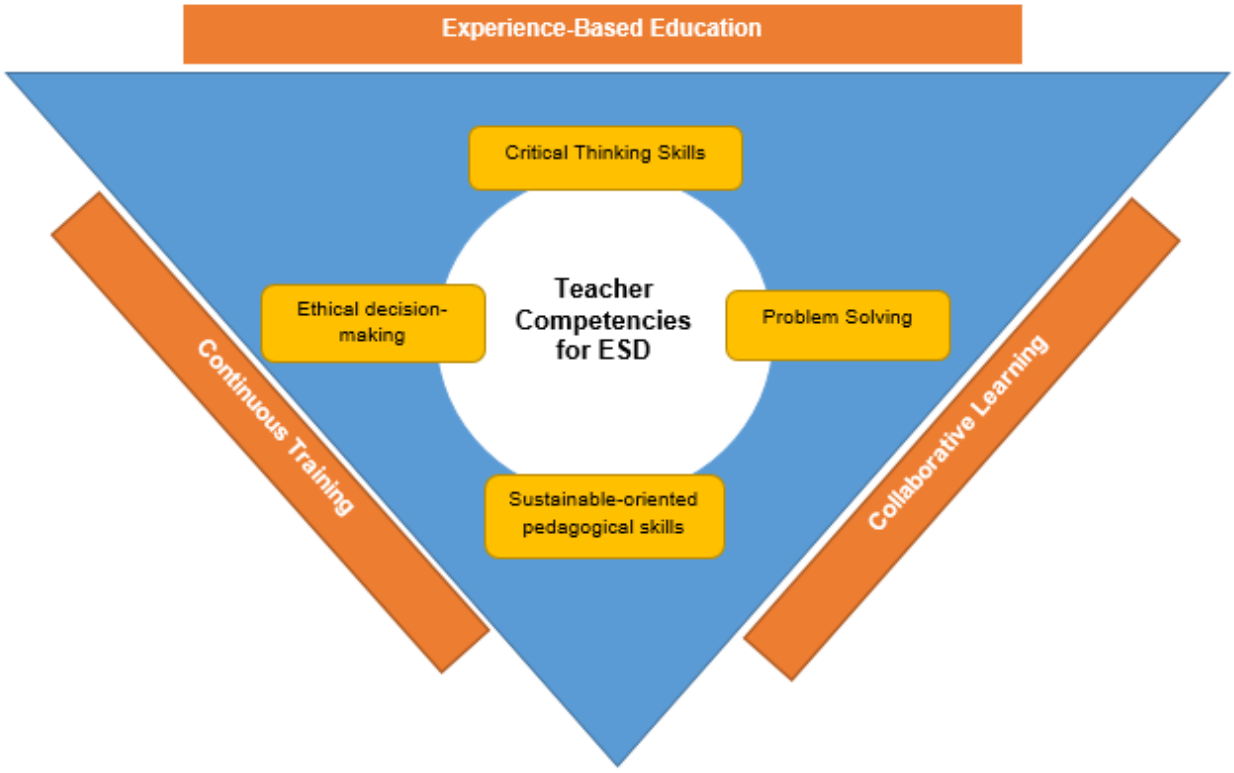

Figure 2. Conceptual Framework of Professional Development of Teacher Competencies for ESD
Source: Author's Design Document 2024

a. Critical Thinking Skills: Critical thinking skills are vital in sustainability education because they enable teachers and students to analyze complex issues deeply (Felix, 2023). Critical thinking is fundamental to understanding sustainability challenges and developing critical perspectives on how we interact with

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the environment and society. In this context, ESD-focused professional development should hone teachers' critical thinking skills to help students navigate sustainability challenges more profoundly and reflectively (Brandt et al., 2022; Bascopé et al., 2019).

b. Solution to the problem: Problem-solving is a skill closely related to critical thinking, where critical thinking skills help analyze problems, while problem-solving focuses on finding effective and creative solutions. In ESD, teachers with critical thinking skills can better facilitate the problem-solving process, guiding students to identify solutions to sustainability issues such as climate change, pollution, or social injustice. Sustainability-oriented professional development strategies help teachers develop these skills through problem-based learning and projects relevant to local and global contexts (Weng et al., 2020; Son & Lee, 2020).

c. Ethical Decision Making: Ethical decision-making is essential in ESD, as sustainability issues often involve moral dilemmas and conflicting values. Teachers must be able to make decisions that consider long-term impacts on the environment, economy, and society. Decision-making based on ethical values is related to critical thinking skills and problem-solving, as teachers need to consider multiple aspects in choosing effective but also fair and sustainable solutions. Professional development strategies should include exercises that support teachers' ability to make informed decisions based on ethical principles of sustainability (Reeves, 2021; Brandt et al., 2022).

d. Sustainability-Oriented Pedagogical Skills: Sustainability-oriented pedagogical skills include the ability to teach sustainability topics in relevant and engaging ways for students. Teachers must be able to integrate sustainability issues into the curriculum and use pedagogical approaches that support active, collaborative, and reflective learning. These pedagogical skills include using methods such as project-based learning, collaborative learning, and problem-based learning, all designed to develop students' critical thinking, problem-solving, and ethical decision-making skills. Targeted professional development to improve these pedagogical skills is essential for teachers to instill sustainability values in students early (Albareda-Tiana et al., 2019; Cebrián et al., 2020).

e. Teacher Professional Development Strategies for ESD: Professional development strategies are the main foundation that connects and strengthens other skills. Through ongoing training, teachers are allowed to develop critical thinking, problem-solving, ethical decision-making, and sustainability-oriented pedagogical skills in an integrated manner. For example, professional development programs designed to improve teachers' competencies in ESD often include components such as training on problem-based teaching, critical reflection, and interdisciplinary learning relevant to sustainability issues (Anđić, 2020; Imara & Altınay, 2021). In addition, this professional development also encourages teachers to integrate sustainability perspectives in all aspects of teaching, from lesson planning to evaluation of learning outcomes (Brandt et al., 2019).

Critical thinking, problem-solving, ethical decision-making, and sustainability-oriented pedagogical skills are all interrelated elements that support teacher competency in ESD. Professional development strategies play a critical role in strengthening these skills, ensuring teachers have the knowledge, skills, and attitudes necessary to guide students in understanding and effectively addressing sustainability challenges. Combining these skills enriches teacher competency and facilitates student learning that is more meaningful and relevant to real-world sustainability challenges.

CONCLUSION

Education for Sustainable Development (ESD) has become an increasingly relevant topic in recent years. Analysis of publication trends from 2016 to 2024 shows a significant increase in articles published, especially after 2019. This surge reflects the growing global attention to sustainability challenges such as

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climate change and the importance of preparing future generations through developing teacher competencies. By 2023, the number of articles reached more than 30,000, marking the peak of global interest in ESD and emphasizing the urgency of teacher professional development in this context.

A content analysis of the literature identified five key components of teacher competence in ESD: critical thinking skills, problem-solving, ethical decision-making, sustainability-based pedagogical skills, and professional development strategies. Pedagogical approaches such as project-based, collaborative, and reflective learning effectively strengthened teachers' skills in teaching sustainability concepts. On the other hand, utilizing technology such as data mining is an innovative strategy to map specific needs in teacher competency development.

Case studies from different countries show that the geographical context and local education policies strongly influence approaches to ESD. Developed countries such as Spain, Germany, and Taiwan highlight success through international collaboration, technology integration, and a focus on developing critical thinking skills. Meanwhile, developing countries such as Vietnam emphasize the importance of contextualizing teacher training according to local needs. These findings suggest that locally-based approaches tailored to a country's specific challenges play an essential role in implementing ESD successfully.

In addition, the professional development framework supporting ESD highlights the importance of continuous teacher training. This strategy improves teachers' competencies and supports implementing sustainability principles in daily learning. With policy support, adequate resources, and an evidence-based approach, ESD development efforts can have a broader impact on education systems globally.

Based on the findings, strengthening the teacher competency framework in Education for Sustainable Development (ESD) is a priority. Competencies such as critical thinking, problem-solving, ethical decision-making, and sustainability-based pedagogical skills need to be thoroughly integrated into teacher training curricula. Pedagogical approaches based on projects, collaboration, and reflection can help teachers develop these skills more effectively, enabling them to support sustainability-relevant learning.

Teacher professional development requires ongoing training strategies to integrate sustainability principles into learning across disciplines. Technology, such as data mining, can help identify teachers' specific needs and provide focused training. In addition, collaboration between teachers, both locally and internationally, is essential to share best practices, resources, and strategies for implementing ESD. This approach can build an educational culture that supports sustainability values in the school environment.

To support the successful implementation of ESD, teacher training should be designed according to the local context, including considering local culture, social needs, and education policies. The interdisciplinary approach must also be strengthened to link sustainability with various disciplines to make learning more holistic. In addition, the government and educational institutions must provide adequate policy support and resources for teacher training and the implementation of ESD programs in formal education. With these strategic steps, teachers can become agents of change who can prepare the younger generation to face global sustainability challenges innovatively and ethically.

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