DEVELOPMENT OF STRATEGIES TO ENHANCE EDUCATION FOR SUSTAINABLE DEVELOPMENT COMPETENCE AMONG PRE-SERVICE TEACHERS AT UNIVERSITIES IN YUNNAN PROVINCE, CHINA

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ZHICHENG ZHANG

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DEVELOPMENT OF STRATEGIES TO ENHANCE EDUCATION
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BY

ZHICHENG ZHANG

HAS BEEN APPROVED BY THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT
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Pre-service teacher's education plays a pivotal role in shaping future educators who will impart Education for Sustainable Development (ESD) competencies to their students and foster a deeper understanding of sustainability in the classroom.Quantitative research, the first phase of this dissertation, using PLS-SEM, found that sustainable leadership had a significant positive impact on ESD holism, ESD pluralism, and ESD professional action competence. In addition, ESD holism and pluralism significantly predicted pre-service teacher's professional action competence in ESD. Furthermore, mediation analysis revealed that ESD holism and pluralism partially mediated the impact of sustainable leadership on pre-service teacher's professional action competence in ESD.In the qualitative research section, the qualitative data for this study were gathered through semi-structured, in-depth interviews. Participants (N=15) were purposively sampled from various stakeholders in Yunnan Province, including normal university teachers, department heads, university leaders, internship supervisors, and ESD research experts. Thematic analysis identified six core themes: (1) Holism and Systems Thinking in ESD; (2) Pluralism in ESD Pedagogy; (3) Sustainable Leadership for ESD Implementation; and (4) Components of ESD Competence which corresponded to the quantitative research constructs, and (5) ESD-Centric Curriculum Reform and (6) Continuous Professional Growth in ESD which emerged as novel factors.

Keyword : Education for Sustainable, Development Sustainable, Leadership ESD- Holism, ESD-Pluralism Professional, Action Competence in ESD, Pre-service Teacher PLS-SEM

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INTRODUCTION

1.1 Introduction

The escalating global sustainability challenges have highlighted the need for a fundamental transformation in education. Education for Sustainable Development (ESD) is central to equipping individuals with the knowledge, skills, and values necessary to address these challenges and contribute to a sustainable future (Leicht et al., 2018; Raman et al., 2022). ESD, an interdisciplinary approach, integrates environmental, social, and economic dimensions, aiming to cultivate competencies that enable learners to respond effectively to sustainability issues (UNESCO, 2005; Nousheen et al., 2020). In this context, pre-service teacher education plays a pivotal role in shaping future educators who will impart these competencies to their students and foster a deeper understanding of sustainability in the classroom.

Pre-service teacher education is essential for equipping future educators with the competencies required to implement ESD and address global sustainability challenges. This foundational training ensures that teachers are not only adept at delivering subject-specific content but are also capable of integrating interdisciplinary approaches and fostering critical thinking about sustainability. Pre-service teacher education programs are designed to develop a wide range of competencies in future teachers, including content knowledge, pedagogy, and professional engagement. For instance, pre-service teachers in the Philippines demonstrated advanced competence in several domains of the Philippine Professional Standards for Teachers (PPST), which highlights the effectiveness of such programs in preparing educators for diverse and dynamic educational settings (Rubio & Saenz, 2023). However, challenges remain, particularly in bridging the gap between theoretical knowledge and practical application, as well as addressing the varied needs of diverse learners.

In the context of ESD, pre-service teacher education emphasizes interdisciplinary approaches, such as STEAM (Science, Technology, Engineering, Arts, and Mathematics), which foster the analytical and integrative skills necessary for

tackling sustainability challenges (Wiegand & Borromeo Ferri, 2023). Experiential learning, such as community-based tasks, further enhances engagement with real-world sustainability issues, promoting critical reflection and self-directed learning (Raman et al., 2022; Boyle et al., 2022). These approaches are essential in equipping pre-service teachers with the skills and perspectives required to address sustainability issues in the classroom and beyond.

Despite the progress made, significant challenges persist. Pre-service teachers often report lower confidence in their pedagogical knowledge related to ESD, highlighting the need for enhanced training in sustainability-focused teaching methodologies (Ammoneit et al., 2022). Furthermore, while self-efficacy beliefs regarding ESD are generally positive, there remains room for improvement through more targeted ESD courses (Avsec & Ferk Savec, 2021). These gaps in teacher education reveals the importance of continuously refining and adapting pre-service teacher training programs to meet the evolving demands of sustainability education.

The integration of ESD into teacher education aligns with global commitments, such as the Education 2030 Framework for Action, which emphasizes the need for well-trained, professionally qualified educators who are equipped to support the achievement of the Sustainable Development Goals (SDGs) (Raman et al., 2022). ESD fosters the development of the knowledge, skills, values, and attitudes essential for creating a more sustainable and equitable society (Leicht et al., 2018). Teacher education institutions are thus tasked with embedding ESD-focused training throughout their curricula, ensuring that future educators are well-prepared to function as change agents who can promote sustainable practices and address complex social-environmental challenges (Raman et al., 2022). Interdisciplinary approaches, which bridge the natural sciences, social sciences, and humanities, are particularly valuable for fostering a holistic understanding of sustainability issues, as they enable pre-service teachers to consider sustainability from multiple perspectives (Raman et al., 2022).

In addition to developing the necessary competencies, pre-service teacher education must focus on cultivating professional action competence, which is crucial for the successful implementation of ESD in future classrooms. Professional action competence involves not only the acquisition of knowledge but also the ability to translate that knowledge into meaningful action, engaging students with sustainability issues and instilling a sense of responsibility for sustainable practices (Raman et al., 2022). As future leaders in education, pre-service teachers must be prepared to integrate sustainability into their teaching practices, thereby contributing to the achievement of the SDGs and fostering a generation capable of addressing the global sustainability challenges ahead.

This research explores the role of sustainable leadership in shaping professional action competence in ESD, with particular focus on the mediating roles of ESD-Holism and ESD-Pluralism. Understanding how these factors influence the development of pre-service teachers' competencies in ESD is critical for ensuring that educators are well-prepared to face the complex sustainability challenges that await them in their classrooms. The integration of ESD into pre-service teacher education is not only an essential strategy for achieving global sustainability goals but also a transformative approach that empowers educators to create meaningful change in the future.

By examining these critical aspects of pre-service teacher education, this study aims to provide insights into how teacher training can be further improved to effectively prepare educators for the challenges and responsibilities associated with teaching for sustainability. The ultimate goal is to ensure that pre-service teachers are equipped with the necessary tools, skills, and mindset to contribute to a more sustainable and just society through their educational practices.

Global Context of Climate Change

The global climate crisis highlights the urgency of embedding Education for Sustainable Development (ESD) into education systems. The rise in global temperatures, driven by increasing levels of greenhouse gases such as carbon dioxide

(CO_2), demands immediate and collective action (Kabir et al., 2023). If left unaddressed, the consequences of global warming could be catastrophic, affecting environmental, agricultural, and socio-economic systems worldwide. Educational institutions, as key drivers of change, hold a critical responsibility in fostering environmental awareness and empowering learners to adopt sustainable behaviors that contribute to mitigating climate change.

Historical data highlights significant fluctuations in global temperatures over the past 140 years, with a clear upward trend linked to human-induced greenhouse gas emissions (Kabir et al., 2023). Figure 1 illustrates global temperature changes from 1880 to 2020, showcasing the deviation from expected norms. Projections suggest that if this trend persists, the average global temperature could rise by approximately 2.5°C, amplifying the risk of severe environmental disruptions.

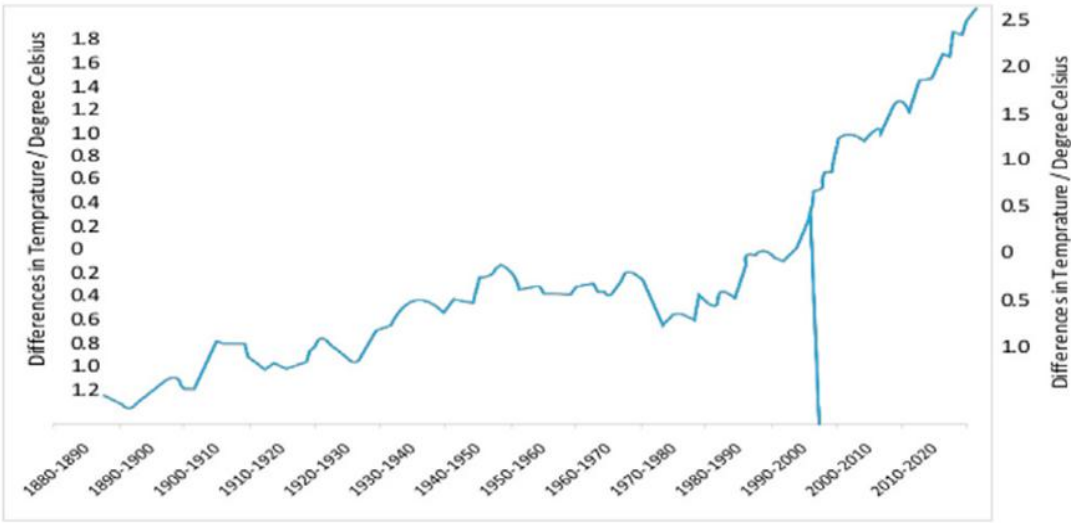

Figure 1 Global Temperatures Experienced Fluctuations between 1880 and 2020.

Source: Kabir et al. (2023)

The implications of climate change are far-reaching. Reduced water availability threatens agricultural productivity, while economic losses stemming from extreme weather events strain global economies. Ecosystems are also at risk, with negative impacts cascading across human, animal, and plant populations. Addressing these challenges requires coordinated efforts to reduce greenhouse gas emissions. Strategies such as afforestation and water reservoir restoration, especially in urban areas, are critical to mitigating these effects.

Every individual has a role to play in safeguarding the environment, highlighting the importance of collective responsibility in combating climate change. Educational institutions are uniquely positioned to lead this charge by integrating sustainability principles into curricula and promoting ecological stewardship. By equipping future generations with the knowledge, skills, and values necessary to tackle climate challenges, such efforts align with the broader goals of ESD, emphasizing its critical role in achieving a sustainable future for all.

Sustainable Leadership and Teacher Training

Sustainable leadership in education is a transformative force that ensures continuity, equity, and long-term positive outcomes for students, schools, and communities. Defined by Hargreaves and Fink (2004), it is characterized by its enduring impact, shared responsibility, and commitment to preserving human and financial resources while fostering organizational diversity and collaborative learning. This leadership style integrates the past, present, and future, balancing tradition with innovation to create sustainable progress (Hargreaves, 2007). Such an approach aligns with the principles of sustainability outlined by the Brundtland Commission, emphasizing ethical practices that meet current needs without compromising future generations (Ferdig, 2007).

In the context of teacher training, sustainable leadership is vital for developing leaders who can cultivate organizational capacity, promote inclusivity, and align educational goals with long-term objectives (Lambert, 2011). Teacher training institutions play a crucial role in instilling these values by fostering collaborative learning

environments, encouraging diversity, and preparing educators to address evolving educational challenges. Sustainable leadership in teacher training not only emphasizes innovation but also ensures continuity, creating a culture that supports both adaptability and resilience.

Pre-service teachers' perceptions of their training institutions' leadership in this regard are pivotal. They observe and internalize leadership practices modeled by their institutions' leaders, shaping their understanding of sustainable leadership principles. When pre-service teachers perceive their leaders as embodying ethical, collaborative, and resource-conscious practices, they are more likely to adopt these principles in their future roles. Effective leaders in teacher training institutions promote a coherent vision that aligns educational practices with sustainable development goals, ensuring pre-service teachers are equipped to navigate complex educational landscapes.

The integration of sustainable leadership with Education for Sustainable Development (ESD) further underscores its importance in teacher training. Leaders must not only understand ESD principles but also implement them by embedding economic, social, and environmental considerations into teaching practices (Abidin et al., 2023). However, challenges remain in translating these principles into actionable strategies, as noted by the DESD conference in Nagoya (2014), which highlighted the need for systemic changes in school values and pedagogies (Iliško & Badyanova, 2014).

In light of these efforts, conducting quantitative research on ESD among pre-service teachers becomes a highly valuable approach. Such research not only highlights the importance of sustainability but also encourages pre-service teachers to reflect on how they can incorporate ESD into their teaching careers. This reflective process helps them consider how to innovate and adapt their teaching strategies to promote sustainability within their own classrooms and beyond. By gaining a deeper understanding of ESD, pre-service teachers can become catalysts for change, shaping the future of education and ensuring that sustainability is embedded in the next generation of learners.

This research ultimately benefits not only teachers and students but also the broader environment, economy, and society. As pre-service teachers engage with ESD, they are better prepared to foster a culture of sustainability in schools, which in turn will create a more sustainable society. Therefore, it is essential that higher education institutions, especially those focused on teacher training, prioritize integrating SD and ESD into their programs. By doing so, they can equip the next generation of educators with the knowledge, skills, and leadership capabilities necessary to drive sustainable change across educational settings and in society as a whole.

Pre-service teachers' perceptions of their institutions' leadership practices thus become critical indicators of the success of such integration efforts. When teacher training institutions demonstrate sustainable leadership, they model the values, behaviors, and collaborative strategies that pre-service teachers will carry into their professional lives, amplifying the ripple effect of sustainable leadership across educational and societal contexts. This alignment ensures that pre-service teachers are not only well-prepared to meet the challenges of modern education but also positioned to inspire lasting, systemic change.

China's Commitment to Sustainable Education

China has made significant strides in embedding sustainable development into its legal system, ensuring that it is a national priority that permeates all aspects of society, including education. The Environmental Protection Law of the People's Republic of China (Standing Committee of the National People's Congress, 2015) mandates the integration of environmental protection into educational curricula, highlighting the central role of education in fostering sustainability values. This law plays a crucial role in advancing the government's goal of promoting "ecological civilization," which connects sustainable practices to national development priorities. Additionally, the Civil Code of the People's Republic of China (Standing Committee of the National People's Congress, 2020) incorporates the "green principle," which mandates resource conservation and environmental protection in civil activities, reinforcing the broader goals of sustainable development. Provisions on property rights and contractual relationships further embed

ecological values in legal structures, supporting the integration of sustainability in every facet of society, including education.

The Criminal Law of the People's Republic of China (Standing Committee of the National People's Congress, 2021) complements these efforts by establishing criminal liability for environmental damage, ensuring that sustainability is prioritized in both legal and societal contexts. Together, these laws form a comprehensive framework that supports Education for Sustainable Development (ESD) by embedding sustainability in the educational system and across various legal domains. This legal framework strengthens China's commitment to sustainable development, ensuring that future generations are equipped with the necessary knowledge, skills, and values to contribute to a sustainable future.

China's Education Modernization Plan and Global Goals

In 2019, the Chinese government introduced the China Education Modernization 2035 plan, a key strategic initiative aimed at advancing the modernization of education in China. This plan not only plays a crucial role in the nation's development but also reflects China's active commitment to the global Sustainable Development Goals (SDGs), particularly SDG 4, which focuses on ensuring inclusive, equitable quality education and promoting lifelong learning opportunities for all. By aligning its national educational policies with global SDG targets, China is taking decisive action to meet the educational objectives set by the international community, especially those outlined by UNESCO.

In 2015, the Incheon Declaration and the Education 2030 Framework for Action were launched by UNESCO, in collaboration with key international stakeholders. These documents set the direction for global education development, establishing the overarching goal to achieve inclusive and equitable quality education by 2030. This goal, which became SDG 4, is closely aligned with China's own educational priorities. The China Education Modernization 2035 plan is designed in line with these international frameworks and underscores China's dedication to achieving the SDG 4 targets, focusing on improving education access, quality, and lifelong learning opportunities.

To further its commitment, China has developed a National Plan for Implementing the 2030 Agenda for Sustainable Development. This plan outlines specific goals and actions for achieving all 17 SDGs, with a strong focus on education. It highlights China's efforts to integrate sustainable development principles into national policies and educational strategies, ensuring that the country's educational system contributes to the global sustainability agenda. By aligning its educational reforms with SDG 4, China is fostering a future generation equipped with the knowledge and skills needed to address global challenges while promoting sustainable development at home and abroad.

Rationale for Focusing on Yunnan Province, China

Yunnan Province, located in southwestern China, is uniquely positioned as a critical region for exploring the integration of sustainable leadership and Education for Sustainable Development (ESD) within teacher training programs. This geographically diverse province encompasses ecosystems ranging from snow-capped mountains, such as the iconic Yulong Snow Mountain, to tropical rainforests in Xishuangbanna. These varied landscapes provide a living laboratory for sustainability practices and exemplify the interdependence of human activities and ecological systems (Huang et al., 2024). Moreover, Yunnan is a biodiversity hotspot, shaped by climatic and topographic factors, and is increasingly vulnerable to the impacts of climate change.

One poignant example of these environmental challenges is the dramatic retreat of glaciers on Yulong Snow Mountain. Between 1982 and 2009, the glacier area decreased by 61.9%, shrinking from 11.61 square kilometers to just 4.42 square kilometers (He, 2014). Concurrently, average annual temperatures in Lijiang have risen significantly, reflecting global warming trends (Li, 2014; Zhang & Lian, 2014). These changes not only threaten local ecosystems but also have far-reaching implications for downstream hydrological cycles, water resources, biodiversity, and socio-economic systems, particularly in tourism and agriculture. Against this backdrop, Yunnan's unique ecological and cultural landscapes make it an ideal context for examining how ESD principles can be effectively integrated into teacher education.

Research Gaps and Contribution

Raman et al. (2022) conducted a systematic review of publications on Education for Sustainable Development (ESD) in teacher education from 2013 to 2022. Their review revealed a significant gap in the literature, particularly regarding the lack of studies on ESD in pre-service teacher education in China. Despite the global emphasis on sustainability and the growing body of literature on ESD in teacher education across various countries, no publications were found specifically addressing ESD in teacher education programs in China during this period. This indicates a notable gap in research in a country that plays a crucial role in the global education landscape and has substantial influence in shaping sustainable development policies.

Table 1 highlights the countries where research on ESD in teacher education was conducted between 2013 and 2022. As shown in the table, while many countries have contributed to this field, China remains conspicuously absent from the research. This absence underlines the need for further investigation into the integration of ESD within China's teacher education programs and the exploration of its potential challenges and opportunities.

Table 1 The Countries Where the Publication Regarding ESD in Teacher Education were Conducted from 2013-2022

Country	Frequency	Country	Frequency
Austria	1	Pakistan	4
Germany	2	Romania	1
Greece	1	Slovenia	1

Table 1 (Continued)

Country	Frequency	Country	Frequency
Country	Frequency	Country	Frequency
India	1	Slovakia	1
Ireland	1	South Africa	1
Italy	1	Spain	4
Korea	2	Sweden	1
Malaysia	1	Thailand	1
Norway	1	Turkey	2

Source: Raman et al. (2022).

As shown in Table 1, there were no publications found regarding ESD in pre-service teacher education in China from 2013 to 2022. This lack of research presents a significant gap in understanding how China is integrating sustainability into teacher education programs, given the country's significant role in global educational development. This research gap offers a compelling opportunity for further investigation into how China's teacher education system addresses, or could address, ESD and its alignment with global sustainability goals.

The absence of publications on ESD in teacher education within China also indicates the potential for exploring the unique challenges and opportunities within the Chinese educational system. It highlights the need for focused studies on the integration of sustainability principles into pre-service teacher education and the development of appropriate pedagogical frameworks that align with China's national educational policies on sustainability. This research gap not only contributes to the global discourse on ESD but also offers a valuable opportunity for expanding the understanding of how different national contexts can influence the implementation of sustainability in teacher education.

In addition, the existing literature on sustainable leadership has primarily focused on its direct impact on sustainability practices in organizations or firm's context. However, there is a notable gap in understanding how sustainable leadership in teacher education institutions influences the integration of holistic and pluralistic approaches to sustainability in pre-service teacher training. More importantly, research is lacking on how ESD-Holism and ESD-Pluralism mediate the relationship between sustainable leadership and professional action competence in ESD among pre-service teachers. Without understanding these mediating processes, it remains unclear how leadership can effectively translate into long-term, actionable competence in ESD for future educators.

By addressing these gaps, this study aims to enhance the current understanding of the pathways through which sustainable leadership fosters professional action competence in ESD. Specifically, it seeks to fill the following research gaps:

Gaps in the Influence of Leadership on ESD-Holism and ESD-Pluralism: Previous research has largely neglected how sustainable leadership within teacher training institutions influences the integration of holistic and pluralistic perspectives in ESD. While leadership is seen as pivotal, its impact on the specific elements of holism and pluralism which are crucial for a comprehensive understanding of sustainability is underexplored.

Gaps in Mediating Effects of ESD-Holism and ESD-Pluralism: While sustainable leadership is understood to affect ESD competence, the mediating role of ESD-Holism and ESD-Pluralism has yet to be investigated. Understanding how these dimensions mediate the relationship between leadership and competence will provide new insights into how leadership practices can be optimized for more effective sustainability education.

Gaps in Developing Professional Action Competence: There is limited empirical research on how ESD-Holism and ESD-Pluralism directly influence professional action competence in ESD. This study will explore how these dimensions are not only shaped by sustainable leadership but also contribute to the teachers' ability to integrate sustainability practices in their classrooms.

The conceptual framework of this study emphasizes the direct and indirect pathways through which sustainable leadership influences the development of professional action competence in ESD. Sustainable leadership is proposed to influence ESD-Holism and ESD-Pluralism, which, in turn, mediate the relationship between leadership and professional action competence. The framework suggests that holism and pluralism provide the cognitive and pedagogical foundations that enable pre-service teachers to apply sustainability principles effectively in their future classrooms.

This research aims to fill critical gaps in the literature by investigating how sustainable leadership influences the development of professional action competence in Education for Sustainable Development (ESD) among pre-service teachers. Specifically, it will examine the mediating effects of ESD-Holism and ESD-Pluralism in this process. By exploring how sustainable leadership fosters the integration of holistic and pluralistic perspectives in teacher training, this study seeks to provide valuable insights into the pathways through which pre-service teachers can be better prepared to address sustainability challenges in their future classrooms. The findings will contribute not only to advancing theoretical knowledge but also to offering practical recommendations for improving teacher education programs and leadership practices, ultimately equipping future educators with the skills and knowledge needed to effectively teach sustainability.

This research will contribute to the field in several ways: (1) Expanding the Understanding of Sustainable Leadership: It will offer a deeper understanding of how sustainable leadership in teacher training institutions shapes the integration of ESD-Holism and ESD-Pluralism, areas that have been underexplored in existing research. (2) Theoretical Advancement in ESD Competence: The study will contribute to theoretical knowledge by exploring the mediating role of ESD-Holism and ESD-Pluralism in the relationship between sustainable leadership and professional action competence in ESD. This will shed light on how these dimensions influence pre-service teachers' ability to effectively teach sustainability. (3) Practical Implications for Teacher Education: The findings will provide actionable insights for improving teacher education programs, particularly in terms of how leadership practices can be optimized to foster a deeper understanding of sustainability and equip future educators with the necessary skills to implement sustainability principles in their teaching. (4) Filling Empirical Gaps: This study will add empirical evidence on the direct and indirect effects of sustainable leadership on ESD competence, addressing the existing lack of research on the mediating role of ESD-Holism and ESD-Pluralism in teacher education.

By addressing these contributions, the research aims to enhance the preparation of pre-service teachers for sustainability education, ultimately fostering a generation of educators who are better equipped to tackle the pressing sustainability challenges of the future.

In summary, this study addresses a set of interrelated gaps: (1) The lack of understanding of how sustainable leadership influences the integration of holistic and pluralistic approaches to sustainability in teacher training. (2) The absence of research on the mediating role of ESD-Holism and ESD-Pluralism in the relationship between leadership and professional action competence in ESD. (3) Limited empirical evidence on how ESD-Holism and ESD-Pluralism directly influence professional action competence in ESD.

By investigating these gaps, this study offers a fresh perspective on how leadership practices shape the preparedness of pre-service teachers to engage in sustainability education in Yunnan, an ideal and underexplored context for studying the integration of sustainability principles in education.

1.2 Statement of the Problem

The integration of Sustainable Development (SD) and Education for Sustainable Development (ESD) into teacher education has become increasingly urgent as the world faces growing challenges such as climate change, environmental degradation, social inequality, and economic instability. A fundamental driver of effective ESD is sustainable leadership within educational institutions, which shapes the preparedness of future educators to embed sustainability principles into their teaching practices. However, while the importance of sustainable leadership in fostering ESD is widely recognized, there is limited research examining how sustainable leadership influences the professional action competence of pre-service teachers within the context of ESD.

Specifically, little attention has been given to understanding the mediating roles of ESD-Holism (the integration of environmental, social, and economic dimensions of sustainability) and ESD-Pluralism (the inclusion of diverse perspectives on sustainability) in enhancing the effectiveness of sustainable leadership within teacher training institutions. While leadership in promoting sustainability within schools is well-documented, the role of sustainable leadership in shaping the competencies of pre-service teachers, both directly and indirectly through mediation by ESD-Holism and ESD-Pluralism remains underexplored.

Moreover, most research in the field of sustainable leadership and ESD has primarily focused on leadership at the school level or the general principles of sustainability education, with limited emphasis on the critical role of teacher training institutions. The lack of research on how sustainable leadership within teacher training universities influences the competencies of pre-service teachers in ESD, particularly through the mediation of ESD-Holism and ESD-Pluralism, represents a significant gap in the field.

This study aims to respond to the current research gap in the field of teacher training for educational for sustainable development (ESD), focusing on the ESD competency development path of normal school students or pre-service teachers in Yunnan Province, China. Specifically, the study will explore how sustainable leadership practices in teacher education colleges affect the professional action competency of normal school students or pre-service teachers in the field of ESD, focusing on the mediating role of ESD-holism and ESD-pluralism. In order to deeply reveal the structural relationship between the variables, the study will use the partial least squares structural equation model (PLS-SEM) for empirical analysis. In addition, in order to fully understand the current effective mechanisms and practical strategies for promoting ESD, the study will use thematic analysis to identify key themes, best practices and institutional support factors through qualitative research: in-depth interviews with 15 Chinese ESD experts. Finally, the study will integrate the findings of both quantitative (PLS-SEM) and qualitative (thematic analysis), use the methodological triangle verification strategy, construct a theoretically based and empirically supported framework for improving the ESD competency of normal school students or pre-service teachers in Yunnan Province, and put forward feasible policy recommendations and teaching practice guidance. Through the above exploration, this study hopes to provide future educators with knowledge, skills and attitude support to effectively implement the concept of sustainable development in teaching, thereby helping to achieve the overall goal of education for sustainable development and sustainable development.

1.3 Research Questions

The research questions are show as follows:

1.What are the core dimensions and key influencing factors of the education for sustainable development (ESD) competence of pre-service teachers in Yunnan Province, China?

2.How can Chinese experts successfully promote education for sustainable development (ESD) in schools and cultivate the relevant education for sustainable development (ESD) competence of pre-service teachers in Yunnan Province, China?

3.How should strategies be developed to enhance the education for sustainable development (ESD) competence of pre-service teachers in Yunnan Province, China?

1.4 Research Objectives

1. To identify the core dimensions and key influencing factors of ESD competence among pre-service teachers in Yunnan Province, China.

2. To explore effective strategies and practices for promoting ESD and cultivating ESD competence among pre-service teachers in Yunnan Province, China.

3. To develop an integrated framework for enhancing ESD competence among pre-service teachers in Yunnan Province, China.

1.5 Scope of the Research

The scope of this research is defined by its focus on examining, exploring, and synthesizing the factors that contribute to the development of Education for Sustainable Development (ESD) competence among pre-service teachers in Yunnan Province, China. The study is delimited by three interrelated objectives, each addressing a distinct but complementary dimension of the research problem.

First, the research empirically investigates the structural dimensions and determinants of ESD competence among pre-service teachers in Yunnan Province. This objective employs Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the relationships among sustainable leadership, ESD-holism, ESD-pluralism, and professional action competences in ESD. Through this quantitative approach, the study identifies the core components and key influencing factors shaping ESD competence in the regional context.

Second, the research extends to a qualitative exploration of successful strategies, mechanisms, and institutional enablers for promoting ESD in schools and fostering ESD competence among pre-service teachers. Drawing on in-depth interviews with 15 Chinese ESD experts, the study applies thematic analysis to capture nuanced

insights, best practices, and contextually grounded approaches that enrich the understanding of ESD implementation at both institutional and pedagogical levels.

Third, the research integrates the findings from both quantitative and qualitative strands. By synthesizing statistical evidence with thematic insights, the study develops relevant strategies for enhancing ESD competence among pre-service teachers in Yunnan Province.

1.6 Contribution of the Research

This study makes significant contributions to the fields of Sustainable Development (SD), Education for Sustainable Development (ESD), and teacher education. The contributions are framed in terms of theoretical, academic, management, and practical implications.

1. Theoretical Contribution:

This research enhances the theoretical understanding of Sustainable Leadership and Education for Sustainable Development (ESD) by exploring the mediating roles of ESD-Holism and ESD-Pluralism. The study provides new insights into how sustainable leadership practices in teacher training institutions influence the professional action competence of pre-service teachers in ESD.

Theoretical Model Development: The research contributes to the theoretical development of sustainable leadership by proposing a model in which sustainable leadership not only influences ESD but also enhances pre-service teachers' professional action competence. The study's focus on the mediating roles of ESD-Holism and ESD-Pluralism introduces a fresh perspective on how leadership practices in educational settings shape teachers' abilities to engage with sustainability education.

Conceptual Framework: This study refines the conceptual framework of ESD by integrating both holistic and pluralistic approaches as essential mediators between leadership and teacher competence. This integration helps develop a more nuanced understanding of how sustainability principles can be effectively embedded into teacher training.

2. Academic Contribution:

This research significantly advances the academic field of ESD and sustainability education by addressing a gap in the literature regarding the role of sustainable leadership in shaping pre-service teachers' competencies in sustainability. Filling the Research Gap: The study bridges the gap in existing literature by examining how sustainable leadership practices in teacher education institutions influence pre-service teachers' professional action competence in ESD, both directly and indirectly (through mediation). While prior studies have focused either on the direct effects of leadership or the theoretical aspects of ESD, this research broadens the scope by exploring how leadership shapes teachers' practical abilities to implement sustainability in education.

Contributing to ESD Theory: By considering ESD-Holism and ESD-Pluralism as mediators, the study deepens the theoretical understanding of ESD. It highlights how a holistic view of sustainability (encompassing environmental, social, and economic aspects) and a pluralistic approach (emphasizing diverse perspectives and solutions) can shape educators' professional actions. This theoretical model sets the stage for future research to further test and refine these concepts.

3. Management Implications:

From a management perspective, the study provides valuable insights for policymakers, university leaders, and educational administrators, highlighting the importance of sustainable leadership in shaping the competencies of future teachers. Leadership Development Programs: The research emphasizes the need for leadership development programs in teacher training institutions that focus on sustainability practices. Findings suggest that administrators should develop strategies that foster a culture of sustainability, ensuring that future teachers are equipped with the competencies necessary to integrate sustainability into their teaching practices.

Curriculum Integration: The study underscores the importance of incorporating ESD principles-both holistic and pluralistic-into teacher education curricula. This suggests that administrators should consider revising curriculum content and teaching methods to reflect sustainable leadership practices, ensuring pre-service

teachers not only understand sustainability but are also prepared to teach sustainability concepts in their classrooms.

4. Practical Implications:

The practical implications of this research are focused on enhancing teacher training and pre-service teacher education, particularly in preparing educators who can integrate sustainability principles into their teaching practices.

Improved Teacher Competence in ESD: By identifying how sustainable leadership and the mediating roles of ESD-Holism and ESD-Pluralism influence pre-service teachers' professional action competence, the research provides practical guidance for designing teacher education programs that equip pre-service teachers with the necessary skills, knowledge, and attitudes to teach sustainability effectively.

Best Practices in Teacher Training: The study advocates for incorporating best practices in teacher training that focus on applying sustainability principles in real-world teaching contexts. Pre-service teachers should be exposed to holistic and pluralistic approaches to sustainability, preparing them to adapt sustainability education across various teaching subjects and contexts.

Actionable Insights for Teacher Educators: For teacher educators, the research provides actionable insights on adapting pedagogical approaches to enhance pre-service teachers' understanding of sustainability. This can help integrate Sustainable Development Goals (SDGs) into teaching practices, enabling future educators to not only understand sustainability but also implement sustainable practices in their classrooms.

5. Contribution to Sustainable Development (SD) and Education for Sustainable Development (ESD):

This study contributes to the broader field of Sustainable Development and ESD by providing a framework for embedding sustainable leadership and ESD principles into teacher education.

Enhancing SD Goals in Education: The research supports the achievement of SDGs, particularly SDG 4 (Quality Education) and SDG 13 (Climate Action), by advocating for teacher education systems that emphasize sustainability. Pre-

service teachers equipped with professional action competence in ESD are more likely to contribute to achieving sustainability goals through their future teaching practices.

Promoting ESD in Teacher Education: The study emphasizes the importance of integrating ESD principles in teacher training institutions to promote sustainability across all sectors of education. By equipping pre-service teachers with both knowledge and the practical ability to take action on sustainability issues, the research contributes to the global transformation of education to better address sustainability challenges.

By focusing on sustainable leadership's influence on pre-service teachers and examining the mediating roles of ESD-Holism and ESD-Pluralism, this research offers significant theoretical advancements and practical strategies for enhancing Education for Sustainable Development worldwide.

1.7 Definition of Terms

Professional Action Competence in Education for Sustainable Development (ESD) is a second-order construct that includes three sub-variables: Self-Efficacy Regarding ESD, Perceived Pedagogical Content Knowledge About ESD, and Willingness to Implement ESD, which together reflect pre-service teachers' ability to effectively apply sustainability principles in their teaching.

Self-Efficacy regarding ESD refers to pre-service teachers' confidence in their ability to effectively implement ESD principles in their teaching. This construct measures how capable they feel in addressing sustainability topics and integrating them into the curriculum.

Perceived Pedagogical Content Knowledge About ESD refers to pre-service teachers' self-assessed knowledge of pedagogical methods and content related to ESD. It assesses their understanding of effective strategies for teaching ESD topics, including both the content of sustainability and the methods for delivering it.

Willingness to implement ESD reflects pre-service teachers' intent and readiness to include ESD principles in their future teaching. It assesses their motivation and commitment to fostering sustainability awareness and practices among their future students.

Education for Sustainable Development (ESD) refers to the integration of key sustainable development issues, such as climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption, into teaching and learning processes. It emphasizes participatory teaching methods that empower learners to adopt sustainable behaviors and take action for a more sustainable future. ESD fosters competencies such as critical thinking, the ability to imagine future scenarios, and collaborative decision-making, all of which are essential for addressing global challenges and promoting sustainable development. Education for Sustainable Development (ESD) includes two distinct features: Holism, which integrates the environmental, social, and economic dimensions of sustainability, and Pluralism, which promotes diverse viewpoints and critical reflection on sustainability issues.

Education for Sustainable Development-Holism measure the pre-service teachers' perception regarding the extent their teachers integrate the environmental, social, and economic dimensions of sustainability issues, as well as focus on their past, present and future, and on their local, regional and global nature occurs in the classroom.

Education for Sustainable Development-Pluralism measure the pre-service teachers' perception regarding the extent their teachers allowing for different viewpoints and opinions to be addressed, to critically reflect on what is being learned, and for students to participate in the decision making around which topics are addressed in the classroom.

Sustainable Leadership, as perceived by pre-service teachers, refers to university leaders' actions and values that support sustainability through social, environmental, and ethical responsibilities, innovation, clear communication, and prioritizing student welfare and educational values over profit.

CHAPTER 2
LITERATURE REVIEW

2.1 Sustainable Development (SD) and Education for Sustainable Development (ESD)

The concept of sustainable development (SD) was first introduced into organizational management by the Brundtland Committee, defining it as development that meets present needs without compromising the ability of future generations to meet their own needs (Liao, 2022). This foundational idea has since evolved into a cornerstone of global efforts to balance environmental, social, and economic priorities. In alignment with this vision, education has been recognized as a critical mechanism for fostering sustainable practices and achieving broader sustainability goals.

In 2020, UNESCO launched the Education for Sustainable Development: Towards achieving the SDGs (ESD for 2030) program, a strategic initiative aligned with the United Nations' 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs). This program aims to accelerate sustainable solutions to global challenges by addressing the interconnections and tensions among different SDGs. By providing learners with opportunities to practice balancing these goals, it seeks to prepare individuals to navigate complex sustainability issues effectively.

The ESD for 2030 initiative emphasizes five priority areas of action: policy, education and training, capacity building for educators, youth empowerment, and local community action. These areas form the backbone of a transformative approach to embedding sustainability into education systems worldwide. The program integrates existing tools, such as the UNESCO-Japan Prize on ESD, and adopts innovative strategies, including addressing psychological and social preconditions for sustainable behavior and mobilizing political action to drive systemic change.

UNESCO's ESD for 2030 framework outlines urgent sustainability challenges while positioning education as a vital tool for creating a more just and sustainable world. Through its roadmap, the program highlights actions to transform learning environments, empower educators, and support youth as catalysts for sustainable practices. Central to its mission is the establishment of the ESD for 2030 Global Network, which fosters cross-

sectoral collaboration to support the implementation of ESD at national, regional, and global levels. This network is structured around four pillars: promising practices, knowledge sharing and mutual learning, global advocacy and policymaking, and monitoring and evaluation.

The transformative potential of the ESD for 2030 framework lies in its ability to create knowledgeable and courageous change agents. By reimagining educational systems and learning environments, the program aims to empower learners to advocate for sustainability within and beyond their institutions. Actions under this initiative emphasize collaboration and partnerships, enhancing the capacity of educators and learners alike to contribute meaningfully to achieving the SDGs.

The ESD for 2030 program represents a comprehensive and forward-thinking approach to integrating sustainable development into education. By addressing urgent global challenges through innovative strategies and fostering collaboration among stakeholders, the program highlights the transformative role of education in building a sustainable future. Its emphasis on policy alignment, educator empowerment, and youth engagement underscores the importance of collective action in realizing the vision of a more sustainable and just world.

2.2 China's Laws and Regulations Related to SD and ESD

This section provides a detailed examination of the Chinese legal and regulatory framework related to sustainable development and education. It covers the Environmental Protection Law of the People's Republic of China, The Civil Code, and other relevant policies that mandate the inclusion of sustainability principles in education. The alignment of China's national education reforms with global SDG targets, particularly SDG 4, is also highlighted.

Education for Sustainable Development (ESD) is a crucial element in preparing future generations to understand, address, and contribute to sustainable development. ESD seeks to equip students with the necessary knowledge, skills, values, and attitudes to promote sustainability in their personal, professional, and social lives. The Chinese government has integrated sustainability into its legal system, and this legislative

framework plays a key role in supporting and promoting Education for Sustainable Development (ESD). By embedding environmental protection and sustainability principles within national laws and regulations, China is ensuring that sustainable development is not only a national priority but also a core element of educational curricula across the country.

The Environmental Protection Law of the People's Republic of China (Standing Committee of the National People's Congress, 2015) explicitly links environmental protection with education. Article 9 of the law mandates that education authorities and schools integrate environmental protection knowledge into their curricula, thus playing a pivotal role in fostering environmental awareness and sustainability values among students. This provision underscores the role of education in shaping a society that prioritizes environmental protection and sustainability, aligning directly with the goals of ESD. Furthermore, the law introduces broader objectives of promoting "ecological civilization" and supporting sustainable economic and social development, which reinforces the long-term goals of ESD by connecting educational practices to national development priorities (Standing Committee of the National People's Congress, 2015).

In addition to the Environmental Protection Law, the Civil Code of the People's Republic of China (Standing Committee of the National People's Congress, 2020) introduces the "green principle," which requires individuals and organizations engaged in civil activities to contribute to resource conservation and environmental protection. This principle not only acknowledges the ecological value of environmental resources but also embodies the essence of ESD, which advocates for integrating sustainability principles into all aspects of society. The Civil Code includes several provisions, such as those in Articles 286, 294, and 326, related to property rights that embed ecological protection within legal regulations, ensuring that sustainability is reflected in property ownership, use, and transfer. These provisions support the broader goal of integrating sustainable development principles across all sectors, including the educational system, and further align with the values promoted through Education for Sustainable Development (ESD). Complementing these, Chapter 7 of Part VII of the Civil Code of the

People's Republic of China, which addresses tort liability for environmental pollution and ecological damage, reinforces the legal framework for ecological preservation and accountability. By specifying responsibilities and liabilities in cases of ecological harm, this chapter emphasizes the need for a robust approach to balancing development with environmental protection. Together, these legal frameworks create a comprehensive foundation for embedding sustainability principles across diverse domains, highlighting the interconnectedness of property rights, ecological preservation, and education in fostering long-term societal resilience and sustainability.

Moreover, the Civil Code addresses “green obligations” in contractual relationships (Articles 619, 625, and 655), ensuring that parties to contracts are required to uphold environmental responsibilities. This approach aligns with ESD’s focus on holistic thinking, where sustainability is not only a scientific or political issue but also a deeply ingrained ethical principle that should guide personal and professional actions. In this way, the Civil Code expands the role of law in reinforcing sustainable practices in everyday life and in professional fields, including education.

Further supporting the government’s emphasis on sustainability, the Criminal Law of the People's Republic of China (Standing Committee of the National People’s Congress, 2021) incorporates provisions related to environmental protection in the context of criminal law. Specifically, section 6 of Chapter 6 of Part 2 of the Criminal Law of the People's Republic of China addresses “Crimes of Damaging Environmental Resources Protection,” emphasizing criminal liability for actions that significantly harm the environment. This inclusion highlights the government’s commitment to safeguarding ecological integrity through legal accountability, reinforcing the importance of sustainability principles in all aspects of society, including in educational contexts.

Together, these laws spanning environmental protection, civil rights, contracts, and criminal law form a comprehensive framework for sustainable development that supports ESD by embedding sustainability within legal structures. This legal framework, alongside the educational initiatives prescribed in the Environmental Protection Law, ensures that sustainable development is a societal priority and that future generations

are equipped with the tools and knowledge to support it. By integrating sustainability into legal systems, China is reinforcing its commitment to both national and global sustainable development goals, ensuring that education and law work in tandem to promote a more sustainable future.

The alignment of China's legal framework with the goals of ESD demonstrates the government's commitment to creating an educational environment that not only emphasizes environmental protection but also fosters broader societal values of sustainability. This legislative approach not only provides a foundation for promoting sustainability in education but also contributes to the development of future leaders who will be equipped to address the pressing challenges of sustainable development.

2.3 Education for Sustainable Development (ESD) in China: Integration of Global Goals and National Initiatives

In 2019, the Chinese government launched the China Education Modernization 2035 plan, which represents a strategic initiative aimed at accelerating the modernization of education and building a strong educational system in China. This plan is not only central to China’s national development strategy but also reflects the country's active commitment to the global Sustainable Development Goals (SDGs), particularly in the area of Education for Sustainable Development (ESD). By aligning national policies with the broader international goals, China is taking proactive steps to fulfill the educational objectives set by the global community, especially those outlined by the United Nations Educational, Scientific and Cultural Organization (UNESCO). This approach holds significant value in both the methodology and content in contributing to the achievement of the 2030 Education Goals.

In May 2015, UNESCO, in partnership with government ministers, Nobel laureates, and various stakeholders, launched the Incheon Declaration and the Education 2030 Framework for Action during a meeting in Incheon, South Korea. These documents set the overarching goal for global education by 2030: to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all,” a vision that would guide global education development for the next 15 years. On

November 4, 2015, the 38th session of the UNESCO General Conference formally adopted the Education 2030 Framework for Action, incorporating the global education goal into the SDGs as Goal 4, now widely known as SDG 4. This goal seeks to ensure access to inclusive and equitable quality education, aligning closely with China's own educational priorities.

China has long recognized the importance of education in driving national development. Chinese leaders consistently emphasize the fundamental role of education not only as a foundation for economic growth but also as a key driver in the modernization process of the entire nation. The China Education Modernization 2035 plan follows UNESCO's educational planning principles, underscoring the country's commitment to achieving SDG 4 by aligning its educational strategies with global goals. In September 2015, the United Nations Sustainable Development Summit set the agenda for the 2030 Sustainable Development Goals, presenting a blueprint for future international development and cooperation. The challenges facing the international community, such as economic instability, the widening development gap, refugee crises, terrorism, and climate change, emphasize the need for coordinated global action on sustainability. China's integration of the SDGs into its national development framework reflects a strong commitment to advancing sustainable development both domestically and globally.

In line with the SDGs, particularly SDG 4, China has developed a comprehensive National Plan for Implementing the 2030 Agenda for Sustainable Development. This document outlines the country's achievements in meeting the Millennium Development Goals and the challenges it faces in advancing the SDGs. It sets forth guiding principles, strategic objectives, and detailed action plans for achieving all 17 SDGs, ensuring that sustainable development is a priority in every sector (State Council of the People's Republic of China, 2016). China's national framework, including the National Plan and the 13th Five-Year Plan, further emphasizes the integration of sustainable development principles into educational policies and

practices. These measures align with international standards, reinforcing China's role as a responsible global actor in advancing sustainability.

China's approach to sustainable development education is closely linked to its legal and policy frameworks, further strengthening the connection between ESD and national growth. Through these frameworks, China is fostering a generation of leaders who are equipped with the knowledge, skills, and values necessary to tackle the global challenges of sustainable development. By integrating the SDGs into its educational strategies, China is not only contributing to the global sustainability agenda but also ensuring that its own educational systems are aligned with international standards and global expectations.

2.4 The Role of Sustainable Leadership in Education for Sustainable Development

This section explores the critical role of leadership in embedding ESD within educational settings. Emphasis is placed on Sustainable Leadership, which promotes long-term sustainability goals and aligns educational practices with sustainability principles. It discusses the responsibilities of school leaders in fostering a culture of sustainability and the challenges they face in integrating ESD into teaching practices.

2.4.1 The Concept of Sustainable Leadership and Its Importance in Teacher Training Institutions for Education for Sustainable Development (ESD)

2.4.1.1 The Concept and Definition of Sustainable Leadership

Sustainable leadership is a comprehensive framework that integrates environmental, social, and economic dimensions to guide organizations, including educational institutions, toward achieving long-term sustainability objectives.

Sustainable leadership is a multifaceted concept that integrates environmental, social, and economic dimensions to guide organizations toward long-term sustainability goals. This leadership approach prioritizes fostering an organizational culture of sustainability, engaging stakeholders, and aligning strategies with the principles of environmental stewardship and ethical responsibility. Sánchez-García et al. (2024) describe sustainable leadership as a paradigm shift, where leaders adopt green transformational practices to enhance organizational culture and green

performance. Further, Eustachio et al. (2023) illustrate its evolution from traditional leadership theories, highlighting connections with sustainable development and corporate social responsibility.

The concept extends across diverse organizational contexts. For example, the Honeybee Pyramid model applied to Hungarian and Polish SMEs underscores how strategic decision-making underpins sustainable leadership practices (Bencsik & Pangsy-Kania, 2023). In tourism, sustainable leadership principles have improved visibility and market entry for territories, emphasizing strategic stakeholder engagement (Lusena-Ezera et al., 2023). Ethical dimensions also play a pivotal role; Slater (2023) suggests that virtue ethics can enrich moral formation within sustainable leadership frameworks. This holistic understanding of sustainable leadership demonstrates its relevance in addressing regulatory, stakeholder, and organizational demands (Jiménez et al., 2023).

In higher education, sustainable leadership involves embedding sustainability principles into institutional frameworks and leadership practices. This approach is characterized by the transformation of institutional missions to align with societal resilience and the United Nations' Sustainable Development Goals (SDGs). Aung and Hallinger (2022) emphasize the role of sustainable leadership in fostering institutional commitment to sustainability through reoriented practices and stakeholder engagement.

The development of sustainable leadership in higher education necessitates integrating leadership skills into curricula, particularly in disciplines like natural sciences (Lukwago et al., 2022). It also involves leveraging transformational leadership to encourage social innovation and the adoption of sustainability in teaching, though the relationship between these elements may not always be significant (Eustachio et al., 2024). Effective cultivation of sustainable leadership demands authentic learning experiences, collaborative engagement, and learner agency, all of which contribute to lifelong leadership development (Odom et al., 2023).

Sustainable leadership in teacher training institutions is a multifaceted endeavor that integrates various leadership styles and educational paradigms to foster sustainability practices. Both sustainability leadership (SL) and transformational leadership (TL) play pivotal roles in embedding sustainability-related aspects within higher education institutions (HEIs). These leadership approaches significantly influence the adoption of sustainability practices among teaching staff, although the direct impact of TL on sustainability adoption remains less clear (Eustachio et al., 2024).

A critical dimension of sustainable leadership in teacher training institutions is addressing the human aspect, which involves nurturing inner development and challenging unsustainable social paradigms. Programs emphasizing ontological and epistemological transformations can achieve these goals (Wamsler et al., 2023). Structured initiatives that support staff members in integrating sustainability practices within institutional frameworks are effective in cultivating sustainability leadership (Alkaher & Avissar, 2018).

Interdisciplinary and transdisciplinary (ITD) approaches are also essential for fostering effective leadership in sustainability. These approaches encourage collaboration, shared cultural values, and communication across diverse audiences, supported by intellectual, institutional, and financial resources (Boone et al., 2020). Moreover, teacher training institutions have a dual responsibility to promote the circular economy (CE): educating students and preparing future educators to incorporate sustainability into various educational levels, thereby empowering them to become active agents of change (Bugallo-Rodríguez & Vega-Marcote, 2020).

Collectively, these insights underscore the importance of comprehensive leadership development programs that integrate sustainability into the core of educational practices. By doing so, teacher training institutions prepare educators to lead transformative changes within their organizations and beyond.

Across various organizational contexts, sustainable leadership transcends mere environmental stewardship to encompass ethical considerations, stakeholder engagement, and strategic alignment with sustainability objectives. Its

applications in higher education and teacher training institutions illustrate its transformative potential. By fostering systemic thinking, interdisciplinary collaboration, and ethical practices, sustainable leadership equips institutions and individuals to address complex sustainability challenges effectively.

This comprehensive understanding highlights the critical role of sustainable leadership in reorienting organizations and educational institutions toward sustainable development, ensuring long-term resilience and adaptability in a rapidly evolving global landscape.

2.4.1.2 The Importance of Sustainable Leadership in Teacher Training Institutions for Education for Sustainable Development (ESD)

Sustainable leadership plays a pivotal role in embedding ESD principles within educational institutions. Leaders who prioritize sustainability foster innovative teaching methods, integrate ESD into curricula, and engage communities in sustainability initiatives. According to Iliško and Badyanova (2014), sustainable leadership requires a shared vision and inclusivity, integrating ESD across all aspects of school policy and culture. Furthermore, effective leadership builds partnerships with stakeholders, ensuring the success of ESD initiatives. Education for Sustainable Development (ESD) is a transformative approach aimed at equipping individuals with the knowledge, skills, and values necessary to create a sustainable future. Within this framework, sustainable leadership plays a crucial role by integrating sustainability principles into educational leadership practices, aligning institutional objectives with the broader goals of the Sustainable Development Goals (SDGs). Specifically, sustainable leadership fosters a culture of systemic thinking, collaborative engagement, and authentic learning, enabling institutions to address current and emerging sustainability challenges effectively.

In teacher training institutions, sustainable leadership assumes particular significance as it shapes the development of future educators tasked with integrating sustainability principles into their teaching practices. These educators, in turn, prepare students to think critically, act responsibly, and contribute meaningfully to sustainable development. The integration of sustainability leadership in teacher training

institutions serves as a catalyst for transformative educational practices, addressing the ontological, epistemological, and praxis dimensions of inner-outer transformation. This empowers educators to challenge unsustainable paradigms and integrate sustainability-focused potential into educational structures (Wamsler et al., 2023).

The role of leadership in advancing ESD is well-supported by empirical evidence. For instance, Barbara et al. (2024) emphasizes the importance of multi-sector partnerships (MSPs) and global leadership for sustainability (GLfS) in addressing complex challenges in educational settings. These partnerships, aligned with SDG 17, highlight the necessity of collaborative efforts in achieving sustainability goals. Similarly, Maqbool et al. (2024) demonstrate how inventive leadership styles in secondary education positively influence students' abilities to address sustainability challenges, thereby underscoring the transformative potential of sustainable leadership in shaping future generations. Despite these promising insights, challenges remain in the integration of ESD into teacher training programs. Sustainable leadership within these institutions can address such challenges by fostering a shared vision, prioritizing sustainability goals, and implementing coherent strategies that bridge existing gaps.

Further emphasizing the importance of leadership, Bryant et al. (2023) explore how transformative learning within leadership programs fosters personal and institutional change. Leadership strategies that promote sustainability can influence institutional culture, decision-making processes, and resource allocation, all of which are critical for effective ESD implementation. For instance, the systematic review of ESD in mathematics teacher training underscores the necessity of integrating ESD into continuous education to enhance the quality of educational practices and prepare educators for evolving sustainability challenges (Su et al., 2023).

Moreover, comparative studies on school principals in Germany, Macau, and the USA illustrate the pivotal role of leadership competencies in the successful implementation of ESD in schools. These studies identify management strategies and leadership qualities, such as adaptability, vision, and collaborative engagement, as

essential for embedding ESD principles within educational institutions (Müller et al., 2022).

In conclusion, sustainable leadership in teacher training institutions is fundamental to reorienting education toward sustainable development. By equipping educators with the necessary knowledge, skills, and values, sustainable leadership ensures the integration of sustainability principles into teaching practices and institutional strategies. This, in turn, prepares future generations to address sustainability challenges effectively and contribute to a sustainable future. The importance of fostering leadership that prioritizes systemic thinking, collaboration, and a commitment to sustainability cannot be overstated, as it represents a cornerstone for achieving the transformative goals of ESD.

2.4.1.3 Sustainable Leadership in Higher Education and Teacher Training Institutions

In the context of higher education, sustainable leadership involves embedding sustainability principles into leadership practices and institutional frameworks. This approach not only transforms the mission and vision of universities but also aligns operations with the global sustainability agenda. Lukwago et al. (2023) emphasize the importance of developing interdisciplinary learning opportunities and integrating leadership skills into university curricula to cultivate a sustainability-oriented mindset among pre-service teachers.

Teacher training institutions, specifically, serve as the foundation for fostering sustainable leadership. Leaders in these institutions must adopt innovative strategies to equip pre-service teachers with the competencies required to integrate sustainability into their future classrooms. Odom et al. (2023) stress the importance of designing educational experiences that promote learner agency, critical thinking, and collaborative engagement, ensuring that future educators are well-prepared to drive sustainable practices in their teaching environments.

Furthermore, research highlights the need for transformative practices within teacher training institutions to challenge unsustainable paradigms. Wamsler et al. (2024) advocate for integrating inner development programs into leadership training,

aligning leadership competencies with ESD objectives. Saleem et al. (2021) provide empirical evidence from Pakistani schools, demonstrating how directive and supportive leadership behaviors can enhance teacher development and promote sustainability in educational settings. These findings suggest that sustainable leadership in teacher training institutions not only benefits pre-service teachers but also contributes to broader societal sustainability goals.

2.4.1.4 Definition of Sustainable Leadership in the Context of This Research

Based on the reviewed literature, this research defines sustainable leadership in teacher training institutions as: Sustainable leadership, as perceived by pre-service teachers in normal universities, refers to the actions and values demonstrated by university leaders that support sustainability in a holistic manner. This includes leaders' commitment to social, environmental, and ethical responsibilities, their willingness to consider the well-being of the entire school community in decision-making, and their dedication to learning from and correcting sustainability-related mistakes. Sustainable leadership also encompasses leaders' efforts to innovate in addressing sustainability challenges, communicate clearly about sustainability goals, and prioritize educational values and student welfare over profit. By promoting a culture of sustainability, university leaders aim to create lasting value that positively influences students and their learning environments.

2.4.2 Measuring Sustainable Leadership: Insights and Applications for Teacher Training Institutions

2.4.2.1 Models and Frameworks of Sustainable Leadership

The concept of sustainable leadership has been explored and operationalized through various models to guide its implementation in organizational and educational contexts. Hargreaves and Fink (2004) proposed a model of sustainable leadership specifically tailored to educational organizations, emphasizing seven core principles: **Creating and preserving sustaining learning:** Sustainable leadership ensures the ongoing development of learning systems that adapt to future challenges.

Securing success over time: It emphasizes the longevity and impact of leadership practices beyond short-term achievements.

Sustaining the leadership of others: Effective sustainable leadership nurtures the leadership potential in others, promoting a collaborative leadership culture.

Addressing issues of social justice: It focuses on inclusivity and equity, ensuring that leadership actions contribute to broader societal goals.

Developing rather than depleting human and material resources: Leadership strategies aim to optimize resource use without compromising their availability for future needs.

Developing environmental diversity and capacity: It highlights the importance of fostering innovation and adaptability within organizational environments.

Undertaking activist engagement with the environment: Sustainable leadership requires proactive efforts to influence and improve external environmental conditions.

Building upon this foundation, Slankis (2006) introduced a broader framework emphasizing the alignment of sustainability with organizational performance. This model, referred to as the "ten pillars of sustainable leadership," encompasses:

Change orientation: A willingness to embrace transformation within the organization.

Broad systems thinking: The ability to interconnect organizational functions and goals.

Social and environmental consciousness: Awareness of the organization's external impacts.

Business savvy and credibility: Linking sustainability initiatives with stakeholder value.

Adaptability: Managing and implementing change effectively.

Patience: Commitment to long-term sustainability goals.

Translational skills: Turning ideas into actionable plans.

Persuasiveness: Building relationships and communicating sustainability goals effectively.

Energy and passion: Encouraging innovation and fostering a shared vision.

Mentoring and development: Cultivating leadership talent to ensure lasting organizational impact.

2.4.2.2 Measurement Instruments for Sustainable Leadership

Iqbal and Ahmad (2021) made significant contributions to the measurement of sustainable leadership in learning organizations. Their research focused on assessing the reliability of items that reflect sustainable leadership practices. The key aspects measured included:

- Acting in a socially, environmentally, and ethically responsible manner.
- Decision-making processes that consider the well-being of the entire organization.
- Acknowledging and rectifying mistakes that impact sustainability.
- Employing innovative methods to address sustainability challenges.
- Balancing social responsibility with organizational profitability.
- Fostering a culture of sustainability through effective communication.
- Demonstrating perseverance in sustainability efforts despite challenges.

These dimensions provide a robust framework for evaluating sustainable leadership in various organizational contexts. Similarly, Verhelst et al. (2022) focused on the validation of the Education for Sustainable Development School Organization Questionnaire, emphasizing sustainable leadership as a crucial component. Their definition of sustainable leadership centered on leadership behaviors that embed Education for Sustainable Development (ESD) principles into school systems, ensuring their continuity and impact over time.

2.4.2.3 Adapting Sustainable Leadership Measurements to Teacher Training Institutions

Despite the availability of established frameworks, there remains a lack of mature measurement instruments specifically designed to assess sustainable leadership from the perspective of pre-service teachers in teacher training institutions. To address this gap, this research adopts and adapts the instrument revised and updated by Iqbal and Ahmad (2020), tailoring it to reflect the unique context of teacher training institutions. In their research article Sustainable Development: The Colors of Sustainable Leadership in Learning Organizations, Iqbal and Ahmad (2020) utilized a 15-item sustainable leadership measurement originally developed by McCann and Holt (2010), which reported a reliability statistic of 0.93 (Al-Zawahreh et al., 2019). However, Iqbal and Ahmad (2020) identified one item with a factor loading below 0.40, leading to its removal to enhance the average variance extracted (AVE) of the sustainable leadership construct. After this adjustment, the composite reliability of the remaining 14-item measurement was 0.922, representing the highest composite reliability among the studied constructs. This result indicates that the revised sustainable leadership scale demonstrates strong internal consistency and reliability. The adapted measurement items include 14-items to measure the pre-service teacher or the student teacher's perspective towards their school leadership regarding sustainable leadership, the adapted 14-items are show as follows:

Social Responsibility: Our school leadership acts in a socially responsible and sustainable manner.

Environmental Responsibility: Our school leadership acts in an environmentally responsible and sustainable manner.

Ethical Responsibility: Our school leadership acts in an ethically responsible and sustainable manner.

Inclusive Decision-Making: Our school leadership considers the entire school community when making important decisions.

Learning from Mistakes: Our school leadership acknowledges and learns from mistakes that impact sustainability.

Corrective Actions: Our school leadership is willing to correct mistakes that impact sustainability.

Innovation: Our school leadership attempts to use unique and innovative methods to address sustainability challenges.

Value Creation: Our school leadership seeks to create lasting value through sustainable efforts.

Purpose Before Profit Our school leadership prioritizes the educational mission and the holistic development of students over financial gains.

Educational values and student well-being Before Profit: Our school leadership places purpose, including educational values and student well-being, before profit.

Perseverance: Our school leadership perseveres in promoting sustainability through all types of changes and challenges.

Student-Centered Approach: Our school leadership is concerned about how sustainability affects students and their learning environment.

Communication: Our school leadership communicates sustainability-related decisions to all involved.

Culture Building: Our school leadership strives to build a culture of sustainability by clearly communicating its goals and actions.

The measurement of sustainable leadership is critical for understanding and improving leadership practices in teacher training institutions. By incorporating insights from established frameworks and adapting them to specific educational contexts, this research contributes to the ongoing development of reliable and contextually relevant measurement tools. These efforts aim to ensure that sustainable leadership practices not only meet the immediate needs of educational organizations but also contribute to the long-term goals of sustainability and Education for Sustainable Development.

2.5 The Development of ESD-Holism: A Systems Thinking Approach to Education for Sustainability

This section covers the development of ESD-Holism, focusing on how sustainability education is approached through a system thinking lens. It discusses the interconnectedness of environmental, social, and economic dimensions of sustainability, and how this holistic view can be incorporated into teacher education programs.

2.5.1 The Concept and Importance of ESD-Holism

Education for Sustainable Development (ESD) represents a transformative educational framework designed to equip learners with the competencies necessary to address the multifaceted challenges of sustainable development. Central to this framework is the concept of holism, which underscores the integration of environmental, social, and economic dimensions into educational practices to create a comprehensive understanding of sustainability. Unlike traditional educational approaches that may focus on isolated aspects of sustainability, ESD-holism embraces the interconnectedness of these dimensions, fostering an interdisciplinary approach that acknowledges the complexity of real-world issues such as climate change, biodiversity loss, poverty alleviation, and sustainable resource management (UNESCO, 2012; Boeve-de Pauw et al., 2015). Moreover, ESD-holism incorporates spatial and temporal perspectives, enabling learners to explore sustainability at local, regional, and global scales while considering historical legacies and future implications of human actions (Atkinson, Dietz, & Neumayer, 2007; Öhman, 2008). A distinctive feature of this approach is its emphasis on participatory and pluralistic methodologies, which engage learners in collaborative decision-making, critical reflection, and action-oriented problem-solving. Through these methods, ESD-holism seeks to transcend traditional didactic teaching and foster a more dynamic and engaging educational experience. ESD-holism provides a robust conceptual framework that addresses the complexity and interdependence of sustainability challenges. By incorporating multiple dimensions, perspectives, and participatory methodologies, this approach equips learners with a holistic understanding of sustainability and empowers them to contribute meaningfully to sustainable development. Its emphasis on interdisciplinary and action-oriented learning

positions ESD-holism as a critical paradigm for addressing global sustainability challenges in education.

The significance of ESD-holism lies in its ability to transform education into a powerful tool for advancing sustainable development. By fostering interdisciplinary thinking, it enables learners to understand the systemic nature of sustainability challenges and the interrelations between environmental, social, and economic factors. This comprehensive understanding is critical for addressing global issues such as resource scarcity, social inequality, and ecological degradation (Borg et al., 2014; Summers & Childs, 2007). Furthermore, ESD-holism promotes the development of action competence-defined as the ability, motivation, and readiness to engage in sustainable practices. Through participatory learning and critical reflection, learners are empowered to analyze complex issues, navigate ethical dilemmas, and implement practical solutions within their communities (Sinakou, 2022; Sass et al., 2024). Additionally, ESD-holism supports the cultivation of values essential for sustainable leadership, such as inclusivity, social responsibility, and adaptability. These values are integrated into curricula and learning experiences, equipping students with the ethical grounding needed to address conflicts of interest and make decisions that balance short-term gains with long-term sustainability goals (Tilbury, 2012; Iliško & Badyanova, 2014). Despite its challenges, including the inherent complexity of integrating diverse perspectives and potential resistance to change in educational systems, ESD-holism offers a transformative vision for education that aligns with the global need for sustainable development. ESD-holism is not merely an educational approach but a strategic framework for empowering learners to become agents of change in the pursuit of sustainability. Its emphasis on interdisciplinary understanding, action competence, and value-based leadership ensures that education remains a pivotal force in addressing the pressing sustainability challenges of our time. As such, ESD-holism stands as an essential element in the broader effort to achieve sustainable development through education.

2.5.2 The Measurement of ESD-Holism

Boeve-de Pauw et al. (2015) made a significant contribution to the field of Education for Sustainable Development (ESD) by developing a measurement instrument to assess students' perceptions of ESD practices in schools. The authors conceptualized ESD based on its foundational definition, which emphasizes the integration of key sustainable development issues such as climate change, biodiversity, disaster risk reduction, poverty alleviation, and sustainable consumption into teaching and learning processes. ESD further advocates for participatory teaching methods that empower learners to engage in critical thinking, envision future scenarios, and make decisions collaboratively (UNESCO, 2012). By adopting this holistic perspective, Boeve-de Pauw et al. (2015) designed their measurement framework to evaluate the extent to which students perceive ESD as a selective teaching tradition that encompasses environmental, social, and economic dimensions, along with temporal (past, present, future) and geographical (local, regional, global) relationships. The authors proposed a 3-item construct specifically focused on the holistic approach to content. The items were designed to assess the degree to which ESD holistically addresses interconnected dimensions of sustainability. These items include: (1) "In school, we look at the connections between the past, the present, and the future as regards various issues," (2) "In school, we look at both local and global problems and the connection between them," and (3) "In school, we look at how economics, social issues, and environmental problems are connected." Using confirmatory factor analysis (CFA), the measurement demonstrated excellent psychometric properties, with model fit indices of RMSEA=0.054, CFI=0.989, and TLI=0.982. These results validated the construct's reliability and its potential for broader application in different contexts.

Since its initial development, Boeve-de Pauw et al. (2015)'s measurement has been utilized in various studies, consistently demonstrating robust psychometric properties across diverse educational settings. For instance, Saqib et al. (2020) employed the 3-item measurement to examine perceptions of sustainability and ESD implementation among 1,915 students and 120 teachers in public and private

universities in Punjab, Pakistan. The study specifically focused on the holistic approach by assessing how well the curriculum integrated social, economic, and environmental interactions across geographical and temporal dimensions. Respondents rated their experiences on a five-point Likert scale ranging from "never" to "very frequently." The results indicated strong reliability (Cronbach's alpha=0.73) and excellent model fit indices (RMSEA=0.058, CFI=0.968, TLI=0.989), underscoring the applicability of the measurement in a higher education context. Similarly, Olsson et al. (2022) applied the measurement in a longitudinal study examining the impact of ESD on students' action competence for sustainability. This study highlighted the importance of holism in integrating social, economic, and environmental dimensions within the ESD framework. The findings showed that the 3-item measurement effectively captured the influence of ESD on students' knowledge, attitudes, and behaviors. Using CFA across multiple steps of longitudinal growth models, the psychometric properties, including CFI, TLI, and RMSEA values, consistently met the standards for excellent model fit, further validating the robustness of the instrument. Saleem et al. (2022) extended the use of Boeve-de Pauw et al.'s measurement to Malaysian universities, involving a diverse sample of 2,678 students and 1,013 teachers from undergraduate and postgraduate programs. The study adapted the 3-item measurement to assess perceptions of holistic ESD approaches in classrooms. Respondents ranged from bachelor's and master's students to doctoral candidates and academic staff, including lecturers and professors. Across all subgroups, the measurement demonstrated strong goodness-of-fit indices, with χ^2/df ratios below 3, CFI and TLI values exceeding 0.90, and RMSEA values below 0.08. These findings reinforced the reliability and adaptability of the instrument across different demographic and institutional contexts.

In conclusion, the 3-item measurement developed by Boeve-de Pauw et al. (2015) represents a highly reliable and valid tool for assessing the holistic integration of ESD in educational settings. Its application in various contexts, such as Pakistan, Sweden, and Malaysia, has consistently yielded strong psychometric properties, confirming its robustness and adaptability. As the field of ESD continues to grow, this

measurement provides researchers and educators with a valuable framework for evaluating and enhancing the implementation of holistic sustainability education worldwide.

2.6 The Development of ESD-Pluralism: Incorporating Diverse Perspectives in Sustainability Education

This section focuses on ESD-Pluralism, which emphasizes the inclusion of diverse perspectives in sustainability education. It explores the importance of incorporating multiple worldviews, cultural perspectives, and approaches to sustainability in teaching practices.

2.6.1 The Concept and Importance of ESD-Pluralism

Education for Sustainable Development (ESD) integrates key sustainability issues into teaching and learning processes, as outlined by UNESCO: "Education for Sustainable Development means including key sustainable development issues into teaching and learning; for example, climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption" (UNESCO, n.d.). A significant emphasis of ESD lies in participatory teaching methods that empower learners to critically analyze issues, envision future scenarios, and collaborate in decision-making processes (Boeve-de Pauw et al., 2015).

ESD-pluralism focuses on skills and action competence for sustainability (Mogensen & Schnack, 2010). Rather than delivering predefined solutions, it employs a pedagogy characterized by pluralism, which seeks to acknowledge and engage with diverse perspectives, values, and worldviews when addressing sustainable development (SD) issues (Lijmbach et al., 2002; Rudsberg & Öhman, 2010). This approach emphasizes reflection on these issues rather than teaching "correct" answers, fostering students' ability to evaluate alternative viewpoints critically (Englund, 2006; Sandell, 2005; Winter & Firth, 2007).

Pluralism in ESD is rooted in the idea that no single ethic is prioritized in teaching, allowing for the democratic inclusion of multiple standpoints (Boeve-de Pauw et al., 2015). Teachers create opportunities for students to critically inspect varying

perspectives, ensuring that democratic participation and decision-making are integral components of the educational experience. This pluralistic approach encourages learners to view sustainability challenges through their own observations and equips them with the competencies required to act for sustainability (Boeve-de Pauw et al., 2015). Pluralistic approaches in ESD teaching acknowledge the complexity, uncertainty, and value conflicts inherent in sustainability issues (Ojala, 2013). Such approaches encourage critical thinking and dialogue, enabling students to form their own informed opinions (Vare & Scott, 2007). Critical thinking, as Mogensen (1995) explains, involves "reflective and evaluative thinking which must lead to a reasoned judgment." This form of thinking is vital for students to question authority, evaluate information sources, and responsibly engage with sustainability challenges (Hasslöf & Malmberg, 2015).

Incorporating pluralism in ESD pedagogy also equips students with skills to analyze and interpret diverse information acquired both inside and outside of school (Harness & Drossman, 2011; Varela-Losada et al., 2016). These skills are critical given the complex nature of SD issues, which often demand a reflection on political structures and power dynamics (Andreotti, 2006; Uzzell & Räthzel, 2009). Students are thus empowered to consider diverse perspectives and make informed decisions, an essential capability for addressing the multifaceted nature of global sustainability (Kincheloe, 2008). Englund's (2006, 2008) deliberative communication model underpins pluralistic ESD by promoting rational discourse and argumentation. The model includes presenting competing arguments, respecting differing viewpoints, and fostering an understanding of others' perspectives through active listening. This framework aligns with the democratic principles of pluralism, where students critically engage with habits, norms, and traditions, enabling them to challenge taken-for-granted assumptions (Ojala, 2013).

As students confront diverse perspectives and values in the classroom, they develop critical thinking, engage in dialogue, and form their own opinions on SD issues (Breiting, 2009; Vare & Scott, 2007; Jensen & Schnack, 2006; Sinakou, 2022). Teachers, in turn, create environments conducive to debate and evaluation, helping students

appreciate the strengths of contesting perspectives (Jickling, 1994; Rudsberg & Öhman, 2010). This pedagogical strategy is particularly relevant given the moral and ethical dimensions of sustainability challenges (Van Poeck, Östman, & Öhman, 2019). Pluralistic ESD calls for reflection and action rather than prescribing solutions, empowering young citizens to develop sustainable behaviors and awareness through observation and critical engagement (Ssossé et al., 2021). By fostering these capacities, pluralistic teaching ensures that students are not only informed but also capable of contributing to meaningful and collaborative solutions for SD issues (Boeve-de Pauw et al., 2015).

2.6.2 The Measurement of ESD-Pluralism

The measurement of Education for Sustainable Development (ESD)-Pluralism has been rigorously developed and evaluated to assess students' perceptions of ESD within educational contexts. Boeve-de Pauw et al. (2015) conceptualized and operationalized ESD as incorporating key sustainable development issues such as climate change, disaster risk reduction, biodiversity, poverty alleviation, and sustainable consumption into teaching and learning. This approach emphasizes participatory methods that empower learners to adopt sustainable behaviors and make informed decisions, promoting critical thinking, collaborative decision-making, and envisioning future scenarios. Building on this foundation, they developed specific measurement items to capture the pluralistic approach to teaching-a hallmark of ESD. Pluralism in this context emphasizes that no single ethical standpoint or value is prioritized in teaching, ensuring that all perspectives are treated as equally valid. This approach fosters critical inspection of alternative viewpoints and promotes democratic engagement, allowing students to influence teaching and learning content. To reflect these principles, Boeve-de Pauw et al. (2015) developed a 4-item construct to measure ESD-Pluralism, capturing essential aspects of pluralistic pedagogy. The items include: (1) "When we have class discussions, it is possible for many different views to emerge," (2) "When we read texts in school, we usually take a critical look at the content," (3) "In school, we are encouraged to take a stand and have our own opinions on the issues at hand," and (4)

"We decide what we study ourselves, with the support of the teacher." These items encapsulate the ethos of pluralistic teaching, encouraging critical thinking, autonomy, and inclusive dialogue.

The psychometric properties of the ESD-Pluralism scale were rigorously tested through confirmatory factor analysis (CFA), yielding excellent results. Boeve-de Pauw et al. (2015) reported an RMSEA value of 0.054, a CFI of 0.989, and a TLI of 0.982, demonstrating robust construct validity and model fit. The scale's reliability and validity make it a valuable tool for assessing students' experiences with pluralistic teaching approaches. Since its development, the ESD-Pluralism scale has been utilized and validated in various contexts, underscoring its versatility and relevance. For instance, Saqib et al. (2020) applied the scale to explore perceptions of sustainability and ESD implementation in higher education institutions (HEIs) in Pakistan. This study involved 1,915 students and 120 teachers across public and private universities in Punjab. Participants rated their experiences using a five-point Likert scale ranging from "never" to "very frequently." The results demonstrated strong reliability (Cronbach's alpha=0.78) and validity, with CFA indicating a good model fit (RMSEA=0.058, CFI=0.968, TLI=0.989). These findings confirm the scale's applicability in measuring pluralistic teaching approaches in diverse educational settings. Similarly, Olsson et al. (2022) investigated the impact of ESD on students' action competence for sustainability over time, focusing on how pluralism influences knowledge, attitudes, and behaviors related to sustainability. Using the ESD-Pluralism scale, this longitudinal study employed growth models to assess changes in students' competence. The CFA results consistently satisfied high-quality standards, with excellent values for CFI, TLI, and RMSEA, further validating the scale's effectiveness in longitudinal research. In the Malaysian context, Saleem et al. (2022) examined ESD practices and perceptions in university classrooms. This study involved 2,678 students and 1,013 teachers, encompassing a wide range of participants, including undergraduate and postgraduate students, lecturers, and professors. The researchers adapted Boeve-de Pauw et al.'s (2015) ESD-Pluralism scale to measure classroom experiences. The goodness-of-fit indices for the measurement

model across different subgroups were excellent, with χ^2/df values below 3, CFI and TLI values above or equal to 0.9, and RMSEA values below 0.08. These findings further underscore the scale's robustness and its capacity to capture pluralistic teaching practices across varied educational levels and cultural contexts.

The consistent validation of the ESD-Pluralism scale across different studies and regions highlights its utility in assessing the pluralistic dimensions of ESD. Its application enables educators and researchers to measure the extent to which pluralistic principles are embedded in teaching practices, fostering critical thinking, dialogue, and inclusivity. Such insights are vital for advancing sustainable education practices globally, ensuring that learners are equipped to navigate complex sustainability challenges.

2.7 ESD Competence and Professional Action Competence

This section explores how ESD competence and professional action competence in pre-service teachers are measured and assessed. It reviews various tools, frameworks, and methods used in the literature to evaluate the effectiveness of ESD training programs.

2.7.1 The Concept and Importance of ESD Competence and Professional Action Competence

Education for Sustainable Development (ESD) is a transformative approach that equips learners with the knowledge, skills, and attitudes required to address sustainability challenges, fostering the societal transformation needed to achieve sustainable development goals (Rieckmann & Barth, 2022; Brundiers et al., 2020). Central to this initiative are educators, who play a pivotal role in implementing ESD by facilitating critical reflection on actions, inspiring transformative learning, and guiding students toward sustainable practices (Rieckmann & Barth, 2022; UNESCO, 2017).

Educators are essential change agents for sustainable development, serving as a critical link between the educational goals of ESD and the societal transformation it seeks to achieve (UNESCO, 2017). Their ability to implement ESD depends on their acquisition of specific competences, which encompass knowledge,

skills, values, attitudes, and motivation tailored to sustainable development issues (Rieckmann & Barth, 2022). To ensure the successful integration of ESD into educational practices, teacher education and professional development programs must align with ESD objectives. Various international declarations and national policy papers emphasize this alignment, underscoring the importance of preparing educators to embed ESD into their pedagogical practices (UNECE, 2005; UNESCO, 2009). Efforts to integrate ESD into teacher education have demonstrated the necessity of educator support for the successful adoption and implementation of ESD (UNESCO, 2014). However, challenges persist, including educators' perceived lack of expertise and confidence in addressing complex interdisciplinary sustainability issues, which often involve unfamiliar and conflicting perspectives (Sass et al., 2022; Boeve-de Pauw et al., 2015). To address these challenges, UNESCO's ESD for 2030 program prioritizes building educators' capacities by equipping them with transformative competences and innovative pedagogical methods that promote sustainable practices (UNESCO, 2020).

The foundation of ESD lies in developing sustainability competences, which enable individuals to perform tasks and solve problems in diverse contexts while addressing ecological, social, and economic challenges (Vare et al., 2019; Rieckmann, 2012). These competences extend beyond technical knowledge, encompassing critical thinking, systems thinking, and the ability to navigate diverse perspectives through interdisciplinary and action-oriented teaching methods (Rieckmann, 2018; Redman et al., 2018). Developing ESD competence requires a transformative, action-oriented pedagogy that prepares educators to guide learners in understanding the complexities of sustainable development and taking meaningful action (Weinert, 2001; Brandt et al., 2019). This includes fostering an understanding of the interlinkages among the 17 Sustainable Development Goals (SDGs), as well as equipping educators with strategies for promoting gender equality, transformative action, and collaborative learning (UNESCO, 2020).

Professional Action Competence in ESD (PACesd) represents a holistic framework that integrates educators' confidence, commitment, knowledge, and pedagogical skills to address sustainability challenges effectively (Sass et al., 2022). Confidence, rooted in self-efficacy, reflects educators' belief in their ability to contribute meaningfully to sustainable education efforts (Bandura, 2001). Commitment encompasses intrinsic motivation and persistence, driving educators to overcome challenges and sustain their efforts toward transformative change (Moeller & Grassinger, 2013; Vallerand, 2015). PACesd also involves mastering ESD-specific knowledge and skills, which are shaped by the particular sustainability issues being addressed. These include understanding ESD principles, the interconnections among SDGs, and methods for fostering transformative learning experiences (Sass et al., 2022). Effective PACesd requires a pluralistic and action-oriented approach, encouraging educators to integrate diverse perspectives, promote critical thinking, and empower learners to take sustainable actions (Öhman, 2008; Sinakou et al., 2019).

The successful implementation of ESD often exceeds the capacity of individual educators, highlighting the importance of collective action and collaboration among teachers, stakeholders, and communities (Redman et al., 2018). Collaborative efforts provide opportunities to share perspectives, develop innovative solutions, and address the complexities of ESD implementation, fostering mutual support and enhancing educators' self-efficacy and commitment to sustainability initiatives. In contexts lacking direct collaboration opportunities, partnerships with external organizations or networks can offer essential support and foster professional development in PACesd. Additionally, vocational education and training institutions, along with private companies, can collaborate to enhance educators' capacities in areas such as sustainable production and green economies (UNESCO, 2020). Policymakers also play a crucial role by supporting and incentivizing educators who successfully integrate ESD into their teaching. Recognizing these efforts through institutional quality reviews and other measures can further encourage the adoption of ESD principles (UNESCO, 2020).

ESD competence and PACesd are critical for achieving the transformative goals of sustainable development. Educators must possess a combination of knowledge, skills, values, and attitudes to address sustainability challenges effectively and guide learners toward meaningful action. By fostering a collaborative and supportive environment, educators can overcome the complexities of ESD implementation and inspire transformative change at both personal and societal levels. Efforts to enhance educators' competences should remain a priority in achieving a sustainable future, with continued support from institutions, policymakers, and global initiatives.

2.7.2 Measurement Tools for ESD Competence

The measurement of competence in Education for Sustainable Development (ESD) has been a key focus in recent years, with several frameworks emerging to guide educators in developing the necessary skills and knowledge. These frameworks aim to assess and support the integration of sustainability principles into educational practices. Table 2 shows the summary of competence frameworks for Education for Sustainable Development (ESD).

Table 2 Summary of Competence Frameworks for Education for Sustainable Development (ESD)

Year	Author(s)	Framework Name	Core Components/Features
2008	Sleurs	CSCT Competence Model	Three dimensions: teaching/communicating, reflecting/visioning, networking. Five domains: knowledge, systems thinking, emotions, values and ethics, action.
2012	UNECE	UNECE Framework	39 competences across four domains: learning to know, learning to do, learning to live together, learning to be. Three principles: holistic approach, envisioning change, transformation.
2013	Rauch and Steiner	KOM-BiNE Model	Group-based competencies, focusing on team action. Competence fields: knowing and acting, valuing and feeling, communicating and reflecting, visioning, planning, organizing, networking.
2013	Bertschy et al.	ESD Competence Model	Based on Baumert & Kunter's model: professional knowledge, motivation, conviction/values, self-regulation. Five fields: pedagogical, content, pedagogical content, organizational, guidance knowledge.
2019	Vare et al.	RSP Framework	12 competences across three domains: holistic approach, envisioning change, achieving transformation. Four phases: integration, involvement, practice, reflection.
2022	Sass et al.	PACesd Framework	Three core components: willingness/passion-commitment, knowledge of pedagogical approaches, confidence/self-efficacy.

Sources: Bertschy et al. (2013); Rauch and Steiner (2013); Rieckmann and Barth (2022); Sass et al. (2022); Sleurs (2008); UNECE (2012); Vare et al., (2019).

The CSCT Competence Model (Sleurs, 2008) was one of the early contributions to ESD competence, focusing on three key dimensions: teaching/communicating, reflecting/visioning, and networking. These dimensions are further divided into five competence domains: knowledge, systems thinking, emotions, values and ethics, and action. While the model provides a comprehensive view of the various competences required by educators, it has been critiqued for the vagueness in distinguishing between some of the domains, particularly the role of emotions in other competencies (Bertschy et al., 2013).

The UNECE Framework (2012) offers a more extensive approach with 39 competences distributed across four domains: learning to know, learning to do, learning to live together, and learning to be. This framework emphasizes holistic education, envisioning change, and achieving transformation, providing a systematic and comprehensive set of competences. However, its breadth and the number of competences may present challenges in practical implementation due to the complexity of managing 39 distinct competences (Vare et al., 2019).

Another model, the KOM-BiNE Model (Rauch & Steiner, 2013), shifts the focus from individual competencies to group-based competencies, highlighting collaborative efforts in team-based actions. It outlines various competence fields, including knowing and acting, valuing and feeling, communicating and reflecting, visioning, planning, organizing, and networking. This approach emphasizes collective action in ESD, with an emphasis on participatory processes within educational institutions and communities.

The ESD Competence Model by Bertschy et al. (2013) builds on Baumert and Kunter's (2013) professional action competence model and is particularly focused on the competencies of educators in kindergarten and primary schools. It identifies four key aspects of competence: professional knowledge, motivation, conviction/values, and self-regulation. This model further distinguishes five fields of competence, including pedagogical, content, pedagogical content, organizational, and guidance knowledge, offering a targeted approach for teachers at early educational stages.

The RSP Framework (Vare et al., 2019) was developed to address the limitations of overly complex models like the UNECE framework, offering a more manageable and focused set of 12 competences. These competences are grouped into three core domains: holistic approach, envisioning change, and achieving transformation, alongside four phases: integration, involvement, practice, and reflection. This framework emphasizes the reflective and transformative role of educators in ESD.

Finally, the PACesd Framework (Sass et al., 2022) stands out for its clear focus on three core components: willingness/passion-commitment, knowledge of pedagogical approaches, and confidence/self-efficacy. These components ensure that educators are not only knowledgeable but also motivated and confident in their ability to implement ESD effectively. The PACesd framework is particularly advantageous in fostering critical thinking and active participation among students and encourages collaborative learning among educators. Thus, The PACesd framework (Sass et al., 2022) stands out in its comprehensive approach to measuring and developing educators' competencies in Education for Sustainable Development (ESD). Unlike other frameworks such as the CSCT Competence Model (Sleurs, 2008) or the UNECE Framework (2012), which offer broad but sometimes overly complex sets of competences, the PACesd framework provides a more focused and pragmatic approach by concentrating on three core components: educators' willingness, pedagogical knowledge, and confidence. These elements are crucial in ensuring that educators are equipped to integrate sustainable development principles effectively into their teaching practices.

When compared to other models like the KOM-BiNE Model (Rauch & Steiner, 2013), which emphasizes team-based actions, the PACesd framework offers a clearer path for individual educator development, particularly in fostering a personal commitment to sustainability and enhancing the educator's own pedagogical skills. Additionally, the PACesd framework’s advantages, such as boosting educator confidence, fostering collaborative learning, and aligning with the Sustainable

Development Goals (SDGs), make it a particularly valuable tool for educational institutions looking to implement and evaluate ESD practices at scale.

Despite these advantages, the PACesd framework could benefit from greater attention to group-based or institutional-level competence development, which is more emphasized in models like KOM-BiNE and RSP. Overall, the PACesd framework appears to offer a more adaptable and focused tool for measuring and improving educator competence in ESD, making it well-suited to large-scale implementation across diverse educational settings.

Regarding the psychometric evaluation of the PACesd framework, Sass et al. (2022) employed Confirmatory Factor Analysis (CFA) to validate the hypothesized factor structure of the model. Specifically, they tested the suitability of a second-order factor model comprising three subconstructs: self-efficacy in education for sustainable development (SEesd), perceived pedagogical content knowledge related to education for sustainable development (pPCKesd), and the willingness to implement education for sustainable development (Wesd). The results indicated strong reliability for the PACesd instrument, with Cronbach's alpha values ranging from 0.84 to 0.96 across the overall scale and its subscales. These high values suggest excellent internal consistency among the components of the PACesd framework. According to the model proposed by Sass et al. (2022), the PACesd construct is conceptualized as a second-order latent variable, which is composed of three first-order latent constructs: Wesd, pPCKesd, and SEesd. This theoretical structure was supported by favorable model fit indices, such as RMSEA=0.077 (90% Confidence Interval: [0.073, 0.081]), CFI=0.964, and TLI=0.961, which align with widely accepted thresholds for CFA models. Further analysis revealed that all 31 items in the PACesd instrument were strong indicators of their respective factors, with factor loadings between 0.609 and 0.965. These substantial loadings demonstrate that the lower-level factors contribute meaningfully to the higher-order construct, consistent with the theoretical framework. Notably, the three core dimensions of PACesd: Wesd, pPCKesd, and SEesd showed significant factor loadings of 0.623, 0.976, and 0.686, respectively. The particularly strong association between perceived

pedagogical content knowledge (pPCKesd) and the PACesd factor (r=0.976) highlights the pivotal role of pedagogical content knowledge in shaping professional action competence for implementing education for sustainable development.

While the three components of professional action competence: willingness, pedagogical knowledge, and self-efficacy are distinct, they are all integral to the broader PACesd framework. The findings indicate that each subconstruct is a strong indicator of professional competence in the implementation of education for sustainable development. Ultimately, the PACesd instrument has proven to be a valid and reliable tool for assessing teachers' professional action competence in implementing education for sustainable development in primary and secondary schools in Flanders. This instrument provides educational practitioners with a useful resource for tracking and identifying professional development needs concerning their competence in ESD implementation. Future studies could further explore the instrument's performance in larger samples of teachers across Belgium and other countries, investigating its measurement invariance across diverse educational contexts. This would enhance the instrument's generalizability and enable comparisons between teachers in different training stages (e.g., pre-service vs. in-service), teaching disciplines, and educational settings (e.g., schools and non-formal education centers.

2.8 Hypothesis Development

This section discusses the formulation of the hypotheses for the study, which aims to examine the influence of sustainable leadership on professional action competence in Education for Sustainable Development (ESD) among pre-service teachers in Yunnan Province, China. It also explores the mediating roles of ESD-Holism and ESD-Pluralism in this relationship. The hypotheses are based on frameworks, prior research findings, and the logical connections between the constructs under investigation.

2.8.1 The Relationship between Sustainable Leadership and ESD-Holism and ESD-Pluralism

Education for Sustainable Development (ESD) integrates key sustainability issues such as climate change, biodiversity, poverty reduction, and sustainable consumption into teaching and learning processes (Boeve-de Pauw et al., 2015). It emphasizes participatory teaching methods that empower learners to adopt sustainable behaviors and take action for a sustainable future. ESD fosters critical thinking, the ability to imagine future scenarios, and collaborative decision-making, which are essential for addressing global challenges (Sinakou et al., 2019). Central to ESD are two key distinct dimensions: Holism and Pluralism. Holism integrates the environmental, social, and economic dimensions of sustainability while addressing their interconnected local, regional, and global implications across time. It reflects pre-service teachers' perceptions of the extent to which these dimensions are integrated into teaching (Andersson, 2017; Boeve-de Pauw et al., 2015; Sinakou et al., 2019). Pluralism measures the degree to which teachers foster discussions, address varying viewpoints, and involve students in topic selection (Andersson, 2017; Boeve-de Pauw et al., 2015; Sinakou et al., 2019). Sustainable leadership refers to a holistic approach to leadership that integrates an understanding of the past, present, and future, both locally and globally (Dries et al., 2023; Hargreaves & Fink, 2006). This type of leadership emphasizes the interconnectedness of various dimensions of sustainability, including environmental, social, and economic aspects. By adopting a holistic perspective, sustainable leaders ensure that their actions and decisions consider the long-term impacts on all these dimensions, fostering a comprehensive approach to sustainability. This aligns with the principles of ESD-Holism, which seeks to integrate these diverse dimensions into educational practices, promoting a broad and interconnected understanding of sustainability issues among students. Sustainable leadership also involves the ability to adapt the appropriate leadership style, considering the specific time and context, and incorporating holistic, pluralistic, and action-oriented perspectives (Dries et al., 2023). Pluralism promotes the inclusion of diverse perspectives, critical reflection, and participatory decision-making on sustainability topics. Leaders who value

inclusivity and innovation enable students and educators to collaboratively address sustainability challenges through participatory decision-making processes (Boeve-de Pauw et al., 2015). Incorporating pluralism in communication facilitates the inclusion of diverse perspectives, making it easier to involve different viewpoints (Verhelst et al., 2021). A pluralistic way of communicating positively impacts a school's efforts toward ESD by presenting opportunities to start a dialogue with and among students. This approach also increases the opportunity to involve students in critical decision-making (Verhelst et al., 2021). Pluralistic communication that involves relevant stakeholders can facilitate this critical decision-making process. Including relevant stakeholders in the process allows ideas and initiatives to grow and mature, which is important for ESD. Additionally, when stakeholders participate in decision-making, a sense of ownership can be established (Verhelst et al., 2021). Thus, sustainable leadership significantly could impact both ESD-Holism and ESD-Pluralism. By fostering an environment where diverse perspectives are valued and participatory decision-making is encouraged, sustainable leadership not only enriches the educational experience but also enhances the effectiveness of ESD by promoting inclusivity and critical engagement with sustainability topics. This comprehensive approach ensures that sustainability is taught in a way that addresses its environmental, social, and economic dimensions, which are essential for professional competence in ESD.

In addition, Sustainable leadership plays a pivotal role in advancing ESD by fostering environments that emphasize holistic and pluralistic approaches. Sustainable leadership entails the strategies, values, and actions leaders adopt to prioritize sustainability, focusing on social, environmental, and ethical responsibilities (Qablan et al., 2023). Leaders who adopt this approach facilitate participatory decision-making, support experiential learning, and create opportunities for teachers and students to engage actively in sustainability projects. For instance, school principals and other educational leaders support ESD implementation by encouraging collaboration, fostering a participative culture, and providing resources for sustainability education (Müller et al., 2020). Previous research has shown that challenges like limited

administrative skills, lack of resources, and resistance to change can make it hard for sustainable leadership to be effective in Education for Sustainable Development (ESD) (Kadji-Beltran et al., 2013; Filho et al., 2020). Addressing these barriers is important for improving professional skills in ESD among pre-service teachers, who often have positive attitudes towards sustainability but need more training in teaching skills and self-confidence (Palomino et al., 2022). Good sustainable leadership can help overcome these challenges. It involves guiding and using school resources to support ESD (Dries et al., 2023). Studies have highlighted the value of sustainable leadership, whether from school leaders or teacher leaders, in supporting school policies towards ESD (Dries et al., 2023). School leaders can give teachers the freedom to take on roles that inspire and motivate others in ESD leadership (Dries et al., 2023). Both teachers and school leaders agree that it is the responsibility of school leaders to provide the right resources at the right time and place to support ESD (Dries et al., 2023). A clear vision of ESD within the school helps other teachers see ESD as part of their job (Dries et al., 2023). Sustainable leadership, school resources, and their relationship in supporting ESD are key to an effective ESD school (Dries et al., 2023). Efficient time management helps in teaching and learning for ESD in a way that includes different subjects and perspectives (Dries et al., 2023; Mogren & Gericke, 2017).

Sustainable leadership significantly contributes to fostering ESD-Holism by integrating environmental, social, and economic dimensions into educational practices. Leaders who prioritize sustainability emphasize long-term development goals that align with holistic education principles (Abidin et al., 2023). School leaders play a pivotal role in interpreting education policies related to sustainability, facilitating comprehensive approaches to sustainable development (Zachariou & Kadji-Beltran, 2009). Kelman's Social Influence Theory (1974) explains that leaders act as influencing agents who deliberate strategies to promote behavioral congruency in line with sustainability values. Through compliance, identification, and internalization, these leaders foster a positive orientation among educators and students, enhancing their predisposition toward adopting ESD-Holism. Sustainable leadership also ensures that school-level practices

encompass systemic integration of sustainability's past, present, and future implications, which is essential for holistic education reform. These practices resonate with Social Influence Theory's assertion that behaviors deeply rooted in personal values yield stronger long-term commitments (Kelman, 1958).

Sustainable leadership promotes ESD-Pluralism by creating environments that encourage diverse perspectives and critical reflection on sustainability issues. Leaders who value inclusivity and innovation enable students and educators to collaboratively address sustainability challenges through participatory decision-making processes (Abidin et al., 2023). The concept of pluralism aligns with Kelman's (1958) identification and internalization processes, where individuals adopt behaviors consistent with intrinsic values and beliefs. Leaders influence this adoption by fostering positive orientations and reducing psychological resistance to diverse viewpoints (Kelman, 1974). For instance, sustainable leaders guide educators in integrating multiple perspectives into the curriculum, promoting collaborative learning and critical engagement with sustainability topics (Zachariou et al., 2013). These efforts align with ESD-Pluralism's aim of enabling students to critically reflect on sustainability issues, ensuring the relevance and inclusivity of educational practices.

Grounded with the understanding of the literatures related to the potential impact of sustainable leadership on the successfully implementation of ESD, specifically ESD-Holism and ESD-Pluralism, the following hypotheses are proposed to explore the relationship between sustainable leadership and ESD-Holism and ESD-Pluralism separately:

H1: Sustainable leadership will positively influence ESD-Holism.

H2: Sustainable leadership will positively influence ESD-Pluralism.

2.8.2 The Relationship between ESD-Holism and ESD-Pluralism and Professional Action Competence in ESD

Education for Sustainable Development (ESD) integrates key sustainability issues such as climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption into teaching and learning. It emphasizes participatory

teaching methods that empower learners to adopt sustainable behaviors and take action for a sustainable future. ESD promotes critical thinking, imagining future scenarios, and collaborative decision-making, all of which are vital for addressing global challenges (UNESCO, 2017). ESD incorporates two distinct features: Holism, which integrates the environmental, social, and economic dimensions of sustainability, and Pluralism, which fosters diverse viewpoints and critical reflection on sustainability issues (Boeve-de Pauw et al., 2015; Brandt et al., 2022; Chaaban et al., 2023; Sass et al., 2022).

Holism in ESD reflects students' perceptions of the extent to which their educators integrate sustainability's environmental, social, and economic dimensions, while considering the past, present, and future, as well as local, regional, and global perspectives in classroom (Boeve-de Pauw et al., 2015). Pluralism in ESD measures students' perceptions of how their educators encourage diverse viewpoints, critical reflection, and student participation in decision-making around topics in the classroom (Ammoneit et al., 2022; Boeve-de Pauw et al., 2015). Together, these two distinct ESD features form the foundation for fostering competencies necessary for effective teaching in sustainability education.

Professional Action Competence (PAC) in ESD is a second-order construct encompassing three subdimensions: Self-Efficacy regarding ESD, Perceived Pedagogical Content Knowledge about ESD, and Willingness to Implement ESD (Sass et al., 2022). This construct evaluates students' or in the current study's context the pre-service teachers' ability to apply sustainability principles in teaching effectively.

Research emphasizes the role of structured ESD training in equipping pre-service teachers with the necessary knowledge, skills, and attitudes to foster sustainability in education. Holistic and pluralistic approaches to ESD are particularly significant for developing competences in ESD, as they encourage an integrated understanding of sustainability and foster active student engagement (Sass et al., 2022; Sinakou et al., 2019; Singh-Pillay, 2023).

ESD-Holism contributes to developing students or pre-service teachers' Professional Action Competence by integrating multidimensional sustainability principles

into their pedagogical practices. Teachers exposed to holistic ESD approaches demonstrate improved self-efficacy and a stronger understanding of sustainability's interconnected aspects, which translates into more effective teaching (Abidin et al., 2023). Kelman's (1974) concept of internalization highlights those behaviors aligned with deeply entrenched values such as sustainability result in greater long-term commitment. Holistic approaches also emphasize the integration of local, regional, and global sustainability perspectives, enhancing teachers' pedagogical content knowledge (Mogaji & Newton, 2020). When teachers integrate the environmental, social, and economic dimensions of sustainability issues, and focus on their past, present, and future, as well as their local, regional, and global nature, students gain a better understanding of the complexity of sustainable development issues (Boeve-de Pauw et al., 2015). This comprehensive approach, known as ESD-Holism, equips students or pre-service teachers with the knowledge, skills, and attitudes necessary to confidently implement sustainability principles. By fostering a holistic understanding of sustainability, ESD-Holism aligns with the principles of professional competence in ESD, enabling students to address complex sustainability challenges effectively (Zachariou & Kadji-Beltran, 2009). ESD-Holism impacts students' competence by enhancing their knowledge of sustainability issues, developing their skills in critical thinking and problem-solving, and fostering a willingness to engage in sustainable practices. This integrated approach ensures that students not only understand the interconnectedness of environmental, social, and economic dimensions but also appreciate the importance of considering these dimensions across different timeframes and geographical contexts. As a result, students are better prepared to apply sustainability principles in their future professional and personal lives, contributing to a more sustainable world.

ESD-Pluralism supports students or pre-service teachers in developing Professional Action Competence by emphasizing critical reflection and the inclusion of diverse perspectives. This approach allows future educators to address sustainability challenges innovatively, fostering readiness to implement ESD principles (Abidin et al., 2023). Kelman's (1958) notion of compliance and identification highlights the importance

of participatory learning environments in enhancing teachers' motivation and engagement with pluralistic approaches. When pre-service teachers are exposed to pluralistic methods, they become more adept at fostering collaborative learning and addressing sustainability issues from multiple viewpoints (Davlembayeva & Papagiannidis, 2024). This aligns with the goals of ESD-Pluralism, which seeks to empower educators to engage critically with sustainability topics and encourage diverse student participation.

Based on the theoretical underpinnings and empirical findings, the following hypotheses are proposed:

H3: ESD-Holism will positively influence pre-service teachers' Professional Action Competence in ESD.

H4: ESD-Pluralism will positively influence pre-service teachers' Professional Action Competence in ESD.

2.8.3 The Relationship between Sustainable Leadership and Professional Action Competence in ESD

The relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD) is central to creating educational systems that effectively promote sustainability. Sustainable leadership provides the foundation for fostering environments where educators can develop and apply competencies essential for implementing ESD. This section explores the theoretical underpinnings of sustainable leadership and professional action competence, defines these constructs, and examines their interrelation to support the development of the hypothesis.

Sustainable leadership, as perceived by pre-service teachers, refers to university leaders' actions and values that support sustainability through social, environmental, and ethical responsibilities, innovation, clear communication, and prioritization of student welfare and educational values over profit. Leaders who embody sustainable leadership adopt strategic management practices, inspire commitment, and foster participative processes that integrate sustainability into institutional culture (Qablan et al., 2023). These leaders play a crucial role in guiding the school community

toward a shared vision for sustainability, emphasizing the interconnectedness of environmental, social, and economic goals (Müller et al., 2020). Through their actions, they create an environment conducive to implementing ESD principles, ensuring that educators and students alike are empowered to engage with sustainability practices.

Professional action competence in ESD is a second-order construct comprising three subvariables: self-efficacy regarding ESD, perceived pedagogical content knowledge about ESD, and willingness to implement ESD. Together, these components reflect pre-service teachers' ability to effectively apply sustainability principles in their teaching (Sass et al., 2022):

1.Self-Efficacy Regarding ESD: This dimension measures pre-service teachers' confidence in their ability to address sustainability topics and integrate them into the curriculum. It reflects their belief in their capacity to apply ESD principles effectively in diverse educational contexts.

2.Perceived Pedagogical Content Knowledge About ESD: This component assesses pre-service teachers' understanding of both sustainability content and the pedagogical methods required to teach it. It emphasizes the integration of holistic, pluralistic, and action-oriented approaches to education.

3.Willingness to Implement ESD: This dimension captures pre-service teachers' intent and readiness to include ESD principles in their teaching. It reflects their motivation and commitment to fostering sustainability awareness and practices among their future students.

Sustainable leadership plays a crucial role in shaping pre-service teachers' Professional Action Competence by creating environments that prioritize sustainability in education. Leaders' actions, such as clear communication of sustainability goals and fostering innovative teaching methods, directly impact teachers' self-efficacy and pedagogical knowledge (Zachariou & Kadji-Beltran, 2009). According to Kelman's (1974) Social Influence Theory, sustainable leaders act as influencing agents, motivating teachers to internalize sustainability principles. This internalization is pivotal in fostering long-term professional competence, as it aligns teachers' intrinsic values with their

teaching practices (Kelman, 1958). By supporting teacher development and embedding sustainability values in educational institutions, leaders ensure that pre-service teachers are well-equipped to implement ESD principles effectively (Abidin et al., 2023).

Social Influence Theory (SIT) provides a critical lens to examine the influence of leaders in fostering Professional Action Competence among pre-service teachers. Leaders, as central figures within a group, significantly shape the group's norms and values, directly impacting members' self-efficacy and willingness to engage in sustainability-related actions. Competence, defined as the interplay of knowledge, skills, motives, and attitudes, integrates cognitive, affective, volitional, and motivational elements, all of which are influenced by group dynamics and leadership (Brundiers et al., 2020; Shephard, 2022).

Leaders in the context of sustainability education play a pivotal role in fostering an environment where pre-service teachers feel both capable and motivated to act. They establish a sense of shared identity and collective purpose, which can elevate individual dispositions into observable and measurable competencies (Shephard, 2022). This aligns with Social Influence Theory's assertion that individuals' willingness to act is shaped by their identification with the group and its leadership. In sustainability-related education, such willingness is critical, as competence involves not only the ability to perform tasks but also the desire to engage meaningfully (Jensen & Schnack, 1997).

Moreover, a leader's influence extends to shaping attitudes and motivations, essential components of competence. Pre-service teachers under effective leadership are more likely to internalize the importance of sustainability and develop the volition to address complex educational challenges. This is particularly vital for those who may possess the requisite knowledge and cognitive abilities but lack the motivation or willingness to act (Shephard, 2022). In this context, leaders can bridge the gap between latent dispositions and active competencies, ensuring successful performance and positive outcomes in sustainability education.

By fostering knowledge, self-efficacy, and willingness among pre-service teachers, leaders amplify the impact of both ESD-Holism and ESD-Pluralism, reinforcing the connection between group identity, individual competence, and sustainable action. This highlights the critical role of sustainable leadership within Social Influence Theory as a mechanism for cultivating Professional Action Competence in ESD.

Based on the theoretical and empirical foundations discussed above, the following hypothesis is proposed:

H5: Sustainable leadership will positively influence the professional action competence of pre-service teachers in Education for Sustainable Development (ESD).

2.8.4 ESD-Holism and ESD-Pluralism as a Mediator between Sustainable Leadership and Professional Action Competence

Despite the growing interest in the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD), there is a notable lack of empirical quantitative research exploring this connection. This gap in the literature highlights the need for further investigation to understand how sustainable leadership influences professional action competence through specific educational approaches.

Holism in ESD refers to an integrated approach that encompasses the environmental, social, and economic dimensions of sustainability. This approach emphasizes the interconnectedness of these dimensions and encourages a comprehensive understanding of sustainability issues. Holistic ESD aims to provide students with a broad perspective on sustainability (Boeve-de Pauw et al., 2015). Pluralism in ESD involves incorporating diverse perspectives and values into the educational process. This approach encourages dialogue and collaboration among students, allowing them to explore different viewpoints and develop a deeper understanding of sustainability issues. Pluralistic ESD promotes inclusivity and democratic participation, enabling students to engage in meaningful discussions and take collective action towards sustainability (Axeithioti & Sinakou, 2021; Boeve-de Pauw et al., 2015).

The integration of holistic and pluralistic approaches in ESD could mediate the relationship between sustainable leadership and professional action competence. Sustainable leadership provides the vision, resources, and support necessary for implementing ESD (Verhelst et al., 2021), while holistic and pluralistic approaches enhance the effectiveness of ESD by fostering critical thinking, collaboration, skill, knowledge, and action-oriented learning (Boeve-de Pauw et al., 2015). By adopting these approaches, educators can develop the competencies needed to effectively integrate sustainability issues into their teaching practices (Axeithioti & Sinakou, 2021; Boeve-de Pauw et al., 2015; Iqbal & Ahmad, 2020; Müller & Qablan, 2023).

ESD-Holism mediates the relationship between sustainable leadership and professional action competence by integrating multidimensional sustainability principles into teaching practices. Leaders who emphasize holistic approaches provide a framework for teachers to adopt sustainability values, fostering long-term behavior change through internalization (Kelman, 1958). According to Kelman's Social Influence Theory (1979), leaders act as influencing agents who can shape the attitudes and behaviors of their followers through three processes: compliance, identification, and internalization. Compliance occurs when individuals adopt behaviors to gain rewards or avoid punishments. In the context of ESD-Holism, sustainable leaders can create policies and incentives that encourage teachers to integrate sustainability principles into their teaching practices. This initial compliance can lead to more consistent and widespread adoption of ESD principles. Identification happens when individuals adopt behaviors to establish or maintain a relationship with a leader or group. Sustainable leaders who model holistic approaches to sustainability can inspire teachers to emulate their practices. By identifying with these leaders, teachers are more likely to integrate environmental, social, and economic dimensions of sustainability into their teaching, fostering a school-wide culture of sustainability. Internalization is the most profound level of influence, where individuals adopt behaviors because they align with their own values and beliefs. Sustainable leaders who emphasize holistic approaches can help teachers internalize sustainability values, making these principles an integral part of their

professional identity. This internalization leads to long-term behavior change, as teachers are motivated by their own commitment to sustainability rather than external rewards or pressures. By leveraging their influence through these processes, sustainable leaders can create opportunities for pre-service teachers to engage with holistic perspectives, enhancing their readiness and motivation to implement ESD principles. This holistic approach ensures that sustainability is taught comprehensively, addressing its environmental, social, and economic dimensions, which are essential for professional competence in ESD (Zachariou & Kadji-Beltran, 2009). As a result, ESD-Holism mediates the relationship between sustainable leadership and pre-service teachers' professional action competence in ESD, equipping them with the knowledge, skills, and attitudes necessary to confidently implement sustainability principles in their future teaching careers.

ESD-Pluralism mediates the relationship between sustainable leadership and professional action competence by promoting diverse viewpoints and participatory decision-making in educational practices. Leaders who value inclusivity and innovation enable teachers to critically engage with sustainability challenges, fostering professional growth (Abidin et al., 2023). According to Kelman's (1974) Social Influence Theory, pluralistic environments reduce resistance to behavioral or attitude change, encouraging pre-service teachers to adopt sustainability values through identification and internalization. Kelman's Social Influence Theory explains that leaders can influence individuals through three processes: compliance, identification, and internalization (Kelman, 1974). Compliance occurs when individuals adopt behaviors to gain rewards or avoid punishments. Identification happens when individuals adopt behaviors to establish or maintain a relationship with a leader or group. Internalization is the most profound level of influence, where individuals adopt behaviors because they align with their own values and beliefs (Davlembayeva & Papagiannidis, 2024). In the context of ESD-Pluralism, sustainable leaders create environments that encourage diverse perspectives and participatory decision-making. This approach reduces resistance to change by fostering identification and internalization of sustainability values among pre-

service teachers. When teachers identify with their leaders and internalize sustainability values, they are more likely to adopt and implement these values in their teaching practices. These pluralistic practices empower educators to address sustainability issues innovatively and inclusively, aligning with the goals of professional action competence in ESD. By promoting critical engagement with sustainability challenges, sustainable leaders help pre-service teachers develop the knowledge, skills, and attitudes necessary to implement ESD principles effectively. This holistic approach ensures that sustainability is taught comprehensively, addressing its environmental, social, and economic dimensions. Thus, ESD-Pluralism could mediate the relationship between sustainable leadership and pre-service teachers' professional action competence in ESD by fostering an environment where diverse perspectives are valued and participatory decision-making is encouraged. This approach not only enriches the educational experience but also enhances the effectiveness of ESD by promoting inclusivity and critical engagement with sustainability topics.

While the theoretical foundations of ESD-Holism and ESD-Pluralism are well-established, empirical quantitative research is needed to explore their mediating role between sustainable leadership and professional action competence. This research will provide valuable insights into how these educational approaches can enhance the effectiveness of ESD and contribute to the development of sustainability competencies among educators and students alike. Therefore, the following hypotheses are proposed:

H6: ESD-Holism will mediate the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD).

H7: ESD-Pluralism will mediate the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD).

2.9 Conceptual Framework for This Study

This section introduces the conceptual framework for the current study, detailing the relationships between the variables being explored: sustainable leadership, ESD-Holism, ESD-Pluralism, and professional action competence in ESD.

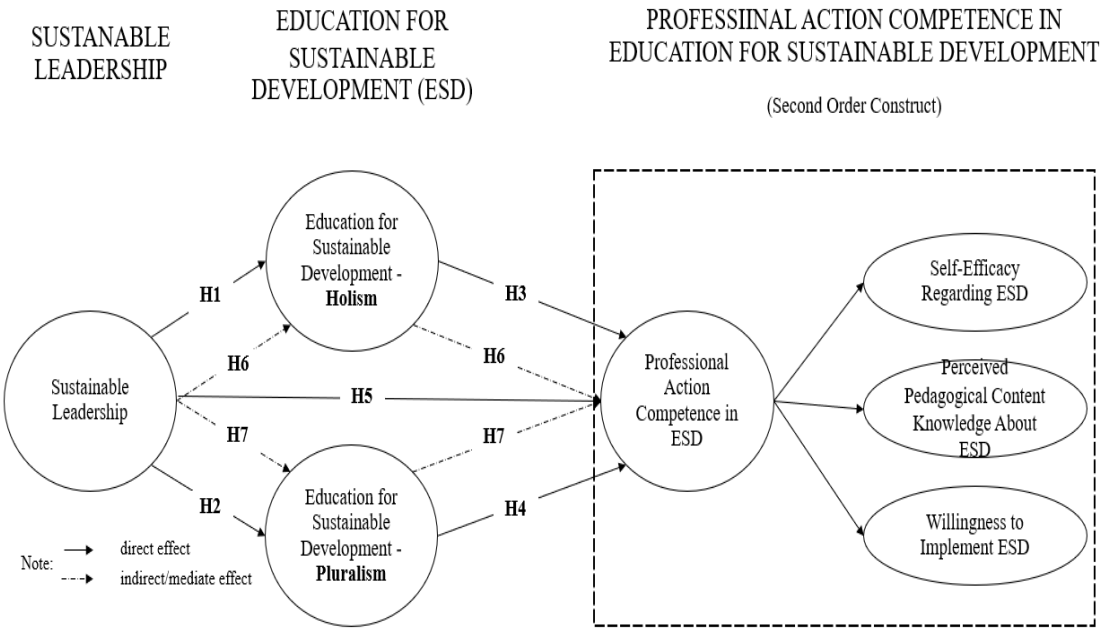

Figure 2 Conceptual Framework of This Study

2.10 Summary of Research Hypotheses Statement

Table 3 Summary of Research Hypotheses

Summary of Research Hypotheses	
H1	Sustainable leadership will positively influence ESD-Holism.
H2	Sustainable leadership will positively influence ESD-Pluralism.
H3	ESD-Holism will positively influence pre-service teachers' Professional Action Competence in ESD.

Table 3 (Continued)

Summary of Research Hypotheses	
H4	ESD-Pluralism will positively influence pre-service teachers' Professional Action Competence in ESD.
H5	Sustainable leadership will positively influence the professional action competence of pre-service teachers in Education for Sustainable Development (ESD).
H6	ESD-Holism will mediate the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD).
H7	ESD-Pluralism will mediate the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD).

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Research Design

This study adopts a multi-stage mixed-methods design (Sequential Mixed-Methods Design) and is divided into three main stages:

Phase 1: Quantitative research - using partial least squares structural equation modeling (PLS-SEM) to examine the key factors and path relationships that affect the ESD competence of pre-service teachers in Yunnan Province, China.

Phase 2: Qualitative research - in-depth interviews with 15 Chinese experts with ESD practical experience in China to summarize effective practices and strategies for successfully promoting ESD.

Phase 3: Comprehensive analysis for strategies development - integrating quantitative and qualitative research results to develop a systematic strategy to improve the ESD competence of pre-service teachers in Yunnan Province, China.

3.2 Phase 1: Quantitative Research

3.2.1 Quantitative Research Design

Phase 1 of this study focuses on pre-service teachers from six universities in Yunnan Province, China. To ensure a sample size of 385 responses, the scale of questionnaire distribution was appropriately expanded during the distribution phase. Ultimately, 527 valid questionnaires were collected through offline channels, exceeding the minimum requirement and meeting the conditions for subsequent statistical analysis. The sampling involves proportional allocation from each university. Non-random sampling techniques, including purposive, convenience, and snowball sampling, will be used to recruit participants. The researcher will obtain approval from the Human Research Ethics Committee (HREC) before data collection. The questionnaire, translated from English to Chinese, includes screening, demographic, and Likert-scale questions. Content validity will be ensured through expert review, and a pretest with 100 samples will assess internal consistency using Cronbach's alpha. Final Data analysis will

employ descriptive statistics, Exploratory Factor Analysis (EFA), and Partial Least Squares Structural Equation Modeling (PLS-SEM).

3.2.2 Population and Sampling

3.2.2.1 Population of Interest

The population for this study consists of pre-service teachers enrolled in teacher training programs at six universities in Yunnan Province, China. These universities include Yunnan Normal University, Kunming University, Qujing Normal University, Chuxiong Normal University, Zhaotong University, and Honghe University. Collectively, they represent key institutions for teacher education across the region, encompassing diverse geographic areas: South (Honghe University), West (Chuxiong Normal University), North (Zhaotong University), and Central Yunnan (Yunnan Normal University and Kunming University). The study's population estimate is based on the total enrollment of pre-service teachers at the six selected universities. In July 2023, the researcher estimated a total population of approximately 23,500 pre-service teachers across these institutions. The distribution is as follows: Yunnan Normal University (8,000 students), Kunming University (5,000 students), Chuxiong Normal University (3,000 students), Qujing University (2,500 students), Zhaotong University (2,500 students), and Honghe University (2,500 students). These universities collectively provide a representative sample of pre-service teachers in Yunnan Province, reflecting the diversity and commonalities of the target population.

3.2.2.2 Target Sample and Sample Size Calculation

The target sample for this study comprises pre-service teachers enrolled in teacher training programs at six universities in Yunnan Province, China. These institutions represent a diverse geographic distribution across the province, ensuring a broad and representative dataset.

Cochran's (1977) formula was utilized to determine the initial appropriate sample size.

$$N = \frac{z^2 \times p \times q}{e^2}$$

Where:

- N stands for the sample size.
- Z stands for the critical value for the desired confidence level (a value of 1.96 for 95% confidence level).
- P represents the estimated proportion of an attribute present in the population (e.g., 0.5 for maximum variability).
- q=1−p=0.5.
- e stands for the desired level of precision (e.g., ±0.05).

Applying the above values to the formula, the calculation for the appropriate sample size is:

$$N = \frac{(1.96)^2(0.5) * (0.5)}{(0.05)^2} = 385$$

However, to make sure the final collect samples reach 385, it is assumed that the maximum nonresponse rate is approximately 32.5%. Thus, the maximum require distributed questionnaires should be 570. The sampling framework includes a proportional allocation of participants from each university based on their respective proportion of the populations of pre-service teachers. The sample is designed to reflect the diversity and educational contexts within the region. Table 4 shows the allocation samples for each of the universities.

Table 4 The Population and Sample of Teacher Training Universities in Yunnan, China

Institution Name	Number of pre-service teachers	Proportion of Total	Sample of pre-service teachers	Region
Honghe University	2500	11%	60	South
Qujing Normal University	2500	11%	60	East
Chuxiong Normal University	3000	13%	75	West
Zhaotong University	2500	11%	60	North
Yunnan Normal University	8000	34%	195	Central
Kunming University	5000	21%	120	Central
Total	23500	100%	570	

3.2.3 Sampling Techniques and Data Collecting Method

This study employs a non-random sampling approach, combining purposive, convenience, and snowball sampling techniques to recruit participants from six teacher training universities in Yunnan Province, China. After reviewing the “Submission Form Preparation Guide” of Srinakharinwirot University, the study plan and validated questionnaires were submitted to the Human Research Ethics Committee (HREC) for approval. Upon receiving ethical clearance, data collection commenced.

Initial allocation sampling was used to determine the sample size from each university. Two pre-service teachers from each institution (totaling 12) were purposively recruited through personal networks to assist in offline questionnaire distribution. Convenience sampling was applied through university events, classes, and online platforms, while snowball sampling further expanded the sample by encouraging participants to refer eligible peers.

Inclusion criteria:

- Pre-service teachers currently enrolled in teacher training programs at one of the six selected universities in Yunnan Province.

- Aged 18 years or older.

Exclusion criteria:

- Individuals under the age of 18.

- In-service teachers or those not currently enrolled in a teacher training program.

- Individuals unwilling or unable to participate or complete the questionnaire.

This multi-method sampling strategy addresses logistical challenges while ensuring a diverse and contextually representative sample of pre-service teachers in Yunnan Province.

3.2.4 Research Instrument Design

The measurement instrument in this study is survey questionnaire to collect primary data from the target samples. The questionnaire of the research includes 3 parts, the part 1 is the composition of screening question in order to select the correct target sample, the second part is demographic questions. The third part is the Likert-scale questions related to the measurement of the research constructs (sustainable leadership, ESD-Holism, ESD-Pluralism, and Professional Action Competences in ESD: Self-Efficacy Regarding ESD, Perceived Pedagogical Content Knowledge About ESD, and Willingness to Implement ESD).

Part 1 includes one screening question to choose the target samples to answer the questionnaire, the screening question ask whether the respondent is currently enrolled as a pre-service teacher in a teacher training program at one of the following universities in Yunnan Province.

Screening Question

Are you currently enrolled as a pre-service teacher in a teacher training program at one of the following universities in Yunnan Province?

- ☐ Yunnan Normal University
- ☐ Kunming University
- ☐ Qujing Normal University
- ☐ Chuxiong Normal University
- ☐ Zhaotong University
- ☐ Honghe University
- ☐ No (please stop the survey here, thank you for your interest, but this study is limited to pre-service teachers from the listed universities)

Part 2 including 3 questions regarding to the respondents' demographic characteristics, the questions are as follows:

What is your gender?

- ☐ Male
- ☐ Female

What is your age?

- ☐ 18-19
- ☐ 20-21
- ☐ 22-23
- ☐ 24 or older

What is your current academic year?

- ☐ First year
- ☐ Second year

- ☐ Third year
- ☐ Fourth year

Part 3 is the Likert-scale questions related to the measurement of the research constructs (sustainable leadership, ESD-Holism, ESD-Pluralism, and Professional Action Competences in ESD: Self-Efficacy Regarding ESD, Perceived Pedagogical Content Knowledge About ESD, and Willingness to Implement ESD).

To ensure the reliability and validity of the survey questions related to the research variables or constructs, the development of the questionnaire items was grounded in an extensive review of relevant literature from reputable and reliable scientific journals and academic studies. All survey questions for the research variables were adopted or adapted from established academic sources that demonstrated high internal consistency and reliability. Additionally, certain scale items were carefully modified to align better with the specific context of this study. The details of the measurement instruments for the research variables are presented below:

3.2.4.1 The Measurement Instrument of Sustainable Leadership

The measurement scale for sustainable leadership consists of a 14-item instrument, which has been adapted and validated based on the updated version presented by Iqbal and Ahmad (2020). This revised 14-item instrument was developed to ensure a robust measurement framework, as it demonstrates strong internal consistency and reliability, making it suitable for research in various contexts.

In their study Sustainable Development: The Colors of Sustainable Leadership in Learning Organizations, Iqbal and Ahmad (2020) initially employed a 15-item sustainable leadership measurement originally proposed by McCann and Holt (2010). The original scale achieved a reliability statistic of 0.93, as reported by Al-Zawahreh et al. (2019). Nevertheless, Iqbal and Ahmad (2020) identified one item within the scale that exhibited a factor loading of less than 0.40. Recognizing the need for improvement, they removed this item to optimize the scale's psychometric properties, specifically enhancing the average variance extracted (AVE) of the sustainable leadership construct. After this refinement, the revised 14-item measurement instrument

attained a composite reliability of 0.922. Notably, this score represented the highest composite reliability among all constructs analyzed in their study, underscoring the scale's robust internal consistency and its reliability as a tool for measuring sustainable leadership. The 14-item instrument has since been adapted for use in the current research context, as illustrated in Table 5.

The scale items in the 14-item measurement instrument are evaluated using a five-point Likert scale. This scale ranges from 1 (Strongly Disagree) to 5 (Strongly Agree), providing a straightforward and effective means of assessing participants' perceptions. The Likert scale is structured as follows:

1=Strongly Disagree

2=Disagree

3=Neutral

4=Agree

5=Strongly Agree

Table 5 The measurement items of sustainable leadership

Constructs	Labels	Items
Sustainable Leadership	SL1	Our school leadership acts in a socially responsible and sustainable manner.
	SL2	Our school leadership acts in an environmentally responsible and sustainable manner.
	SL3	Our school leadership acts in an ethically responsible and sustainable manner.
	SL4	Our school leadership considers the entire school community when making important decisions.
	SL5	Our school leadership acknowledges and learns from

Constructs	Labels	Items
		mistakes that impact sustainability.
	SL6	Our school leadership is willing to correct mistakes that impact sustainability.
	SL7	Our school leadership attempts to use unique and innovative methods to address sustainability challenges.
	SL8	Our school leadership seeks to create lasting value through sustainable efforts.
	SL9	Our school leadership prioritizes the educational mission and the holistic development of students over financial gains.
	SL10	Our school leadership places purpose, including educational values and student well-being, before profit.
	SL11	Our school leadership perseveres in promoting sustainability through all types of changes and challenges.
	SL12	Our school leadership is concerned about how sustainability affects students and their learning environment.
	SL13	Our school leadership communicates sustainability-related decisions to all involved.
	SL14	Our school leadership strives to build a culture of sustainability by clearly communicating its goals and actions.

Note: The items were adapted from Iqbal and Ahmad (2020) to fit the current study.

3.2.4.2 The Measurement Instrument of ESD-Holism

The measurement scale for ESD-Holism consists of a 3-item instrument, which has been adopted from Boeve-de Pauw et al. (2015). This instrument assesses students' perceptions of ESD practices in schools, emphasizing a holistic integration of environmental, social, and economic dimensions along with temporal (past, present,

future) and geographical (local, regional, global) relationships. Developed to reflect ESD's foundational definition, which integrates sustainable development issues such as climate change, biodiversity, and poverty alleviation into participatory teaching and learning processes (UNESCO, 2012), the instrument includes items such as: (1) "In school, we look at the connections between the past, the present, and the future as regards various issues," (2) "In school, we look at both local and global problems and the connection between them," and (3) "In school, we look at how economics, social issues, and environmental problems are connected." Confirmatory factor analysis (CFA) confirmed its strong psychometric properties, with model fit indices of RMSEA=0.054, CFI=0.989, and TLI=0.982. This tool has been widely applied, including studies by Saqib et al. (2020) in Pakistan, which demonstrated strong reliability (Cronbach's alpha=0.73) and excellent model fit indices, and by Olsson et al. (2022) in Sweden, which highlighted its effectiveness in capturing ESD's impact on students' action competence for sustainability. Saleem et al. (2022) further validated its adaptability in Malaysian universities, where it exhibited strong psychometric properties across diverse demographics and educational contexts. Collectively, these findings underscore the reliability, validity, and versatility of the 3-item ESD-Holism measurement instrument for evaluating the implementation of holistic sustainability education worldwide. Table 6 illustrates the 3-items.

The scale items in the 3-item measurement instrument are evaluated using a five-point Likert scale. Followed Boeve-de Pauw et al. (2015), this scale ranges from 1 (Never) to 5 (Very Often), providing a straightforward and effective means of assessing participants' perceptions about ESD-holism in their school. The Likert scale is structured as follows:

1=Never

2=Seldom

3=Sometimes

4=Often

5=Very Often

Table 6 The measurement items of ESD-Holism

Constructs	Labels	Items
ESD-Holism	ESDH1	In school, we look at the connections between the past, the present, and the future as regards various issues.
	ESDH2	In school, we look at both local and global problems and the connection between them.
	ESDH3	In school, we look at how economics, social issues, and environmental problems are connected.

Source: Boeve-de Pauw et al. (2015).

3.2.4.3 The Measurement Instrument of ESD-Pluralism

The measurement scale for ESD- Pluralism consists of a 4-item instrument, which has been adopted from Boeve-de Pauw et al. (2015). This scale was designed to assess students' perceptions of pluralistic teaching approaches within Education for Sustainable Development (ESD), emphasizing the integration of diverse perspectives and participatory learning methods. ESD-Pluralism ensures that no single ethical standpoint or value dominates, fostering critical evaluation of alternative views, democratic engagement, and student autonomy in learning. The items include: (1) "When we have class discussions, it is possible for many different views to emerge," (2) "When we read texts in school, we usually take a critical look at the content," (3) "In school, we are encouraged to take a stand and have our own opinions on the issues at hand," and (4) "We decide what we study ourselves, with the support of the teacher." These items encapsulate the pluralistic ethos by promoting critical thinking, inclusivity, and collaboration. Psychometric testing through confirmatory factor analysis (CFA) demonstrated robust construct validity, with RMSEA=0.054, CFI=0.989, and TLI=0.982,

confirming its reliability and applicability. Studies have further validated the scale in various contexts. For example, Saqib et al. (2020) used it in Pakistan to assess sustainability perceptions in higher education institutions, reporting strong reliability (Cronbach's alpha=0.78) and excellent model fit indices. Similarly, Olsson et al. (2022) applied it in Sweden to explore the impact of pluralistic teaching on students' sustainability competencies, achieving consistently high CFA values in longitudinal analyses. In Malaysia, Saleem et al. (2022) adapted the scale for diverse academic participants and confirmed its strong psychometric properties across educational levels. These findings highlight the ESD-Pluralism scale's versatility and importance in evaluating pluralistic teaching practices globally, offering a robust framework for advancing sustainable education. Table 7 illustrates the 4-items.

The scale items in the 4-item measurement instrument are evaluated using a five-point Likert scale. Followed Boeve-de Pauw et al. (2015), this scale ranges from 1 (Never) to 5 (Very Often), providing a straightforward and effective means of assessing participants' perceptions about ESD-Pluralism in their school. The Likert scale is structured as follows:

1=Never

2=Seldom

3=Sometimes

4=Often

5=Very Often

Table 7 The measurement items of ESD-Pluralism

Constructs	Labels	Items
ESD-Pluralism	ESDP1	When we have class discussions, it is possible for many different views to emerge.
	ESDP2	When we read texts in school, we usually take a critical look at the content.
	ESDP3	In school, we are encouraged to take a stand and have our own opinions on the issues at hand.
	ESDP4	We decide what we study ourselves, with support of the teacher.

Source: Boeve-de Pauw et al. (2015).

3.2.4.4 The Measurement Instrument of Professional Action Competences in ESD

For the measurement instrument of pre-service teacher's professional action competence in ESD, this research selected Sass et al. (2022) professional action competence in ESD instrument, which consists of 31 items measuring three core features: ESD self-efficacy (10 items), which assesses teachers' confidence in working with ESD principles such as pluralism, holism, and action-orientedness; willingness to implement ESD (10 items), reflecting teachers' commitment and passion for ESD; and teachers' perceived pedagogical content knowledge (11 items), focusing on their skills and knowledge for implementing ESD using holistic, pluralistic, and action-oriented approaches. The PACesd framework is particularly valued for its clear emphasis on these three components: willingness, pedagogical knowledge, and self-efficacy which are crucial for equipping educators to integrate sustainable development principles into

their teaching. Unlike broader models such as the CSCT Competence Model or UNECE Framework, PACesd provides a more focused approach, which is practical for individual educator development. It supports educators in fostering critical thinking, active participation, and collaboration, and aligns well with the Sustainable Development Goals (SDGs). Psychometric evaluations using Confirmatory Factor Analysis (CFA) have shown strong reliability, with Cronbach's alpha values ranging from 0.84 to 0.96 and good model fit indices (RMSEA=0.077, CFI=0.964, TLI=0.961). The instrument's high factor loadings (0.609 to 0.965) and the strong association between pedagogical content knowledge and the overall PACesd factor underscore its validity in measuring professional action competence in ESD. Despite its strong individual-focused approach, the PACesd framework could benefit from more emphasis on group-based competence development, as seen in other models. This instrument has proven to be a valid and reliable tool for assessing teachers' professional action competence in ESD, providing a valuable resource for tracking and identifying professional development needs in formal education. Table 8 illustrates the 31 items and the 3 subconstructs.

The scale items in the 31 items measurement instrument are evaluated using a five-point Likert scale. This scale ranges from 1 (Strongly Disagree) to 5 (Strongly Agree), providing a straightforward and effective means of assessing participants' perceptions. The Likert scale is structured as follows:

1=Strongly Disagree

2=Disagree

3=Neutral

4=Agree

5=Strongly Agree

Table 8 The measurement items of professional action competence in ESD

Constructs	Labels	Items
Self-Efficacy Regarding ESD	SESD1	I am confident that as a teacher I can develop students' ability to view a problem from different points of view.
	SESD2	I am confident that as a teacher I can develop students' ability to weigh different solutions to sustainability issues.
	SESD3	I am confident that as a teacher I can develop students' ability to reflect on their own actions.
	SESD4	I am confident that as a teacher I can develop students' ability to express their own views on sustainability issues.
	SESD5	I am confident that as a teacher I can develop students' ability to understand the interconnectivity between the social, environmental and economic aspects of sustainable development.
	SESD6	I am confident that as a teacher I can make students realize that there are conflicting interests on the road to sustainable development.
	SESD7	I am confident that as a teacher I can make students realize that the road to sustainable development contains a high degree of uncertainty.
	SESD8	I am confident that as a teacher I can develop students' ability to act for sustainable development at a local level (e.g., in the school).
	SESD9	I am confident that as a teacher I can develop students' ability to act for sustainable development at a regional level (e.g., in the municipality).

Constructs	Labels	Items
	SESD10	I am confident that as a teacher I can develop students' ability to act globally for sustainable development (e.g., boycott certain goods).
Perceived Pedagogical Content Knowledge About ESD	PESD1	I am confident that as a teacher I can make Education for Sustainable Development happen in my class (es).
	PESD2	I am confident that as a teacher I can make Education for Sustainable Development happen in my school.
	PESD3	I am confident that as a teacher I can evaluate an ESD project I (we) have implemented.
	PESD4	I am confident that as a teacher I can address the environmental aspects of sustainability issues in my teaching.
	PESD5	I am confident that as a teacher I can address the social aspects of sustainability issues in my teaching.
	PESD6	I am confident that as a teacher I can address the socio-economic aspects of sustainability issues in my teaching.
	PESD7	I am confident that as a teacher I can address the global aspects of sustainability issues in my teaching.
	PESD8	I am confident that as a teacher I can work on sustainable development in the spirit of the attainment targets.
	PESD9	I am confident that as a teacher I can work across disciplines on sustainable development.
	PESD10	I am confident that as a teacher I can formulate learning objectives for my students regarding sustainable development.
	PESD11	I am confident that as a teacher I can have the flexibility to design learning environments to work on sustainability issues.

Constructs	Labels	Items
Willingness to Implement ESD	WESD1	Each day, I make sure that I have enough opportunities to dedicate myself to Education for Sustainable Development (ESD).
	WESD2	ESD is typically me.
	WESD3	ESD is close to my heart. Without ESD I wouldn't be myself.
	WESD4	Implementing ESD gives me energy.
	WESD5	I would try to plan my daily work so that I have as much time as possible to spend on ESD.
	WESD6	When I'm working on ESD, I experience that as an intense experience.
	WESD7	ESD will play an important role in my life.
	WESD8	I often feel a strong urge to work with ESD.
	WESD9	I am often really looking forward to working with ESD.
	WESD10	Many of my personal goals are related to ESD.

Source: Sass et al. (2022).

3.2.5 Research Questionnaire: English to Chinese Translation Process

Since the measurement scales for all research variables were derived from English literature, they were originally written in English. However, as the target participants for this study are pre-service teachers in Yunnan Province, China, it was essential to ensure accurate understanding and clarity by translating the questionnaires from English into Chinese. A rigorous three-step translation process was followed to ensure a precise Chinese version of the scale (Ægisdóttir et al., 2008). First, two graduates who majored in English, had passed the TEM-8 (Test for English Majors, Band 8), and held professional English translation certificates, independently translated

the scale into Chinese. Both of them had substantial experience in professional English translation after graduation, ensuring the accuracy of the translation. Any differences in the translations were discussed and adjusted for precision. Next, the Chinese version was translated back into English by two additional graduates, also with an English major, who had passed the TEM-8 and held professional translation certificates. Their strong proficiency in English helped ensure the accuracy of the back-translation. Finally, two experts, both holding doctoral degrees in English translation and specializing in advanced English translation, independently reviewed both the original English and back-translated Chinese versions. Adjustments were made step by step until no discrepancies remained, ensuring that the Chinese translation was both accurate and clear.

3.2.6 IOC for Content Validity

To ensure the content validity of the Likert scale questionnaire designed for this study, a systematic approach involving expert review was employed. Specifically, the researcher invited five experts to conduct validity tests using the Index of Item-Objective Congruence (IOC) as proposed by Rovinelli and Hambleton (1976). The experts were selected based on the following criteria:

1.Professional knowledge background in education management, ESD, or research methods.

2.Have experience in education management or teaching.

3.Extensive experience in questionnaire design and measurement.

These experts were rigorously screened and all possessed doctoral degrees and are professors in teacher training institutions. Since the target respondents are Chinese pre-service teachers, thus, after the translation of the questionnaire into formal Chinese, the combine version of English and Chinese were sent to three Chinese professor for IOC evaluation, and English version for 2 Thai professors for IOC evaluation. The experts' backgrounds covered education, management, and education development disciplines, and they had enough teaching and research experience in higher education. The IOC was used to systematically quantify the experts' agreement

on the relevance and clarity of the questionnaire's content, ensuring that it was not only theoretically sound but also practically relevant and clear to the respondents, thus improving the reliability and validity of the data.

Each expert evaluated the scale items using the IOC, where 1 indicated relevance, 0 indicated uncertainty, and -1 indicated irrelevance. If the IOC index of a specific scale item was greater than 0.5, it indicated that the item was qualified to measure the assigned variable. The formula to calculate the IOC is shown as follows:

$$IOC = \frac{\sum R}{N}$$

Where:

- IOC stands for the index of Item-Objective Congruence.
- $\sum R$ stands for the sum of the scores of all the 5 experts.
- N stands for the number of experts.

The IOC evaluation process was conducted by 5 experts during 5 December 2024 to 16 December 2024. The research gathered and combined all 5 experts IOC feedback on 16 December 2024, among the 5 experts, 4 of the experts evaluated with all the 52 items with all 1 score, which means the items were relevant to measure the assigned variable, only one expert evaluated 1 item (SL5) with 0, but evaluated other 51 items with 1. After calculated the IOC of the items, the IOC of the items range from 0.8 to 1, 51 of the items were scored with 1, with only one item (SL5) got 0.8 IOC score. In conclusion, since all the IOC of the 52 items were all far higher than the threshold IOC score of 0.5, thus, all the 52 were qualified items to measure the assigned variable. Table 9 shows the detail of the IOC evaluations.

Table 9 Expert Review Using the Index of Item Objective Congruence (IOC)

No.	Constructs	Labels	Experts					Sum	IOC	Decision
			1	2	3	4	5			
1	Sustainable Leadership	SL1	1	1	1	1	1	5	1	Qualified
2		SL2	1	1	1	1	1	5	1	Qualified
3		SL3	1	1	1	1	1	5	1	Qualified
4		SL4	1	1	1	1	1	5	1	Qualified
5		SL5	1	1	0	1	1	4	0.8	Qualified
6		SL6	1	1	1	1	1	5	1	Qualified
7		SL7	1	1	1	1	1	5	1	Qualified
8		SL8	1	1	1	1	1	5	1	Qualified
9		SL9	1	1	1	1	1	5	1	Qualified
10		SL10	1	1	1	1	1	5	1	Qualified
11		SL11	1	1	1	1	1	5	1	Qualified
12		SL12	1	1	1	1	1	5	1	Qualified
13		SL13	1	1	1	1	1	5	1	Qualified
14		SL14	1	1	1	1	1	5	1	Qualified
15	ESD-Holism	ESDH1	1	1	1	1	1	5	1	Qualified
16		ESDH2	1	1	1	1	1	5	1	Qualified

No.	Constructs	Labels	Experts					Sum	IOC	Decision
17		ESDH3	1	1	1	1	1	5	1	Qualified
18	ESD-Pluralism	ESDP1	1	1	1	1	1	5	1	Qualified
19		ESDP2	1	1	1	1	1	5	1	Qualified
20		ESDP3	1	1	1	1	1	5	1	Qualified
21		ESDP4	1	1	1	1	1	5	1	Qualified
22	Self-Efficacy Regarding ESD	SESD1	1	1	1	1	1	5	1	Qualified
23		SESD2	1	1	1	1	1	5	1	Qualified
24		SESD3	1	1	1	1	1	5	1	Qualified
25		SESD4	1	1	1	1	1	5	1	Qualified
26		SESD5	1	1	1	1	1	5	1	Qualified
27		SESD6	1	1	1	1	1	5	1	Qualified
28		SESD7	1	1	1	1	1	5	1	Qualified
29		SESD8	1	1	1	1	1	5	1	Qualified
30		SESD9	1	1	1	1	1	5	1	Qualified
31		SESD10	1	1	1	1	1	5	1	Qualified
32	Perceived Pedagogical Content Knowledge About ESD	PESD1	1	1	1	1	1	5	1	Qualified
33		PESD2	1	1	1	1	1	5	1	Qualified
34		PESD3	1	1	1	1	1	5	1	Qualified
35		PESD4	1	1	1	1	1	5	1	Qualified

No.	Constructs	Labels	Experts					Sum	IOC	Decision
36		PESD5	1	1	1	1	1	5	1	Qualified
37		PESD6	1	1	1	1	1	5	1	Qualified
38		PESD7	1	1	1	1	1	5	1	Qualified
39		PESD8	1	1	1	1	1	5	1	Qualified
40		PESD9	1	1	1	1	1	5	1	Qualified
41		PESD10	1	1	1	1	1	5	1	Qualified
42		PESD11	1	1	1	1	1	5	1	Qualified
43	Willingness to Implement ESD	WESD1	1	1	1	1	1	5	1	Qualified
44		WESD2	1	1	1	1	1	5	1	Qualified
45		WESD3	1	1	1	1	1	5	1	Qualified
46		WESD4	1	1	1	1	1	5	1	Qualified
47		WESD5	1	1	1	1	1	5	1	Qualified
48		WESD6	1	1	1	1	1	5	1	Qualified
49		WESD7	1	1	1	1	1	5	1	Qualified
50		WESD8	1	1	1	1	1	5	1	Qualified
51		WESD9	1	1	1	1	1	5	1	Qualified
52		WESD10	1	1	1	1	1	5	1	Qualified

3.2.7 Pilot Test

After the research questionnaire passed the content validity test, however, since one expert recommend to slightly revised some items to fit the current research context for pre-service teacher. Therefore, the researcher conducted in-depth interview with three respondents to try to revised the items based on the target respondents perspective, finally, the target respondents felt 50 of the items were easy to answer, but 2 items (WESD5 and WESD6) were hard to answer, because the two items were specified for in-service teacher, pre-service teachers are not in work, thus, the research remain the original meaning of the 2 items, but slightly revised the items for pre-service teacher, after slightly adapted WESD5 from “I would try to plan my daily work so that I have as much time as possible to spend on ESD.” to be “I would try to plan my daily activities so that I have as much time as possible to spend on ESD”, and slightly adapted WESD6 from “When I’m working on ESD, I experience that as an intense experience” to be “When I engage with ESD, I experience that as an intense experience”, all the three target respondents all agreed that after the adaption they felt much easier to respond. The final qualified questionnaire was used to conduct a pretest with 100 samples. Conducting a pretest is a crucial step in the research process to ensure the reliability and validity of the measurement instruments. By administering the finalized questionnaire to a sample of 100 participants, researchers can assess the internal consistency of the constructs using Cronbach's alpha, where a value exceeding 0.8 indicates that the constructs are reliable and exhibit strong internal consistency. This step is critical to confirm that the items within each construct consistently measure the intended underlying concept. The pilot test was from 17 December 2024 to 21 December 2024.

Selection of Pilot Sample

Researchers typically select a small sample of the target population or individuals similar to the participant group to participate in the pilot test. This sample should represent the demographics and characteristics of the questionnaire respondents. In this study, 100 pre-service teachers from normal universities in Yunnan Province, China, were selected for the pilot test.

Conducting the Questionnaire

The researcher distributed the first draft of the questionnaire to the pilot sample according to the requirements and procedures of the research design. Participants were asked to complete the questionnaire and provide their feedback and suggestions during the survey.

Collecting and Collating Feedback

After completing the questionnaire, the researcher collected and collated feedback and suggestions from the participants regarding various aspects of the questionnaire. This mainly included comments on the clarity, relevance, wording, options, and overall structure of the questions in the questionnaire.

Revision of the Questionnaire

The researcher carefully analyzed the feedback collected from the pilot test to identify possible problems or areas for improvement in the questionnaire. Based on this feedback, the researcher revised the content of the questions, which mainly included rewriting the expression of items, adding or deleting items, or making other adjustments to improve the overall reliability and validity of the questionnaire.

3.2.7.1 Pilot Test Methods

The population for this study comprised pre-service teachers enrolled in teacher training programs at six universities in Yunnan Province, China. These universities included Yunnan Normal University, Kunming University, Qujing Normal University, Chuxiong Normal University, Zhaotong University, and Honghe University.

To collect data, an offline questionnaire method was employed. The researcher recruited two pre-service teachers from each university (a total of 12 individuals) through personal connections to assist in distributing the questionnaires to the target sample until 100 valid responses were obtained. To ensure that the pretest sample accurately reflected the population distribution across the six universities, the required allocation was as follows: Yunnan Normal University (33), Kunming University (21), Qujing Normal University (12), Chuxiong Normal University (11), Zhaotong University (13), and Honghe University (10). Once each university's questionnaire collectors collected the valid and complete target questionnaires followed the require

allocation, they inserted the questionnaire data into excel file and then sent to the researcher, the researcher then merge all the questionnaire data in one file for pretest analysis.

To improve representativeness and accessibility, a convenience sampling method was initially applied to recruit participants who were readily available and willing to participate, such as those attending university events, classes, or online platforms. Additionally, snowball sampling was used to expand the sample size by encouraging initial participants to refer other eligible pre-service teachers from their networks. This combined approach addressed logistical challenges and ensured a diverse representation of pre-service teachers across the six universities.

For the pretest analysis, data from 100 valid questionnaires were analyzed to assess the reliability and validity of the questionnaire, ensuring its clarity, structure, and statistical robustness. Statistical analysis was conducted using SPSS software.

To evaluate the reliability of the scale, the internal consistency analysis technique was applied using Cronbach's α coefficient, a widely used measure of internal consistency. Cronbach's α determines how closely related a set of items are as a group, providing an indicator of scale reliability. The following thresholds were used to interpret the results (Sharma, 2016):

- Cronbach's $\alpha > 0.9$: Excellent reliability
- Cronbach's $\alpha > 0.8$: Good reliability
- Cronbach's $\alpha > 0.7$: Acceptable reliability

During the pretest analysis, Cronbach's α for the entire scale was calculated. If the value fell below the acceptable threshold, problematic items were identified for potential removal to enhance overall reliability. To further refine the scale, item analysis was performed. This involved evaluating the impact of each item on the overall reliability using two key indicators:

1.Corrected Item-Total Correlation (CITC): CITC measures the correlation between an individual item and the total score of the scale (excluding the item itself). Higher CITC values indicate better alignment with the overall scale. Items with CITC values below 0.3 were flagged for potential removal (Cristobal et al., 2007).

2.Cronbach's α if Item Deleted: This measure indicates the Cronbach's α value if a specific item is removed. If deleting an item result in a higher overall Cronbach's α, the item is considered misaligned with the scale and may be removed.

To assess the construct validity of the scale, exploratory factor analysis (EFA) was conducted. The appropriateness of EFA was determined by examining the Kaiser-Meyer-Olkin (KMO) value and Bartlett's sphericity test. Specifically:

- A KMO value above 0.8 indicated sampling adequacy for factor analysis (Howard, 2016).

- A statistical significance ($p < 0.05$) for Bartlett's sphericity test confirmed the suitability of the data for factor extraction (Howard, 2016).

The principal component analysis (PCA) method with varimax rotation was used to identify the underlying structure of the scale. Components with eigenvalues greater than one were extracted (Howard, 2016), as they met the established criterion for factor retention.

3.2.7.2 Descriptive Statistical of Pretest Respondents

The demographic profile of the pretest respondents is presented in Table 10, detailing their distribution across universities, gender, age, and academic year. Respondents were drawn from six universities, with the largest representation from Yunnan Normal University (33.00%), followed by Kunming University (21.00%), Zhaotong University (13.00%), Qujing Normal University (12.00%), Chuxiong Normal University (11.00%), and Honghe University (10.00%). Regarding gender, the sample was fairly balanced, with 48% male respondents and 52% female respondents. In terms of age, the majority fell within the 20-21 age group (32.00%), followed by 22-23 years (30.00%), 18-19 years (20.00%), and a smaller proportion aged 24 or older (18.00%).

The distribution of respondents across academic years indicates that 27% were in their second year, followed by 25% in the fourth year, and an equal proportion of 24% each in the first year and third year. This demographic profile highlights a well-rounded and diverse sample, reflecting variations in institutional affiliation, gender, age, and academic progression, providing a robust foundation for subsequent analyses.

Table 10 Descriptive Statistical of Pretest Respondents

Demographics	Items	Frequency	Percentage (%)
Universities	Yunnan Normal University	33	33.00
	Kunming University	21	21.00
	Qujing Normal University	12	12.00
	Chuxiong Normal University	11	11.00
	Zhaotong University	13	13.00
	Honghe University	10	10.00
	Total	100	100.00
Gender	Male	48	48.00
	Female	52	52.00
Age	18-19	20	20.00
	20-21	32	32.00
	22-23	30	30.00
	24 or older	18	18.00
	Total	100	100.00
Academic year	First year	24	24.00
	Second year	27	27.00
	Third year	24	24.00
	Fourth year	25	25.00
	Total	100	100.00

3.2.7.3 Reliability Analysis of Pretest Data

The Reliability Analysis of the Overall Scale Items of Pretest Samples

Cronbach's alpha is a commonly used statistic for evaluating the reliability of psychometric tests. Generally, values exceeding 0.7 are considered to indicate acceptable reliability, values from 0.8 to 0.9 are regarded as demonstrating good reliability, and values exceeding 0.9 are considered to indicate excellent reliability (Sharma, 2016).

As illustrated in Table 11, the overall 52-item questionnaire achieved a Cronbach's alpha of 0.969. According to widely accepted standards in the literature, values above 0.7 are considered to indicate acceptable reliability, while values exceeding 0.8 are seen as indicative of good reliability (Sharma, 2016). Consequently, the obtained Cronbach's alpha value of 0.969 signifies that the questionnaire exhibits excellent reliability, suggesting a high degree of internal consistency among the items. This high level of reliability supports the use of the questionnaire for assessing the targeted constructs in this study.

To further assess the reliability of individual scale items, Corrected Item-Total Correlation (CITC) and Cronbach's alpha if an item was deleted were examined. According to Cristobal et al. (2007), CITC values below 0.30 are considered unacceptable. As shown in Table 11, all items had CITC values well above this threshold, with the lowest value being 0.384 and the highest 0.730, indicating that all items were consistent with the overall scale. The analysis of Cronbach's alpha if an item was deleted revealed values that were very close to the overall Cronbach's alpha of 0.969. This result indicates that removing any individual item would not significantly affect the scale's reliability. Specifically, for all 52 items, the Cronbach's alpha values remained stable, suggesting that no single item negatively impacted the internal consistency of the scale. In conclusion, the analysis confirmed that the 52-item scale demonstrates excellent reliability, with all items exhibiting high CITC values and negligible impact on Cronbach's alpha if deleted. Therefore, it is recommended to retain all 52 items in the questionnaire.

Table 11 The Overall Reliability Analysis of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
SL1	196.55	825.482	0.654	0.969	0.969	52
SL2	196.57	819.985	0.721	0.968		
SL3	196.61	824.543	0.609	0.969		
SL4	196.58	828.792	0.622	0.969		
SL5	196.53	821.625	0.730	0.968		
SL6	196.58	825.438	0.664	0.969		
SL7	196.56	829.703	0.565	0.969		
SL8	196.64	821.425	0.712	0.968		
SL9	196.64	823.970	0.689	0.968		
SL10	196.62	821.369	0.682	0.968		
SL11	196.64	824.031	0.678	0.968		
SL12	196.66	824.570	0.629	0.969		
SL13	196.70	826.253	0.614	0.969		
SL14	196.63	826.983	0.611	0.969		
ESDH1	196.53	836.575	0.393	0.969		
ESDH2	196.34	832.429	0.467	0.969		
ESDH3	196.50	835.081	0.384	0.969		
ESDP1	196.68	827.654	0.589	0.969		
ESDP2	196.63	826.013	0.614	0.969		
ESDP3	196.67	823.153	0.647	0.969		
ESDP4	196.58	823.297	0.662	0.969		
SESD1	196.36	833.586	0.511	0.969		
SESD2	196.47	831.039	0.547	0.969		

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
SESD3	196.45	833.765	0.483	0.969		
SESD4	196.45	833.705	0.484	0.969		
SESD5	196.43	835.763	0.455	0.969		
SESD6	196.40	827.960	0.621	0.969		
SESD7	196.43	830.672	0.530	0.969		
SESD8	196.47	832.252	0.508	0.969		
SESD9	196.44	829.602	0.563	0.969		
SESD10	196.42	827.862	0.574	0.969		
PESD1	196.39	829.836	0.501	0.969		
PESD2	196.30	824.778	0.702	0.968		
PESD3	196.41	828.022	0.540	0.969		
PESD4	196.33	829.637	0.574	0.969		
PESD5	196.34	826.146	0.615	0.969		
PESD6	196.35	832.129	0.501	0.969		
PESD7	196.32	829.311	0.561	0.969		
PESD8	196.38	827.147	0.629	0.969		
PESD9	196.37	823.528	0.699	0.968		
PESD10	196.39	825.877	0.633	0.969		
PESD11	196.35	825.907	0.650	0.969		
WESD1	196.65	816.997	0.725	0.968		
WESD2	196.66	821.621	0.677	0.968		
WESD3	196.72	820.183	0.712	0.968		
WESD4	196.63	817.710	0.724	0.968		
WESD5	196.56	819.825	0.701	0.968		
WESD6	196.60	819.273	0.718	0.968		

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
WESD7	196.68	828.664	0.528	0.969		
WESD8	196.71	823.602	0.625	0.969		
WESD9	196.71	818.854	0.690	0.968		
WESD10	196.77	824.906	0.595	0.969		

The Reliability Analysis of Sustainable Leadership Construct of Pretest

According to Table 12, the Sustainable Leadership Construct consists of 14 items, with an overall Cronbach's alpha of 0.976, indicating excellent internal consistency. A Corrected Item-Total Correlation (CITC) value below 0.30 is typically considered unacceptable (Cristobal et al., 2007; Shan & Li, 2012). In this case, all items demonstrated CITC values well above the threshold, ranging from 0.777 (SL7) to 0.939 (SL5), confirming that each item contributes positively to the scale's reliability. The analysis of Cronbach's alpha if an item was deleted showed values ranging from 0.973 to 0.976, all very close to the overall alpha of 0.976. This result suggests that removing any individual item would not significantly improve the scale's reliability. Therefore, the 14-item scale of Sustainable Leadership Construct demonstrates excellent reliability, with all items showing high CITC values and minimal changes in Cronbach's alpha if deleted. Consequently, there is no need to remove any items from the scale.

Table 12 Reliability Analysis of Sustainable Leadership Construct of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
SL1	48.98	101.757	0.858	0.974	0.976	14
SL2	49.00	100.040	0.905	0.973		
SL3	49.04	101.453	0.789	0.976		
SL4	49.01	103.000	0.834	0.975		
SL5	48.96	100.382	0.939	0.973		
SL6	49.01	101.404	0.894	0.974		
SL7	48.99	103.020	0.777	0.976		
SL8	49.07	100.934	0.876	0.974		
SL9	49.07	101.439	0.884	0.974		
SL10	49.05	100.472	0.863	0.974		
SL11	49.07	102.046	0.834	0.975		
SL12	49.09	101.012	0.843	0.974		
SL13	49.13	102.256	0.795	0.975		
SL14	49.06	101.653	0.848	0.974		

The Reliability Analysis of ESD-Holism Construct of Pretest

According to Table 13, the ESD-Holism Construct consists of 3 items, with an overall Cronbach's alpha of 0.802, indicating excellent internal consistency. A Corrected Item-Total Correlation (CITC) value below 0.30 is typically considered unacceptable (Cristobal et al., 2007; Shan & Li, 2012). In this case, all items demonstrated CITC values well above the threshold, ranging from 0.642 (ESDH1) to 0.655 (ESDH3), confirming that each item contributes positively to the scale's reliability.

The analysis of Cronbach's alpha if an item was deleted showed values ranging from 0.725 to 0.736, all lower than the overall alpha of 0.802. This result suggests that removing any individual item would not significantly improve the scale's reliability. Therefore, the 3-item scale of ESD-Holism Construct demonstrates excellent reliability, with all items showing high CITC values and minimal changes in Cronbach's alpha if deleted. Consequently, there is no need to remove any items from the scale.

Table 13 Reliability Analysis of ESD-Holism Construct of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
ESDH1	7.92	3.044	0.642	0.736	0.802	3
ESDH2	7.73	3.007	0.650	0.728		
ESDH3	7.89	2.766	0.655	0.725		

The Reliability Analysis of ESD-Pluralism Construct of Pretest

According to Table 14, the ESD-Pluralism Construct consists of 4 items, with an overall Cronbach's alpha of 0.942, indicating excellent internal consistency. A Corrected Item-Total Correlation (CITC) value below 0.30 is typically considered unacceptable (Cristobal et al., 2007; Shan & Li, 2012). In this case, all items demonstrated CITC values well above the threshold, ranging from 0.847 (ESDP1) to 0.876 (ESDP2), confirming that each item contributes positively to the scale's reliability. The analysis of Cronbach's alpha if an item was deleted showed values ranging from 0.920 to 0.929, all lower than the overall alpha of 0.942. This result suggests that removing any individual item would not significantly improve the scale's reliability. Therefore, the 4-item scale of ESD-Pluralism Construct demonstrates excellent reliability,

with all items showing high CITC values and minimal changes in Cronbach's alpha if deleted. Consequently, there is no need to remove any items from the scale.

Table 14 Reliability Analysis of ESD-Pluralism Construct of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
ESDP1	11.26	6.619	0.847	0.929	0.942	4
ESDP2	11.21	6.471	0.876	0.920		
ESDP3	11.25	6.371	0.861	0.925		
ESDP4	11.16	6.479	0.864	0.924		

The Reliability Analysis of Self-Efficacy Regarding ESD Construct of Pretest

According to Table 15, the Self-Efficacy Regarding ESD Construct consists of 10 items, with an overall Cronbach's alpha of 0.955, indicating excellent internal consistency. A Corrected Item-Total Correlation (CITC) value below 0.30 is typically considered unacceptable (Cristobal et al., 2007; Shan & Li, 2012). In this case, all items demonstrated CITC values well above the threshold, ranging from 0.720 (SESD4) to 0.922 (SESD6), confirming that each item contributes positively to the scale's reliability. The analysis of Cronbach's alpha if an item was deleted showed values ranging from 0.946 to 0.954, all lower than the overall alpha of 0.955. This result suggests that removing any individual item would not significantly improve the scale's reliability. Therefore, the 10-item scale of Self-Efficacy Regarding ESD Construct demonstrates excellent reliability, with all items showing high CITC values and minimal changes in Cronbach's alpha if deleted. Consequently, there is no need to remove any items from the scale.

Table 15 Reliability Analysis of Self-Efficacy Regarding ESD Construct of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
SESD1	35.46	43.443	0.855	0.949	0.955	10
SESD2	35.57	44.005	0.771	0.952		
SESD3	35.55	44.270	0.731	0.954		
SESD4	35.55	44.391	0.720	0.954		
SESD5	35.53	44.353	0.746	0.953		
SESD6	35.5	42.636	0.922	0.946		
SESD7	35.53	42.918	0.834	0.949		
SESD8	35.57	43.621	0.783	0.951		
SESD9	35.54	43.079	0.838	0.949		
SESD10	35.52	42.495	0.856	0.948		

The Reliability Analysis of Perceived Pedagogical Content Knowledge About ESD Construct of Pretest

According to Table 16, the Perceived Pedagogical Content Knowledge About ESD Construct consists of 11 items, with an overall Cronbach's alpha of 0.967, indicating excellent internal consistency. A Corrected Item-Total Correlation (CITC) value below 0.30 is typically considered unacceptable (Cristobal et al., 2007; Shan & Li, 2012). In this case, all items demonstrated CITC values well above the threshold, ranging from 0.740 (PESD7) to 0.925 (PESD9), confirming that each item contributes positively to the scale's reliability. The analysis of Cronbach's alpha if an item was deleted showed values ranging from 0.961 to 0.967, all lower or close the overall alpha of 0.967. This result suggests that removing any individual item would not

significantly improve the scale's reliability. Therefore, the 11-item scale of Perceived Pedagogical Content Knowledge About ESD Construct demonstrates excellent reliability, with all items showing high CITC values and minimal changes in Cronbach's alpha if deleted. Consequently, there is no need to remove any items from the scale.

Table 16 Reliability Analysis of Perceived Pedagogical Content Knowledge About ESD Construct of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
PESD1	40.26	59.002	0.774	0.966	0.967	11
PESD2	40.17	59.294	0.904	0.962		
PESD3	40.28	59.517	0.746	0.967		
PESD4	40.2	60.081	0.801	0.965		
PESD5	40.21	58.713	0.868	0.963		
PESD6	40.22	59.769	0.789	0.965		
PESD7	40.19	60.479	0.740	0.967		
PESD8	40.25	59.038	0.893	0.962		
PESD9	40.24	58.568	0.925	0.961		
PESD10	40.26	58.598	0.895	0.962		
PESD11	40.22	58.739	0.911	0.962		

The Reliability Analysis of Willingness to Implement ESD Construct of Pretest

According to Table 17, the Willingness to Implement ESD Construct consists of 10 items, with an overall Cronbach's alpha of 0.978, indicating excellent

internal consistency. A Corrected Item-Total Correlation (CITC) value below 0.30 is typically considered unacceptable (Cristobal et al., 2007; Shan & Li, 2012). In this case, all items demonstrated CITC values well above the threshold, ranging from 0.788 (WESD7) to 0.936 (WESD5), confirming that each item contributes positively to the scale's reliability. The analysis of Cronbach's alpha if an item was deleted showed values ranging from 0.975 to 0.980, all close the overall alpha of 0.978. This result suggests that removing any individual item would not significantly improve the scale's reliability. Therefore, the 10-item scale of Willingness to Implement ESD Construct demonstrates excellent reliability, with all items showing high CITC values and minimal changes in Cronbach's alpha if deleted. Consequently, there is no need to remove any items from the scale.

Table 17 Reliability Analysis of Willingness to Implement ESD Construct of Pretest

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	N of Items
WESD1	33.38	61.450	0.911	0.976	0.978	10
WESD2	33.39	62.018	0.924	0.975		
WESD3	33.45	62.250	0.917	0.975		
WESD4	33.36	61.505	0.923	0.975		
WESD5	33.29	61.642	0.936	0.975		
WESD6	33.33	61.860	0.930	0.975		
WESD7	33.41	63.497	0.788	0.980		
WESD8	33.44	62.431	0.870	0.977		
WESD9	33.44	61.421	0.911	0.976		
WESD10	33.5	62.758	0.838	0.978		

3.7.4 The Exploratory Factor Analysis of Pretest Data

To evaluate the validity of the pretest scale used in this present research, an Exploratory Factor Analysis (EFA) was performed using SPSS. EFA is a statistical technique employed to reveal the underlying structure of a large set of variables. It aids in identifying the number of latent constructs and the underlying factor structure without imposing a preconceived structure on the outcome. In this current research, the pretest scale consists of 52 items across six latent constructs: Sustainable Leadership (14 items), ESD-Holism (3 items), ESD-Pluralism (4 items), Self-Efficacy Regarding ESD (10 items), Perceived Pedagogical Content Knowledge About ESD (11 items), and Willingness to Implement ESD (10 items).

The criteria for conducting a robust EFA include ensuring that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is greater than 0.8, indicating that the sample is adequate for factor analysis (Howard, 2016). Additionally, Bartlett's test of sphericity should have a p-value less than 0.05, suggesting that the variables are sufficiently correlated to provide a reasonable basis for factor analysis (Howard, 2016). Factor loadings, which represent the correlation between the observed variables and the latent factors, should ideally be greater than 0.7 to confirm that the variables strongly contribute to the factor (Evers et al., 2013). Eigenvalues, which indicate the amount of variance explained by each factor, should be greater than 1 to be considered significant (Howard, 2016).

Table 18 reveals that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.842. This value signifies that the pretest sample was appropriate for conducting factor analysis. Additionally, Bartlett's test of sphericity produced a p-value of less than 0.001, further confirming the suitability of the data for factor analysis. These results indicate that the sample was adequate and the variables were sufficiently correlated, making it feasible to proceed with the factor analysis.

Table 18 KMO and Bartlett's Test of Pretest Data

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.842
Bartlett's Test of Sphericity	Approx. Chi-Square	6528.432
	df	1326
	Sig.	0.000

Consequently, a factor analysis was conducted using principal component analysis. The results, as presented in Table 19, indicate that all 52 scale items were grouped into six primary constructs or factors, which align with the theoretical framework of this research. This classification is substantiated by the presence of only six components with eigenvalues exceeding 1. These six components collectively accounted for 78.10% of the total variance, which is considered high. This high percentage of explained variance underscores the robustness of the factor structure and supports the validity of the constructs being measured in this study.

Table 19 Total Variance Explained of Pretest Data

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	20.74	39.88	39.88	20.74	39.88	39.88	11.34	21.81	21.81
2	8.27	15.91	55.79	8.27	15.91	55.79	8.51	16.37	38.18
3	5.34	10.27	66.06	5.34	10.27	66.06	8.48	16.32	54.49
4	2.77	5.33	71.39	2.77	5.33	71.39	7.29	14.03	68.52
5	1.95	3.75	75.15	1.95	3.75	75.15	2.81	5.41	73.93
6	1.54	2.96	78.10	1.54	2.96	78.10	2.17	4.17	78.10

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
7	0.96	1.84	79.94						
8	0.81	1.56	81.51						
9	0.72	1.39	82.90						
10	0.69	1.33	84.23						
11	0.65	1.24	85.47						
12	0.56	1.08	86.55						
13	0.50	0.97	87.52						
14	0.46	0.89	88.41						
15	0.46	0.88	89.28						
16	0.44	0.85	90.14						
17	0.39	0.75	90.89						
18	0.36	0.69	91.58						
19	0.34	0.65	92.23						
20	0.32	0.62	92.85						
21	0.30	0.57	93.42						
22	0.28	0.53	93.96						
23	0.25	0.47	94.43						
24	0.24	0.47	94.89						
25	0.22	0.42	95.31						
26	0.22	0.41	95.73						
27	0.20	0.39	96.11						
28	0.19	0.37	96.48						
29	0.18	0.35	96.83						
30	0.16	0.31	97.14						

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
31	0.15	0.29	97.43						
32	0.14	0.27	97.70						
33	0.14	0.26	97.96						
34	0.13	0.25	98.21						
35	0.10	0.20	98.41						
36	0.09	0.18	98.59						
37	0.09	0.17	98.76						
38	0.09	0.16	98.92						
39	0.08	0.15	99.07						
40	0.07	0.14	99.21						
41	0.07	0.13	99.33						
42	0.06	0.11	99.44						
43	0.05	0.10	99.54						
44	0.05	0.09	99.63						
45	0.04	0.08	99.72						
46	0.04	0.07	99.79						
47	0.03	0.06	99.85						
48	0.03	0.05	99.90						
49	0.02	0.04	99.94						
50	0.01	0.02	99.96						
51	0.01	0.02	99.98						
52	0.01	0.02	100.00						

The scree plot generated from EFA is show in figure 3. The scree plot displays the eigenvalues on the y-axis and the factor numbers on the x-axis. The first few factors have high eigenvalues, indicating that they explain a significant portion of the variance in the data. The plot shows a clear "elbow" at the sixth factor, which is the point where the slope of the curve levels off, suggesting that additional factors beyond this point contribute minimally to the explained variance. According to the scree plot, the first six factors have eigenvalues greater than 1, which aligns with the current theoretical framework. These six factors together explain 78.10% of the cumulative variance, indicating a strong factor structure. Based on the scree plot, it is concluded that retaining six factors is appropriate for the current analysis. This supports the validity of the constructs being measured and confirms that the items are grouped into meaningful factors.

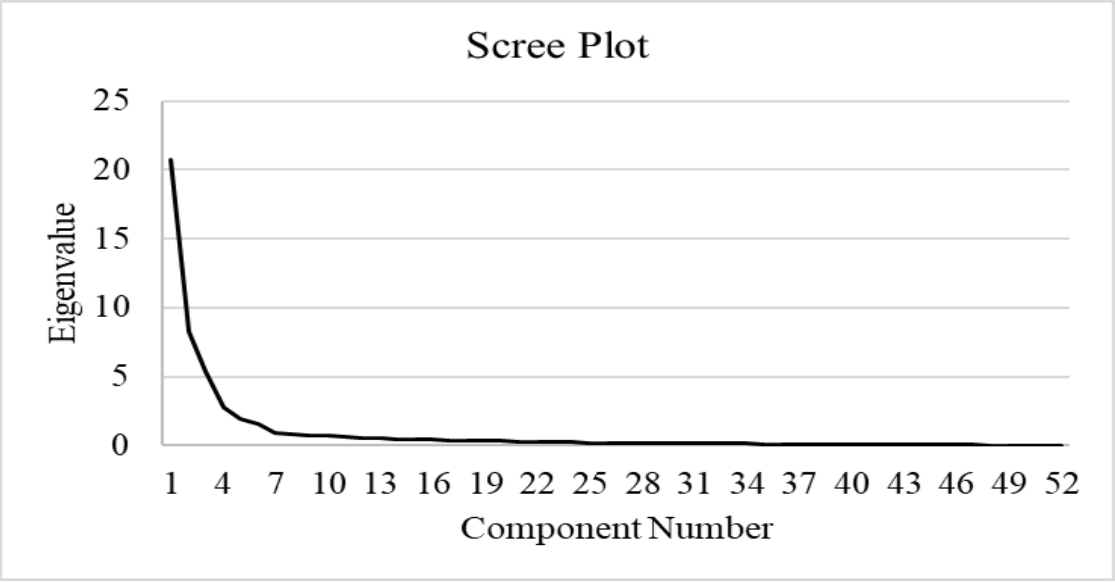

Figure 3 Scree Plot of Pretest

To enhance the clarity of factor loadings, the Varimax rotation matrix was utilized in the Exploratory Factor Analysis (EFA). Varimax rotation, an orthogonal method, optimizes the sum of the variances of the squared loadings. This technique simplifies the factor structure by increasing high loadings and decreasing low loadings on each factor (Acal et al., 2020). It is widely favored in EFA for its orthogonality, simplicity, and the clear interpretation it provides for factor loadings (Osborne, 2015). Varimax rotation is particularly effective in producing a clear and easily interpretable factor structure, which is essential for comprehending the latent variables identified through EFA.

As shown Table 20, the Rotated Component Matrix showed that all scale item loadings were 0.7 or higher. This high level of loading indicates a strong association between the scale items and their respective theoretical constructs: Sustainable Leadership (14 items), ESD-Holism (3 items), ESD-Pluralism (4 items), Self-Efficacy Regarding ESD (10 items), Perceived Pedagogical Content Knowledge About ESD (11 items), and Willingness to Implement ESD (10 items). It is important to note that loadings below 0.4 were excluded from the analysis.

Table 20 Rotated Component Matrix of Pretest

	Component					
	1	2	3	4	5	6
SL1	0.829					
SL2	0.869					
SL3	0.775					
SL4	0.817					
SL5	0.899					
SL6	0.876					
SL7	0.776					
SL8	0.834					
SL9	0.845					

	Component					
	1	2	3	4	5	6
SL10	0.823					
SL11	0.805					
SL12	0.851					
SL13	0.795					
SL14	0.847					
ESDH1						0.787
ESDH2						0.731
ESDH3						0.801
ESDP1					0.782	
ESDP2					0.789	
ESDP3					0.753	
ESDP4					0.745	
SESD1				0.841		
SESD2				0.730		
SESD3				0.748		
SESD4				0.724		
SESD5				0.745		
SESD6				0.862		
SESD7				0.826		
SESD8				0.774		
SESD9				0.822		
SESD10				0.821		
PESD1			0.777			
PESD2			0.841			
PESD3			0.725			

	Component					
	1	2	3	4	5	6
PESD4			0.795			
PESD5			0.846			
PESD6			0.807			
PESD7			0.723			
PESD8			0.850			
PESD9			0.860			
PESD10			0.867			
PESD11			0.871			
WESD1		0.846				
WESD2		0.879				
WESD3		0.850				
WESD4		0.852				
WESD5		0.878				
WESD6		0.863				
WESD7		0.805				
WESD8		0.857				
WESD9		0.862				
WESD10		0.827				

In summary, the Exploratory Factor Analysis (EFA) conducted on the pretest samples validated that all 52 scale items were accurately categorized into six primary constructs, aligning with the theoretical framework of this study. The EFA revealed six components with eigenvalues exceeding 1, collectively accounting for 78.10% of the total variance, which signifies a substantial explanatory power. The Rotated Component Matrix indicated that all scale items had loadings of 0.7 or higher, confirming strong

correlations with their respective constructs: Sustainable Leadership (14 items), ESD-Holism (3 items), ESD-Pluralism (4 items), Self-Efficacy Regarding ESD (10 items), Perceived Pedagogical Content Knowledge About ESD (11 items), and Willingness to Implement ESD (10 items). This high level of internal consistency highlights the robustness of the constructs and supports the reliability of the scale for assessing the targeted variables in this research. Consequently, the validated questionnaire is appropriate for further data collection from the target population, facilitating comprehensive final data analysis.

3.2.8 Data Analysis Methods

The final data analysis for this research employs a combination of descriptive statistics, Exploratory Factor Analysis (EFA), and Partial Least Squares Structural Equation Modeling (PLS-SEM). These methods were selected to ensure a comprehensive analysis of the data and address the research objectives effectively. The detailed explanation of each method is as follows:

3.2.8.1 Descriptive Statistics

Descriptive statistics provide a foundational overview of the dataset by summarizing its key characteristics. This includes the calculation of frequency, which identifies the number of occurrences for each category or response, offering insight into patterns and trends. Percentages are used to express relative frequencies, enabling an understanding of proportional distributions across categories. The mean (M), or arithmetic average, represents the central tendency of the data, indicating the typical value for a variable, while the standard deviation (SD) measures the dispersion or spread of values around the mean, highlighting variability within the responses. Together, these statistical measures allow the researcher to evaluate the distribution, trends, and variability within the dataset, ensuring a solid foundation for more complex analyses.

3.2.8.2 Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis (EFA) is a statistical technique utilized to identify the underlying structure of a large set of variables, uncovering latent constructs and their associated factor structures without imposing a predefined framework. To

ensure the robustness of EFA, several criteria must be met. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy should exceed 0.8, indicating a sufficient sample for factor analysis (Hoffman et al., 2022; Sjölander & Greenland, 2022). Bartlett's test of sphericity should yield a p-value less than 0.05, confirming that the variables are adequately correlated for factor extraction (Charansonney et al., 2022). Factor loadings, representing the correlation between observed variables and latent factors, should ideally exceed 0.7 to demonstrate strong contributions to the factors (Evers et al., 2013). Furthermore, eigenvalues greater than 1 are considered significant, reflecting the variance explained by each factor (Braun et al., 2019). To enhance interpretability, the Varimax rotation method, an orthogonal rotation technique, was applied to simplify the factor loading matrix. Varimax rotation optimizes the variance of squared loadings, producing a clearer factor structure by accentuating high loadings while reducing low loadings on each factor (Acal et al., 2020). This approach is widely favored for its simplicity and effectiveness in clarifying factor structures, thereby facilitating the identification and interpretation of latent variables extracted through EFA (Osborne, 2015).

3.2.8.3 Partial Least Squares Structural Equation Modeling (PLS-SEM)

Confirmatory Composite Analysis (CCA): Before proceeding to the assessment of the structural model, it is essential to ensure that the measurement models are appropriately validated. This is achieved through the Confirmatory Composite Analysis (CCA) process, as outlined by Hair et al. (2020). CCA represents a systematic methodology used to confirm the quality and robustness of measurement models within the Partial Least Squares Structural Equation Modeling (PLS-SEM) framework. This validation step is critical to ensure that the constructs and their indicators reliably and accurately represent the theoretical framework underpinning the research.

The process of Confirmatory Composite Analysis begins with the estimation of indicator loadings and their statistical significance. Indicator loadings measure the extent to which each item contributes to the underlying construct, and they

should meet a threshold value of at least 0.7. This ensures that the item contributes sufficiently to the reliability of the construct. Hair et al. (2011) and Hair et al. (2020) emphasize the importance of achieving this threshold, as it provides evidence of indicator reliability and strengthens the measurement model's validity. However, other scholars viewed that indicator loadings higher than 0.50 is considered as acceptable indicator reliability, and loading less than 0.40 should be deleted (Iqbal & Piwowar-Sulej, 2022). Following the evaluation of individual item reliability, the internal consistency of each construct is assessed through composite reliability (CR). This metric reflects the degree to which the set of indicators consistently measures the construct. A CR value of 0.70 or higher is required (Hair et al., 2020), indicating that the items collectively provide reliable and consistent measurement. Cronbach's alpha, another reliability measure, is also used to corroborate these results, although composite reliability is often preferred in PLS-SEM due to its ability to account for varying indicator loadings. Convergent validity is another critical aspect of the CCA process, evaluated using the Average Variance Extracted (AVE). The AVE metric quantifies the average proportion of variance in a construct that is explained by its indicators. An AVE value of 0.50 or higher is considered adequate (Hair et al., 2020), as it demonstrates that the construct shares sufficient variance with its indicators. This ensures that the construct represents a meaningful and coherent dimension of the theoretical framework. Additionally, discriminant validity is assessed to verify that the constructs are distinct from one another. Discriminant validity is achieved when the variance shared between a construct and its indicators (as measured by the AVE) exceeds the variance shared with other constructs. The Heterotrait-Monotrait (HTMT) ratio is widely recognized as a robust method for assessing discriminant validity. Values below 0.85 or, in some cases, 0.90 indicate that the constructs are sufficiently distinct, thereby supporting the validity of the measurement model (Henseler et al., 2015). The Fornell and Larcker (1981) criterion is another widely recognized method for assessing discriminant validity. This criterion ensures that a latent construct shares more variance with its assigned indicators than with any other latent construct in the model. Additionally, it is essential to evaluate cross

loadings. Each item's loading with its assigned latent construct should be higher than its loadings with all other latent constructs in the model (Hair et al., 2011). This approach helps confirm that the items are more strongly associated with their respective constructs, thereby supporting the validity of the measurement model. By systematically confirming the reliability and validity of the measurement models through CCA, researchers can ensure that the constructs accurately represent their intended theoretical dimensions. This step is fundamental to establishing the credibility of the subsequent structural model assessment.

Structural Model Assessment in PLS-SEM: Once the measurement models are validated, the structural model can be evaluated. This involves assessing the relationships among constructs and the overall predictive power of the model. Hair et al. (2020) provides a comprehensive framework for structural model assessment in PLS-SEM. The size and significance of the path coefficients are examined to test the hypothesized relationships among the constructs. Path coefficients, which are standardized values ranging from -1 to +1, indicate the strength and direction of relationships. Values closer to zero suggest weaker relationships, while those approaching the absolute value of one indicate stronger predictive relationships. This evaluation provides insights into the causal mechanisms underlying the structural model. In addition to assessing path coefficients, the predictive power of the structural model is evaluated using the coefficient of determination (R^2). R^2 measures the proportion of variance in the dependent variables (endogenous constructs) explained by the independent variables (exogenous constructs). Higher R^2 values indicate greater explanatory power. However, R^2 should be interpreted cautiously, as its magnitude is influenced by the number of predictors in the model and the sample size. Adjusted R^2 is often reported alongside R^2 to account for these factors, providing a more reliable measure of predictive accuracy. The effect size (f^2) is another important metric used to assess the contribution of each independent construct to the model. This involves systematically removing each predictor from the model and comparing the resulting R^2 values. Effect sizes are categorized as small (0.02 to 0.15), medium (0.15 to 0.35), or

large (above 0.35), based on established guidelines (Cohen, 1988). The effect size provides a nuanced understanding of the relative importance of individual predictors. Finally, the predictive relevance of the model is assessed using the Q^2 statistic, obtained through a technique known as blindfolding. A Q^2 value greater than zero indicates that the model has meaningful predictive relevance, with higher values reflecting stronger predictive power. Q^2 values of 0.25 and 0.50 are interpreted as medium and large predictive relevance, respectively. By rigorously evaluating the structural model using these metrics, researchers can establish the validity of their findings and ensure that the model provides meaningful insights into the research questions. This comprehensive approach underscores the robustness of PLS-SEM as a methodological tool for analyzing complex theoretical frameworks.

In addition, mediation analysis in PLS-SEM explores how an independent variable influences a dependent variable through a mediator, revealing the underlying mechanism of their relationship. This involves testing the direct effect between the variables and the indirect effect through the mediator using bootstrapping, a robust method for assessing significance. If both effects are significant, partial mediation is present; if only the indirect effect remains significant, full mediation occurs.

3.3 Phase 2: Qualitative Research

3.3.1 Qualitative Research Design

The phase 2 of this study focus on qualitative research, and the thematic analysis method was used to conduct a systematic analysis of the 15 Chinese ESD expert's in-depth interview data. Specifically, this study chose a theory-oriented thematic analysis based on the following two considerations: first, this study start by focuses on the PLS-SEM results, and it is necessary to verify the consistency between the expert opinions and the quantitative path relationships; second, the educational contexts that this study focuses on are complex and diverse, and the theory-oriented thematic analysis can take into account the needs of both theoretical verification and practical problem exploration. In short, through in-depth interviews, this paper aims to explore the

crucial experiences, effective practices, and suggestions of Chinese ESD experts in successfully promoting ESD in schools.

3.3.2 Qualitative Research Samples

The research subjects are experts with practical ESD work experience in normal universities and their affiliated institutions in Yunnan Province, China, including education administrators, researchers, teachers from normal colleges, etc., with strong representativeness and professionalism, ensuring that the interview results can be directly applied to the reform and development of the teacher education system in Yunnan Province, China.

3.3.2.1 Sample size and composition

15 ESD experts from the normal system of Yunnan Province, China will be recruited. The sample composition is as follows:

- Scholars and course leaders engaged in ESD in provincial and local normal universities (such as Yunnan Normal University, Chuxiong Normal University, Qujing Normal University, Honghe University, etc.);
- Teaching/research backbones in the teacher education college, school of educational science, environmental education center and other departments of normal colleges;
- Cadres and teachers with leadership experience or project participation experience in ESD curriculum development, teacher training, and education internship guidance inside and outside the school;
- Heads of school-level research institutions or policy-making participants related to ESD.

3.3.3 In-depth Interview Instrument

This study uses a semi-structured in-depth interview survey as the main data collection tool to obtain an in-depth understanding of the professional action competence of ESD of pre-service teachers. The design of this tool is based on the Theoretical Thematic Analysis method. This study has been based on a solid theoretical foundation from the beginning, and has completed a systematic literature review and quantitative empirical verification (Phase 1: PLS-SEM quantitative empirical research).

Therefore, in terms of the structure and topic setting of the interview instrument, it has a clear theoretical logic and research direction. In the previous quantitative research, the researchers found and confirmed based on the verification of the theoretical model: the professional action competence in ESD of pre-service teachers is mainly composed of the following three key variables: Self-efficacy regarding ESD, Perceived Pedagogical Content Knowledge about ESD, and Willingness to Implement ESD. In addition, the study also found that: Key teaching methods such as ESD-holism and ESD-pluralism can significantly improve the professional action competence of pre-service teachers. Sustainable leadership of the school Leadership can not only effectively promote the actual implementation of ESD teaching methods, but also positively affect the professional action competence of pre-service teachers.

Therefore, in order to verify and further enrich these findings, the interview tools used in the qualitative stage of this study are designed around the above theoretical variables and key practical factors, specifically covering the following six core topics: 1) ESD Holism; 2) ESD Pluralism; 3) Sustainable Leadership; 4) Self-Efficacy regarding ESD; 5) Pedagogical Content Knowledge in ESD; 6) Topic 6: Willingness to Implement ESD.

In order to further expand the depth and breadth of the in-depth interview data, the researchers specially added four conclusion questions in the interview outline. These four conclusion questions are intended to guide the interviewees to conduct a comprehensive reflection based on their long-term practical experience, which will not only help to discover important themes and variables that may exceed the original theoretical framework, but also be expected to put forward forward-looking and practical suggestions for the development strategies of improve pre-service teachers professional action competence in ESD.

In summary, the design of this interview instrument is based on a solid theoretical and empirical foundation, and emphasizes the experience feedback and comparability of the interviewees, which not only ensures the depth and breadth of the

data, but also lays the foundation for subsequent theme induction, cross-case analysis and theoretical construction.

3.3.4 Qualitative Research Data Collection

In the second phase of this study, semi-structured in-depth interviews were used to collect qualitative data, with the goal of deeply exploring the key experiences, challenges and suggestions of ESD experts in Yunnan Province, China, in promoting education for sustainable development and cultivating the ESD professional action competence of pre-service teachers. To ensure that the research sample is representative and professional, and meets ethical requirements, the specific data collection arrangements are as follows:

1. Inclusion Criteria

To ensure that the participants have relevant practical experience and expression ability, the following inclusion criteria are formulated:

- Affiliated to normal universities or affiliated research institutions and teaching units in Yunnan Province, China;
- Have more than three years of experience in research, teaching or projects related to education for sustainable development (ESD);
- Directly participated in matters related to the training of normal students or pre-service teachers, curriculum design, ESD practical teaching, ESD related policy promotion, etc. in Yunnan Province, China;
- Explicitly agree to participate in this study, accept in-depth interviews, and be willing to sign informed consent;
- Agree to accept online or offline interviews;
- Agree to record the interview process, and know that the audio is only for research use and is strictly confidential.

2. Exclusion Criteria

In order to improve data quality and ensure the smooth progress of the interview, the exclusion criteria include:

- Not affiliated with the Yunnan Provincial Education System or Normal University;

- Although being an education practitioner, but not participating in any form of ESD teaching, research or project;

- Unable to provide effective ESD practice cases or weak expression ability, unable to successfully complete the interview;

- Explicitly expressed disagreement to participate in the research, refused to record or was unwilling to provide informed consent;

- Continuous loss of contact, refusal to cooperate or unsuitable to continue participating in the research process.

3. Withdrawal and Termination Criteria

The interviewee has the right to withdraw at any time during the research process without giving reasons. The researcher also reserves the right to terminate the interview in the following circumstances:

- Explicitly refused to continue participating before or during the interview;

- Found that it did not meet the inclusion criteria;

- Cancelled the interview without reason for more than three times or did not respond to contact;

- The interviewee used offensive language or inappropriate behavior during the interview;

- Physical discomfort or psychological pressure occurred during the interview.

4. Recruitment and Contact Procedures

This study adopts a strategy combining purposive sampling and snowball sampling. The specific process is as follows:

- Recommendations are made through the Teacher Education College, Academic Affairs Office, relevant ESD projects or cooperative units of normal universities in Yunnan Province, China;

Initial contact methods include email, WeChat, phone, etc.;

- Send invitation letters, "Interview Instructions" and "Informed Consent Form" to the interviewees;

- Choose online or offline interviews according to the interviewees' wishes. The interview time is controlled within 45-60 minutes, and the interview location is decided by the interviewees.

5. Informed Consent Procedure

Before all in-depth interviews, the principal researcher (the researcher of this study) will provide ethical explanations to the interviewees, including the purpose, content, data processing methods, and interviewee rights. The interviewees will receive the "Informed Consent Form" and "Interview Instructions Letter" in Chinese, and can choose to sign the consent in paper or electronically. No recording or formal interview will begin before the signed consent form is obtained.

6. Potential Risks and Management

During the semi-structured in-depth interviews, this study took into full account the various risks that the interviewees may face when participating in the research, and preset a systematic response mechanism to maximize the protection of the rights, mental health and information security of the interviewees. The specific explanations are as follows:

Mental Fatigue: Since the interview duration is expected to be 45 to 60 minutes, some interviewees may experience cognitive load and mental fatigue during the long information feedback process. In order to reduce the psychological burden, the researcher will inform the interviewee of the estimated interview time in advance, master the rhythm and guide them in time during the actual interview, and conduct the interview in sections or take a break when necessary to ensure that the interview process meets the comfort level of the interviewee.

Digital Access Challenges: The interview may be mainly conducted through Chinese online conference platforms (such as Tencent Meeting, etc.). In order to avoid the quality of the interview being affected by technical operation inconveniences for some experts, the research team will provide concise operation

instructions, and arrange connection tests and technical support before the formal interview to help the interviewee enter the meeting and use the functions smoothly.

Psychological Discomfort: Some interview questions may involve sensitive topics such as education system reform, teaching difficulties, and organizational support, which may cause some interviewees to experience emotional fluctuations or psychological pressure during the discussion. In this regard, researchers will avoid leading and sensitive questions, respect the respondents' autonomy, and clearly inform them that they have the right to skip questions, suspend or terminate the interview at any time to ensure their psychological safety and dignity.

Confidentiality Concerns: Interviewees may worry that their opinions or case descriptions will be identified in the research report, which will affect their professional image or the reputation of their institutions. In this regard, the researcher promises to strictly follow research ethics, use anonymization and data desensitization technology to ensure that no identifiable personal or institution information appears during data collation, analysis and publication, and all research materials are encrypted and stored for use only by authorized members of the researcher only.

Informed Consent Procedure: Before the formal interview, the researcher will explain in detail to the interviewee the purpose of the research, the interview process, the use of data, possible risks, and the protection of their rights and interests, and provide a written informed consent or electronic consent document. Respondents can participate in the interview only after signing the consent form based on a full understanding of the relevant information. This ensures that the respondents participate in the research on an informed and voluntary basis, reflecting ethical respect and research transparency.

Withdrawal Mechanism (Right to Withdraw): Respondents have the right to withdraw their participation unconditionally at any stage before, during, and after the interview. If the respondent wishes to withdraw the information he/she has provided, the researcher will immediately stop using their interview data for analysis,

and completely delete the relevant interview records and text materials, and will not include them in the research report or results release, to ensure that their wishes are respected and implemented.

7. Data Confidentiality and Disposal

To ensure the confidentiality, security and ethical compliance of research data, this study will take the following systematic measures:

Purpose restrictions: All interview materials will be used only for the purpose of this study and will not be used for any other non-research related activities;

Encrypted storage: All interview recordings will be kept by the researcher himself, stored in an encrypted hard drive, and cannot be accessed by unauthorized others;

Anonymous processing: All text materials will be transcribed in pseudonyms, and all identifiable personal names, institutional information or other sensitive identifiers will be completely deleted during the transcription process to protect the privacy of the interviewees;

Destruction mechanism: All audio materials will be completely destroyed within 12 months after the end of the study; One year after the research results are published, all text transcription materials will be deleted to ensure that no long-term identifiable information is retained;

Publication norms: No real names, institution names or identifiable identity information will appear in the final research report and related papers, and only pseudonyms or abstract descriptions will be used to present research data.

Through the above mechanism, the researcher will earnestly fulfill his commitment to respondents' privacy, data security and research ethics, and ensure that the research process is legal, compliant and trustworthy.

3.3.5 Qualitative Research Data Analysis Method

In the second phase of this study, the thematic analysis method proposed by Braun and Clarke (2006) was used to encode and summarize the expert interview data in a systematic and scientific way to ensure that the qualitative data can effectively supplement the research results of the PLS-SEM quantitative model in the first phase. In terms of analytical strategy, this study adopted theoretical thematic analysis, based on the theoretical model path verified in the first phase, focusing on core variables such as sustainable leadership, ESD-related teaching methods (such as ESD-holism and ESD-pluralism), and the three key dimensions in the Professional Action Competence in ESD framework model (self-efficacy regarding ESD, perceived pedagogical content knowledge about ESD, willingness to implement ESD) for key analysis. In addition, although this study is mainly driven by intensive review of relevant model, framework, and theory, the analysis process also retains openness and sensitivity to new topics or themes to explore important viewpoints that may go beyond the scope of existing literature and empirical quantitative models. This qualitative analysis strategy, which is both focused and open, can not only deepen the understanding of the explanatory power of the PLS-SEM model, but also help capture the potential factors and practical experiences that are not fully revealed in the complex context of ESD education.

Based on the five key decision points proposed by Braun and Clarke (2006), this study makes the following specific settings: First, in terms of the scope of analysis, this study chooses the path of detailed analysis, that is, to conduct in-depth analysis around each key theme to ensure that the qualitative data can correspond to the previous quantitative results one by one and strengthen the integration of the research. Second, in terms of the type of themes, the analysis is mainly based on semantic themes, that is, to summarize the core ideas from the clear expressions of experts; but at the same time, it also pays attention to latent themes, especially the implicit factors in values, structural barriers, etc. Third, regarding the dominant analysis method, this study adopts theoretically driven as the core direction, emphasizing the confirmation analysis based on the existing model as the main axis; at the same time, it

also takes into account the exploratory nature of data-driven (inductive) to identify emerging issues that have not yet been covered by theory. Fourth, in terms of thematic objectives, this study focuses on a detailed focus, focusing on the key factors that affect the ESD competence of pre-service teachers, avoiding generalized discussions, so as to improve the accuracy and practicality of the analysis. Finally, at the level of analysis, this study adopts a group-level analysis perspective, focusing on the consensus and disagreement among expert groups, in order to extract practical suggestions with broad applicability, rather than focusing on individual experiences.

Regarding the analysis process of qualitative data analysis, the qualitative data analysis of this study strictly follows the six-stage thematic analysis method proposed by Braun and Clarke (2006) to ensure that the qualitative analysis is systematic, transparent and theoretically profound. Through a solid and rigorous process, the researchers were able to extract deep themes that reflect the key connotations of educational for sustainable development (ESD) from the expert interview data and form a comprehensive understanding that complements the results of the quantitative model (PLS-SEM). The specific operation process is as follows: First, in the first stage regarding Familiarization with The Data, the researcher repeatedly read the transcripts of all expert interviews and combined them with the observation notes recorded during the interview process to fully grasp the viewpoints, contexts and expression points of the interviewees. This stage helps to establish sensitivity to the overall interview content and lay the foundation for subsequent coding work. Secondly, entering the second stage regarding Preliminary Coding, the researcher conducted open coding based on the research questions and the main path variables in the first stage quantitative model (such as self-efficacy regarding ESD, perceived pedagogical content knowledge about ESD, willingness to implement ESD, ESD-related teaching methods: ESD-holism, ESD-pluralism, and sustainable leadership). The coding is based on keywords, core sentences, and logic of viewpoints. The semantic fragments related to the research topic are systematically marked, and a large number of original meaning units are preliminarily sorted out. In the third stage regarding Searching for Potential

Themes, the researchers classified and integrated the previous coding results, and preliminarily aggregated them into several theme groups to identify the commonalities and differences between the views of different experts. This stage also pays special attention to whether new topics or implicit factors beyond the original PLS-SEM model have emerged to expand the breadth of understanding of ESD education action competence. Then, in the fourth stage regarding Reviewing Themes, the researchers systematically examined the logical consistency between the themes, further clarified the boundaries of the themes, and deleted weak themes with repeated concepts or insufficient data support. This stage emphasizes the generalization and recognition of the themes to ensure that the selected themes have theoretical relevance and empirical support. When entering the fifth stage regarding Confirming and Naming Themes, the researchers give clear names to each theme based on the core concepts and underlying meanings represented by each theme, and write theme summaries to ensure that the theme labels can truly reflect the main views and potential values of the expert group. In this process, the researchers also reviewed existing literature and model frameworks to further compare the consistency between theory and data. Finally, the sixth stage regarding Writing a Report integrates the interview theme analysis with the results of the first stage of quantitative research to present a complete and explanatory research result. In the process of writing the report, the original words of the experts were quoted as evidence, and qualitative interpretation and path analysis were combined to explain how each theme responded to the research questions and confirmed or expanded the conclusions of the quantitative model.

3.4 Phase 3: Comprehensive Analysis and Strategy Development

The core task of this research's third phase, comprehensive analysis and strategy development, lies in systematically integrating the quantitative research (the results of PLS structural equation modeling) and qualitative research (thematic analysis of in-depth interview of 15 experts) from the first two phases to form a scientific, comprehensive, and practically instructive strategic development framework. The primary goal of this phase is not only to reveal the mechanisms underlying the

interaction between key factors influencing the development of pre- service teachers professional action competence in education for sustainable development (ESD) but also to propose practical and feasible teaching and leadership practice recommendations based on empirical findings and expert experience, which in turn providing strong decision-making support for university teacher education curriculum reform, teacher training system development, and the cultivation of sustainable campus cultures. The strategy development followed three logical steps: First, in the data integration phase, quantitative research results were cross-referenced and categorized with expert interview data to identify potential relationships between variables and their manifestations in actual educational contexts. Second, in the key area induction phase, data evidence was combined with the theoretical framework to identify the core areas that influence normal school students' ESD professional action competence. Finally, in the strategy element development phase, corresponding strategies and implementation recommendations were proposed for the key areas. Through this systematic process, the research not only proposed scientific and reasonable intervention paths but also provided highly operational policy and practice references for the cultivation of ESD competence in future teacher education.

CHAPTER 4
RESEARCH FINDINGS

4.1 Quantitative Research Findings

4.1.1 Demographic Statistics of Respondents

The population for this study comprised pre-service teachers enrolled in teacher training programs at six universities in Yunnan Province, China, including Yunnan Normal University, Kunming University, Qujing Normal University, Chuxiong Normal University, Zhaotong University, and Honghe University. To collect primary data, an offline questionnaire method was employed. The researcher recruited two pre-service teachers from each university (a total of 12 individuals) through personal connections to assist in distributing the questionnaires to the target sample.

To ensure that the collected questionnaires accurately reflected the population distribution across the six universities, the research prepared the printed questionnaires for each university as follows: Yunnan Normal University (195), Kunming University (120), Qujing Normal University (60), Chuxiong Normal University (75), Zhaotong University (60), and Honghe University (60). To improve representativeness and accessibility, a convenience sampling method was initially applied to recruit participants who were readily available and willing to participate, such as those attending university events, classes, or online platforms. Additionally, snowball sampling was used to expand the sample size by encouraging initial participants to refer other eligible pre-service teachers from their networks. This combined approach addressed logistical challenges and ensured a diverse representation of pre-service teachers across the six universities.

Before the actual offline distribution, the author held an online meeting with the 12 questionnaire distributors to remind them to verify whether respondents were pre-service teachers and to ensure that all questionnaires were fully completed. If a questionnaire was incomplete, distributors were instructed to encourage respondents to complete it. At the end of each distribution day, distributors were required to insert the collected valid and complete questionnaires into an Excel file and send it to the

researcher, who then merged the files into one final Excel file. Data collection took place from December 22, 2024, to December 28, 2024.

Out of the 570 questionnaires distributed, 43 were excluded due to being incomplete or not meeting the qualifications, resulting in a total of 527 valid questionnaires. This yielded a response efficiency rate of 92%. The distribution of the valid questionnaires was as follows: Yunnan Normal University (187), Kunming University (119), Qujing Normal University (57), Chuxiong Normal University (56), Zhaotong University (55), and Honghe University (53). These 527 valid questionnaires were then used for the final data analysis.

The demographic profile of the final respondents is presented in Table 21, providing detailed insights into their distribution across various categories. Universities: The largest proportion of respondents came from Yunnan Normal University, comprising 187 individuals (35.48%), followed by Kunming University with 119 respondents (22.58%). Other institutions included Qujing Normal University (57 respondents, 10.82%), Chuxiong Normal University (56 respondents, 10.63%), Zhaotong University (55 respondents, 10.44%), and Honghe University (53 respondents, 10.06%). Gender: The gender distribution was relatively balanced, with 256 male respondents (48.58%) and 271 female respondents (51.42%). Age: The respondents were grouped into four age categories, with the majority falling within the age ranges of 20-21 years (152 respondents, 28.84%) and 22-23 years (151 respondents, 28.65%). The remaining respondents were aged 18-19 years (101 respondents, 19.17%) and 24 years or older (123 respondents, 23.34%). Academic year: A substantial number of respondents were second-year students, accounting for 154 individuals (29.22%), followed by third-year students (147 respondents, 27.89%), fourth-year students (133 respondents, 25.24%), and first-year students (93 respondents, 17.65%). Overall, the demographic data provide a comprehensive overview of the respondents, highlighting their diversity in terms of institutional affiliation, gender, age, and academic year.

Table 21 Demographics Statistics of the Respondents

Demographics	Items	Frequency	Percentage (%)
Universities	Yunnan Normal University	187	35.48
	Kunming University	119	22.58
	Qujing Normal University	57	10.82
	Chuxiong Normal University	56	10.63
	Zhaotong University	55	10.44
	Honghe University	53	10.06
	Total	**527**	**100.00**
Gender	Male	256	48.58
	Female	271	51.42
	Total	**527**	**100.00**
Age	18-19	101	19.17
	20-21	152	28.84
	22-23	151	28.65
	24 or older	123	23.34
	Total	**527**	**100.00**
Academic year	First year	93	17.65
	Second year	154	29.22
	Third year	147	27.89
	Fourth year	133	25.24
	Total	**527**	**100.00**

4.1.2 Analysis of Level of Five Point Likert-Scale Measurements

This research employs two types of five-point Likert scales. The first type, used for Sustainable Leadership, Self-Efficacy Regarding ESD, Perceived Pedagogical Content Knowledge About ESD, and Willingness to Implement ESD, ranges from 1 (Strongly Disagree) to 5 (Strongly Agree). The second type, applied to ESD-Holism and

ESD-Pluralism, ranges from 1 (Never) to 5 (Very Often). Table 22 illustrates the range and interpretation of these five-point Likert scale measurements. This table provides a clear interpretation of the Likert scale intervals, facilitating a better understanding of the respondents' attitudes and behaviors as measured by the different constructs in this study.

Table 22 Interpretation of Five Point Likert-Scale Measurements

Likert-Scale	Interval	Interpretation 1	Interpretation 2
1	1.00- 1.80	Strongly Disagree	Never
2	1.81- 2.60	Disagree	Seldom
3	2.61- 3.40	Neutral	Sometimes
4	3.41-4.20	Agree	Often
5	4.21-5.00	Strongly Agree	Very Often

Source: Nyutu et al. (2021) and Pimentel (2010).

Analysis of Level of Overall Research Constructs

In this analysis of the overall research constructs, the researcher examines various dimensions of the study. According to the table, Sustainable Leadership (SL) reflects pre-service teachers' perceptions of university leaders' actions supporting sustainability through innovation, ethical practices, and prioritizing educational values. The mean score (M=3.726, SD=0.755) indicates a general agreement that leadership practices promote sustainability, with a slightly lower standard deviation suggesting consistency in perceptions across participants.

Education for Sustainable Development-Holism (ESDH) measures perceptions of the extent to which ESD integrates environmental, social, and economic dimensions, as well as global and local perspectives. The mean score (M=3.782, SD=0.888) reflects frequent recognition of holistic approaches to sustainability in the classroom, emphasizing interconnectedness and multi-dimensionality.

Education for Sustainable Development-Pluralism (ESDP) assesses perceptions of inclusivity and critical reflection within ESD practices. The mean score (M=3.588, SD=0.756) suggests that participants often perceive diverse viewpoints and participatory decision-making within sustainability education, though pluralism may not be as prominent as other aspects of ESD.

Professional Action Competence in Education for Sustainable Development (ESD) is a second-order construct combining Self-Efficacy Regarding ESD, Perceived Pedagogical Content Knowledge About ESD, and Willingness to Implement ESD. This reflects the ability of pre-service teachers to effectively integrate sustainability principles into their teaching. The overall mean score (M=3.777, SD=0.616) indicates that participants generally agree they possess the skills and confidence necessary for implementing ESD. Within this construct, Perceived Pedagogical Content Knowledge About ESD has the highest mean score (M=3.843, SD=0.762), suggesting that pre-service teachers feel well-prepared to design and deliver sustainability content effectively. The lowest mean score (Willingness to Implement ESD, M=3.671, SD=0.809) highlights some hesitation or uncertainty regarding the actual application of ESD in future teaching, signaling a potential area for motivational enhancement. Self-Efficacy Regarding ESD (SESD) reflects confidence in implementing ESD principles in teaching. The mean score (M=3.810, SD=0.771) underscores high confidence among pre-service teachers in addressing sustainability topics and integrating them into the curriculum, suggesting they feel capable of fostering sustainability-related awareness and action in their classrooms.

The data reveal that Perceived Pedagogical Content Knowledge About ESD received the highest rating (M=3.843, SD=0.762), reflecting strong confidence in pedagogical preparation for sustainability education. On the other hand, Willingness to Implement ESD scored the lowest (M=3.671, SD=0.809), indicating that motivational support may be necessary to ensure the translation of knowledge and confidence into actionable teaching practices. Both ESD-Holism and ESD-Pluralism highlight frequent engagement with sustainability practices, though the slightly lower score for pluralism underscores the importance of fostering diverse perspectives and participatory learning further. Sustainable Leadership maintains a positive yet moderate level of agreement, suggesting opportunities to strengthen leadership-driven sustainability efforts.

Table 23 Level of Overall Research Constructs

Construct	Mean	Std. Deviation	Level
Sustainable Leadership (SL)	3.726	0.755	Agree
ESD-Holism (ESDH)	3.782	0.888	Often
ESD-Pluralism (ESDP)	3.588	0.756	Often
Professional Action Competence in ESD	3.777	0.616	Agree
Self-Efficacy Regarding ESD (SESD)	3.810	0.771	Agree
Perceived Pedagogical Content Knowledge About ESD (PESD)	3.843	0.762	Agree
Willingness to Implement ESD (WESD)	3.671	0.809	Agree

4.1.3 Reliability Analysis by Cronbach Alpha

In terms of the Cronbach's Alpha reliability coefficients for each variable in this research. The results indicate that all variables achieved high reliability, with Cronbach's Alpha coefficients ranging from 0.828 to 0.970. The Sustainable Leadership (SL) scale, comprising 14 items, had the highest reliability coefficient of 0.970. The ESD-Pluralism (ESDP) scale had the lowest reliability coefficient of 0.828, but this still exceeded the generally accepted critical reliability value of 0.70, indicating good internal consistency. Overall, the reliability coefficient for all 52 items was 0.968, further validating the reliability of the research instrument.

Table 24 The Cronbach Alpha of Research Variables

Variable	Cronbach's Alpha of Final Data (n=527)	Item
Sustainable Leadership (SL)	0.970	14
ESD-Holism (ESDH)	0.894	3
ESD-Pluralism (ESDP)	0.828	4
Self-Efficacy Regarding ESD (SESD)	0.947	10
Perceived Pedagogical Content Knowledge About ESD (PESD)	0.950	11
Willingness to Implement ESD (WESD)	0.963	10
Cronbach's Alpha of Final Data (n=527) (All 52 items)	0.968	52

4.1.4 Exploratory Factor Analysis

To evaluate the validity of the 52 scale items used in this current research, an Exploratory Factor Analysis (EFA) was performed using SPSS. EFA is a statistical technique employed to reveal the underlying structure of a large set of variables. It aids in identifying the number of latent constructs and the underlying factor structure without imposing a preconceived structure on the outcome. In this current research, the scale

items consist of 52 items across six latent constructs: Sustainable Leadership (14 items), ESD-Holism (3 items), ESD-Pluralism (4 items), Self-Efficacy Regarding ESD (10 items), Perceived Pedagogical Content Knowledge About ESD (11 items), and Willingness to Implement ESD (10 items).

The criteria for conducting a robust EFA include ensuring that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is greater than 0.8, indicating that the sample is adequate for factor analysis (Howard, 2016). Additionally, Bartlett's test of sphericity should have a p-value less than 0.05, suggesting that the variables are sufficiently correlated to provide a reasonable basis for factor analysis (Howard, 2016). Factor loadings, which represent the correlation between the observed variables and the latent factors, should ideally be greater than 0.7 to confirm that the variables strongly contribute to the factor (Evers et al., 2013). Eigenvalues, which indicate the amount of variance explained by each factor, should be greater than 1 to be considered significant (Howard, 2016).

Table 25 reveals that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.958. This value indicates that the sample was appropriate for conducting factor analysis. Additionally, Bartlett's test of sphericity produced a p-value of less than 0.001, further confirming the suitability of the data for factor analysis. These results indicate that the sample was adequate and the variables were sufficiently correlated, making it feasible to proceed with the factor analysis.

Table 25 KMO and Bartlett's Test of Final Data

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.958
Bartlett's Test of Sphericity	Approx. Chi-Square	25916.71
	df	1326
	Sig.	0.000

Consequently, a factor analysis was conducted using principal component analysis. The results, as presented in Table 26, indicate that all 52 scale items were grouped into six primary constructs or factors, which align with the theoretical framework of this research. This classification is substantiated by the presence of only six components with eigenvalues exceeding 1. These six components collectively accounted for 71.57% of the total variance, which is considered high. This high percentage of explained variance reveals the robustness of the factor structure and supports the validity of the constructs being measured in this study.

Table 26 Total Variance Explained of Final Data

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	20.27	38.99	38.99	20.27	38.99	38.99	10.25	19.71	19.71
2	6.13	11.79	50.77	6.13	11.79	50.77	7.60	14.61	34.33
3	4.35	8.37	59.15	4.35	8.37	59.15	7.56	14.54	48.87
4	2.86	5.49	64.64	2.86	5.49	64.64	6.92	13.31	62.18
5	2.07	3.98	68.62	2.07	3.98	68.62	2.71	5.21	67.39
6	1.54	2.95	71.57	1.54	2.95	71.57	2.18	4.18	71.57
7	0.78	1.49	73.07						
8	0.70	1.35	74.42						
9	0.66	1.27	75.69						
10	0.65	1.25	76.94						
11	0.59	1.14	78.08						
12	0.57	1.11	79.19						
13	0.54	1.04	80.23						
14	0.51	0.99	81.22						

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
15	0.48	0.93	82.14						
16	0.48	0.91	83.06						
17	0.44	0.85	83.91						
18	0.43	0.83	84.74						
19	0.42	0.81	85.55						
20	0.41	0.78	86.33						
21	0.39	0.76	87.08						
22	0.38	0.73	87.82						
23	0.37	0.71	88.53						
24	0.36	0.69	89.22						
25	0.33	0.64	89.86						
26	0.31	0.60	90.46						
27	0.31	0.59	91.05						
28	0.29	0.57	91.62						
29	0.29	0.55	92.17						
30	0.27	0.53	92.69						
31	0.27	0.51	93.21						
32	0.26	0.50	93.71						
33	0.24	0.47	94.18						
34	0.23	0.45	94.63						
35	0.23	0.44	95.07						
36	0.21	0.41	95.48						
37	0.20	0.39	95.87						
38	0.20	0.38	96.25						

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
39	0.19	0.37	96.62						
40	0.18	0.34	96.96						
41	0.18	0.34	97.30						
42	0.17	0.32	97.61						
43	0.16	0.31	97.92						
44	0.15	0.28	98.20						
45	0.14	0.27	98.48						
46	0.14	0.26	98.74						
47	0.13	0.25	98.98						
48	0.12	0.22	99.21						
49	0.12	0.22	99.43						
50	0.11	0.21	99.64						
51	0.09	0.18	99.82						
52	0.09	0.18	100.00						

The scree plot generated from EFA is show in figure 4. The scree plot displays the eigenvalues on the y-axis and the factor numbers on the x-axis. The first few factors have high eigenvalues, indicating that they explain a significant portion of the variance in the data. The plot shows a clear "elbow" at the sixth factor, which is the point where the slope of the curve levels off, suggesting that additional factors beyond this point contribute minimally to the explained variance. According to the scree plot, the first six factors have eigenvalues greater than 1, which aligns with the current theoretical framework. These six factors together explain 71.57% of the cumulative variance, indicating a strong factor structure. Based on the scree plot, it is concluded that

retaining six factors is appropriate for the current analysis. This supports the validity of the constructs being measured and confirms that the items are grouped into meaningful factors.

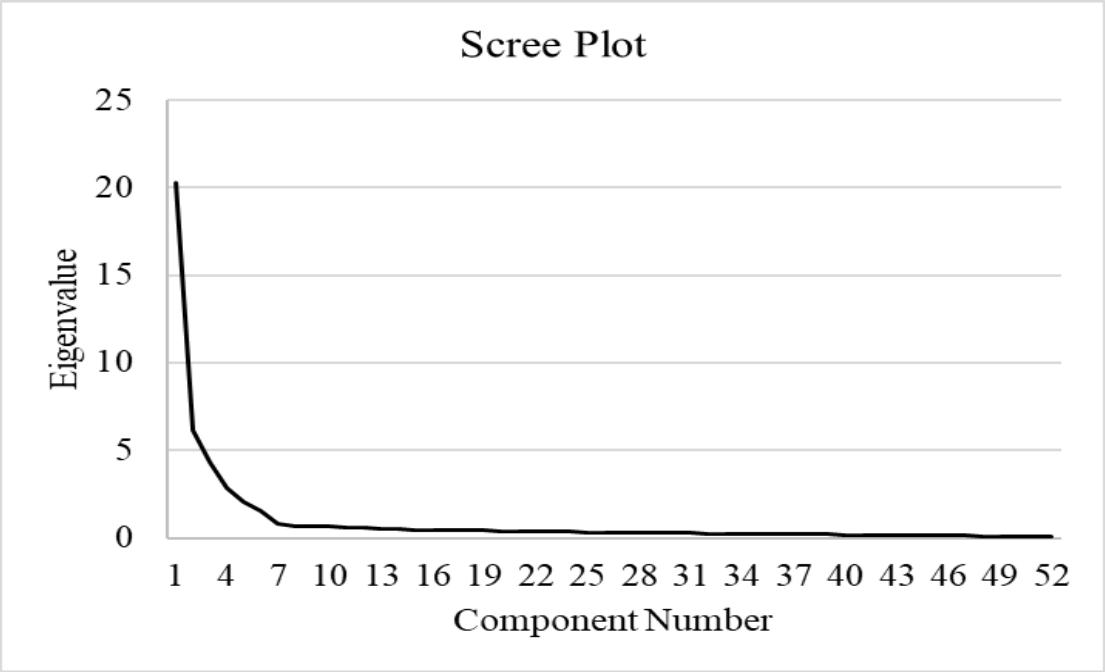

Figure 4 Scree Plot of Final Data

To enhance the clarity of factor loadings, the Varimax rotation matrix was utilized in the Exploratory Factor Analysis (EFA). Varimax rotation, an orthogonal method, optimizes the sum of the variances of the squared loadings. This technique simplifies the factor structure by increasing high loadings and decreasing low loadings on each factor (Acal et al., 2020). It is widely favored in EFA for its orthogonality, simplicity, and the clear interpretation it provides for factor loadings (Osborne, 2015). Varimax rotation is particularly effective in producing a clear and easily interpretable factor structure, which is essential for comprehending the latent variables identified through EFA.

As shown Table 27, the Rotated Component Matrix showed that all scale item loadings were 0.7 or higher. This high level of loading indicates a strong association between the scale items and their respective theoretical constructs: Sustainable Leadership (14 items), ESD-Holism (3 items), ESD-Pluralism (4 items), Self-Efficacy Regarding ESD (10 items), Perceived Pedagogical Content Knowledge About ESD (11 items), and Willingness to Implement ESD (10 items). It is important to note that loadings below 0.4 were excluded from the analysis.

Table 27 Rotated Component Matrix of Final Data

	Component					
	1	2	3	4	5	6
SL1	0.802					
SL2	0.766					
SL3	0.769					
SL4	0.785					
SL5	0.831					
SL6	0.833					
SL7	0.813					
SL8	0.739					
SL9	0.822					
SL10	0.805					
SL11	0.744					
SL12	0.773					
SL13	0.752					
SL14	0.802					
ESDH1						0.806
ESDH2						0.769
ESDH3						0.759
ESDP1					0.726	

	Component					
	1	2	3	4	5	6
ESDP2					0.768	
ESDP3					0.761	
ESDP4					0.787	
SESD1				0.789		
SESD2				0.753		
SESD3				0.706		
SESD4				0.704		
SESD5				0.728		
SESD6				0.836		
SESD7				0.831		
SESD8				0.757		
SESD9				0.738		
SESD10				0.809		
PESD1			0.748			
PESD2			0.784			
PESD3			0.776			
PESD4			0.704			
PESD5			0.791			
PESD6			0.777			
PESD7			0.710			
PESD8			0.771			
PESD9			0.848			
PESD10			0.709			
PESD11			0.796			
WESD1		0.764				
WESD2		0.828				
WESD3		0.793				

	Component					
	1	2	3	4	5	6
WESD4		0.813				
WESD5		0.819				
WESD6		0.790				
WESD7		0.735				
WESD8		0.842				
WESD9		0.822				
WESD10		0.787				

In conclusion, the Exploratory Factor Analysis (EFA) conducted on the final data validated that all 52 scale items were accurately categorized into six primary constructs, aligning with the theoretical framework of this present study. The EFA revealed six components with eigenvalues exceeding 1, collectively accounting for 71.57% of the total variance, which indicates a substantial explanatory power. The Rotated Component Matrix indicated that all scale items had loadings higher than 0.7, confirming strong correlations with their respective constructs: Sustainable Leadership (14 items), ESD-Holism (3 items), ESD-Pluralism (4 items), Self-Efficacy Regarding ESD (10 items), Perceived Pedagogical Content Knowledge About ESD (11 items), and Willingness to Implement ESD (10 items). This high level of internal consistency highlights the robustness of the constructs and supports the reliability of the scale for assessing the targeted variables in this research. Consequently, the validated questionnaire is appropriate for further data analysis.

4.1.5 Measurement Model Assessment: Confirmatory Composite Analysis

For the measurement model quality assessment, this research follows Hair et al. (2020), who highlight the emerging role of Confirmatory Composite Analysis (CCA) as an alternative to Confirmatory Factor Analysis (CFA) in the development, adaptation, and confirmation of measurement scales. Compared to CFA, CCA is a recently proposed approach used to confirm measurement models when employing Partial Least

Squares Structural Equation Modeling (PLS-SEM). The Confirmatory Composite Analysis was conducted by used SmartPLS software.

Before assessing the structural model, it is crucial to validate the measurement models through the CCA process, as outlined by Hair et al. (2020). CCA provides a systematic methodology to confirm the quality and robustness of measurement models within the PLS-SEM framework. This validation step ensures that the constructs and their indicators reliably and accurately represent the theoretical framework underpinning the research.

The CCA process begins with estimating indicator loadings and their statistical significance. Indicator loadings measure the extent to which each item contributes to the underlying construct, and they should meet a threshold value of at least 0.7 to ensure sufficient reliability. Hair et al. (2011) and Hair et al. (2020) emphasize the importance of this threshold, as it provides evidence of indicator reliability and strengthens the measurement model's validity. However, other scholars suggest that indicator loadings higher than 0.50 are acceptable, and loadings less than 0.40 should be deleted (Iqbal & Piwowar-Sulej, 2022).

Following the evaluation of individual item reliability, the internal consistency of each construct is assessed through composite reliability (CR). This metric reflects the degree to which the set of indicators consistently measures the construct. A CR value of 0.70 or higher is required (Hair et al., 2020), indicating that the items collectively provide reliable and consistent measurement. Cronbach’s alpha, another reliability measure, is also used to corroborate these results, although composite reliability is often preferred in PLS-SEM due to its ability to account for varying indicator loadings.

Convergent validity is another critical aspect of the CCA process, evaluated using the Average Variance Extracted (AVE). The AVE metric quantifies the average proportion of variance in a construct that is explained by its indicators. An AVE value of 0.50 or higher is considered adequate (Hair et al., 2020), as it demonstrates that the construct shares sufficient variance with its indicators, ensuring that the construct represents a meaningful and coherent dimension of the theoretical framework.

Additionally, discriminant validity is assessed to verify that the constructs are distinct from one another. Discriminant validity is achieved when the variance shared between a construct and its indicators (as measured by the AVE) exceeds the variance shared with other constructs. The Heterotrait-Monotrait (HTMT) ratio is widely recognized as a robust method for assessing discriminant validity. Values below 0.85 or, in some cases, 0.90 indicate that the constructs are sufficiently distinct, thereby supporting the validity of the measurement model (Henseler et al., 2015). The Fornell and Larcker (1981) criterion is another widely recognized method for assessing discriminant validity. This criterion ensures that a latent construct shares more variance with its assigned indicators than with any other latent construct in the model. Additionally, it is essential to evaluate cross loadings. Each item's loading with its assigned latent construct should be higher than its loadings with all other latent constructs in the model (Hair et al., 2011). This approach helps confirm that the items are more strongly associated with their respective constructs, thereby supporting the validity of the measurement model.

By systematically confirming the reliability and validity of the measurement models through CCA, researchers can ensure that the constructs accurately represent their intended theoretical dimensions. This step is fundamental to establishing the credibility of the subsequent structural model assessment.

Convergent Validity

Table 28 presents the reliability and validity metrics for the constructs measured in this study. The table includes the loadings, Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) for each construct.

For Sustainable Leadership, the item loadings range from 0.726 to 0.920, all significant at the 0.01 level. The Cronbach's alpha is 0.970, the CR is 0.970, and the AVE is 0.698. These values exceed the threshold values of 0.7 for Cronbach's alpha and CR, and 0.5 for AVE, indicating excellent reliability and a high degree of internal consistency.

In terms of ESD-Holism, the item loadings range from 0.839 to 0.871, all significant at the 0.01 level. The Cronbach's alpha is 0.894, the CR is 0.894, and the AVE is 0.739. These values exceed the threshold values of 0.7 for Cronbach's alpha and CR, and 0.5 for AVE, indicating good reliability and a high degree of internal consistency.

Regarding ESD-Pluralism, the item loadings range from 0.688 to 0.816, all significant at the 0.01 level. Although one loading is slightly below the 0.7 threshold, it is close enough to be considered acceptable. The Cronbach's alpha is 0.828, the CR is 0.828, and the AVE is 0.546. These values exceed the threshold values of 0.7 for Cronbach's alpha and CR, and 0.5 for AVE, indicating good reliability and a high degree of internal consistency.

For Professional Action Competence in ESD, the loadings for the sub-constructs (SESD, PESD, WESD) are 0.870, 0.829, and 0.781, respectively, all significant at the 0.01 level. The overall Cronbach's alpha is 0.957, the CR is 0.867, and the AVE is 0.685, indicating excellent reliability and internal consistency.

In terms of Self-Efficacy Regarding ESD, the item loadings range from 0.678 to 0.906, all significant at the 0.01 level. Although one loading is slightly below the 0.7 threshold, it is close enough to be considered acceptable. The Cronbach's alpha is 0.947, the CR is 0.948, and the AVE is 0.648. These metrics suggest excellent reliability and strong internal consistency.

Regarding Perceived Pedagogical Content Knowledge About ESD, the item loadings range from 0.695 to 0.892, all significant at the 0.01 level. Although one loading is slightly below the 0.7 threshold, it is close enough to be considered acceptable. The Cronbach's alpha is 0.950, the CR is 0.950, and the AVE is 0.637. These values indicate excellent reliability and internal consistency.

In terms of Willingness to Implement ESD, the item loadings range from 0.731 to 0.948, all significant at the 0.01 level. The Cronbach's alpha is 0.963, the CR is 0.963, and the AVE is 0.725. These values exceed the threshold values of 0.7 for

Cronbach's alpha and CR, and 0.5 for AVE, indicating excellent reliability and a high degree of internal consistency.

Overall, the Table 28 demonstrates that all constructs exhibit high reliability and internal consistency, supporting the robustness of the measurement model used in this study. The significance of the loadings at the 0.01 level indicates that the items are strongly associated with their respective constructs, further validating the measurement model.

Table 28 Reliability, Internal Consistency, and Convergent Validity

Constructs	Labels	Loading	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Sustainable Leadership	SL1	0.888***	0.970	0.970	0.698
	SL2	0.802***			
	SL3	0.772***			
	SL4	0.787***			
	SL5	0.920***			
	SL6	0.902***			
	SL7	0.865***			
	SL8	0.856***			
	SL9	0.896***			
	SL10	0.853***			
	SL11	0.780***			
	SL12	0.823***			
	SL13	0.802***			
	SL14	0.726***			
ESD-Holism	ESDH1	0.839***	0.894	0.894	0.739

Constructs	Labels	Loading	Cronbach's	Composite	Average
	ESDH2	0.868***			
	ESDH3	0.871***			
ESD-Pluralism	ESDP1	0.816***	0.828	0.828	0.546
	ESDP2	0.735***			
	ESDP3	0.688***			
	ESDP4	0.712***			
Professional Action Competence in ESD	SESD	0.870***	0.957	0.867	0.685
	PESD	0.829***			
	WESD	0.781***			
Self-Efficacy Regarding ESD	SESD1	0.832***	0.947	0.948	0.648
	SESD2	0.832***			
	SESD3	0.728***			
	SESD4	0.731***			
	SESD5	0.678***			
	SESD6	0.899***			
	SESD7	0.858***			
	SESD8	0.792***			
	SESD9	0.760***			
	SESD10	0.906***			
Perceived Pedagogical Content Knowledge About ESD	PESD1	0.791***	0.950	0.950	0.637
	PESD2	0.892***			
	PESD3	0.759***			
	PESD4	0.799***			
	PESD5	0.831***			
	PESD6	0.769***			
	PESD7	0.695***			
	PESD8	0.738***			

Constructs	Labels	Loading	Cronbach's	Composite	Average
	PESD9	0.885***			
	PESD10	0.748***			
	PESD11	0.847***			
	WESD1	0.831***	0.963	0.963	0.725
	WESD2	0.845***			
	WESD3	0.896***			
	WESD4	0.948***			
Willingness to	WESD5	0.896***			
Implement ESD	WESD6	0.818***			
	WESD7	0.731***			
	WESD8	0.884***			
	WESD9	0.848***			
	WESD10	0.801***			

Note: *** $p < 0.01$.

Discriminant Validity

Discriminant validity ensures that constructs are distinct from one another. This research used three different methods to assess discriminant validity for robustness. Firstly, the Heterotrait-Monotrait (HTMT) ratio, a robust method, was employed. Values below 0.85 or 0.90 indicate sufficient distinctiveness (Henseler et al., 2015). Secondly, the Fornell and Larcker (1981) criterion was used, ensuring that a latent construct shares more variance with its assigned indicators than with any other latent construct in the model. Lastly, cross loadings were evaluated, confirming that each item's loading with its assigned latent construct was higher than with other constructs (Hair et al., 2011). This comprehensive approach supports the validity of the measurement model.

Table 29 presents the Heterotrait-Monotrait (HTMT) ratio values for assessing discriminant validity among the constructs in this study. The HTMT ratio, a

robust method, was employed. Values below 0.85 or 0.90 indicate sufficient distinctiveness between constructs (Henseler et al., 2015). The HTMT ratios between the constructs are as follows: ESD-Holism (ESDH) and ESD-Pluralism (ESDP) have an HTMT ratio of 0.425, indicating a clear distinction between these constructs. ESD-Holism (ESDH) and Perceived Pedagogical Content Knowledge About ESD (PESD) have an HTMT ratio of 0.454, showing sufficient discriminant validity. ESD-Holism (ESDH) and Self-Efficacy Regarding ESD (SESD) have an HTMT ratio of 0.410, confirming their distinctiveness. ESD-Holism (ESDH) and Sustainable Leadership (SL) have an HTMT ratio of 0.572, indicating a clear distinction. ESD-Holism (ESDH) and Willingness to Implement ESD (WESD) have an HTMT ratio of 0.456, showing sufficient discriminant validity. ESD-Pluralism (ESDP) and Perceived Pedagogical Content Knowledge About ESD (PESD) have an HTMT ratio of 0.314, indicating a clear distinction. ESD-Pluralism (ESDP) and Self-Efficacy Regarding ESD (SESD) have an HTMT ratio of 0.249, confirming their distinctiveness. ESD-Pluralism (ESDP) and Sustainable Leadership (SL) have an HTMT ratio of 0.483, indicating a clear distinction. ESD-Pluralism (ESDP) and Willingness to Implement ESD (WESD) have an HTMT ratio of 0.390, showing sufficient discriminant validity. Perceived Pedagogical Content Knowledge About ESD (PESD) and Self-Efficacy Regarding ESD (SESD) have an HTMT ratio of 0.566, confirming their distinctiveness. Perceived Pedagogical Content Knowledge About ESD (PESD) and Sustainable Leadership (SL) have an HTMT ratio of 0.443, indicating a clear distinction. Perceived Pedagogical Content Knowledge About ESD (PESD) and Willingness to Implement ESD (WESD) have an HTMT ratio of 0.344, showing sufficient discriminant validity. Self-Efficacy Regarding ESD (SESD) and Sustainable Leadership (SL) have an HTMT ratio of 0.384, confirming their distinctiveness. Self-Efficacy Regarding ESD (SESD) and Willingness to Implement ESD (WESD) have an HTMT ratio of 0.462, indicating a clear distinction. Sustainable Leadership (SL) and Willingness to Implement ESD (WESD) have an HTMT ratio of 0.575, showing sufficient discriminant validity.

Overall, the HTMT ratios in Table 29 demonstrate that all constructs exhibit sufficient discriminant validity, supporting the robustness of the measurement model used in this study.

Table 29 Discriminant Validity (HTMT Ratio)

	ESDH	ESDP	PESD	SESD	SL	WESD
ESDH						
ESDP	0.425					
PESD	0.454	0.314				
SESD	0.410	0.249	0.566			
SL	0.572	0.483	0.443	0.384		
WESD	0.456	0.390	0.344	0.462	0.575	

Table 30 presents the discriminant validity assessment using the Fornell-Larcker criterion. Discriminant validity ensures that each construct is distinct from the others. The bold values on the diagonal are the square root of the average variance extracted (AVE) of the latent constructs, while the off-diagonal values are the correlations among the constructs.

For ESD-Holism (ESDH), the square root of the AVE is 0.859, which is greater than its correlations with other constructs, indicating good discriminant validity. The correlation between ESD-Holism and ESD-Pluralism (ESDP) is 0.427, with Perceived Pedagogical Content Knowledge About ESD (PESD) is 0.455, with Self-Efficacy Regarding ESD (SESD) is 0.409, with Sustainable Leadership (SL) is 0.573, and with Willingness to Implement ESD (WESD) is 0.458. Regarding ESD-Pluralism (ESDP), the square root of the AVE is 0.739, which is greater than its correlations with other constructs, confirming discriminant validity. The correlation between ESD-Pluralism and PESD is 0.314, with SESD is 0.252, with SL is 0.485, and with WESD is 0.390. In terms of PESD, the square root of the AVE is 0.798, which is greater than its correlations with

other constructs, supporting discriminant validity. The correlation between PESD and SESD is 0.567, with SL is 0.443, and with WESD is 0.348.

For SESD, the square root of the AVE is 0.805, which is greater than its correlations with other constructs, indicating good discriminant validity. The correlation between SESD and SL is 0.385, and with WESD is 0.464. For SL, the square root of the AVE is 0.836, which is greater than its correlations with other constructs, confirming discriminant validity. The correlation between SL and WESD is 0.577. Regarding WESD, the square root of the AVE is 0.852, which is greater than its correlations with other constructs, supporting discriminant validity.

Overall, the Fornell-Larcker criterion in Table 30 demonstrates that all constructs exhibit sufficient discriminant validity, as the square root of the AVE for each construct is greater than its correlations with other constructs. This further supports the robustness of the measurement model used in this study.

Table 30 Discriminant Validity (Fornell-Larcker Criterion)

	ESDH	ESDP	PESD	SESD	SL	WESD
ESDH	**0.859**					
ESDP	0.427	**0.739**				
PESD	0.455	0.314	**0.798**			
SESD	0.409	0.252	0.567	**0.805**		
SL	0.573	0.485	0.443	0.385	**0.836**	
WESD	0.458	0.39	0.348	0.464	0.577	**0.852**

Note: The bold values on the diagonal are the square root of the average variance extracted (AVE) of the latent constructs, while the off-diagonal values are the correlations among the constructs.

Table 31 presents the discriminant validity assessment using cross loadings. Discriminant validity ensures that each construct is distinct from the others. For each item, the loading with its assigned latent construct should be higher than its loadings with all other latent constructs in the model (Hair et al., 2011). This approach helps confirm that the items are more strongly associated with their respective constructs, thereby supporting the validity of the measurement model.

With respect to Sustainable Leadership (SL), the item loadings range from 0.726 to 0.920, all of which are higher than their loadings with other constructs, indicating good discriminant validity. For instance, SL1 has a loading of 0.888 with SL, which is higher than its loadings with ESDH (0.507), ESDP (0.458), SESD (0.318), PESD (0.394), and WESD (0.495).

For ESD-Holism (ESDH), the item loadings range from 0.839 to 0.871, all of which are higher than their loadings with other constructs, confirming discriminant validity. For instance, ESDH1 has a loading of 0.839 with ESDH, which is higher than its loadings with SL (0.471), ESDP (0.343), SESD (0.383), PESD (0.393), and WESD (0.360).

Regarding ESD-Pluralism (ESDP), the item loadings range from 0.688 to 0.816, all of which are higher than their loadings with other constructs, supporting discriminant validity. For example, ESDP1 has a loading of 0.816 with ESDP, which is higher than its loadings with SL (0.405), ESDH (0.346), SESD (0.222), PESD (0.251), and WESD (0.283).

In terms of Self-Efficacy Regarding ESD (SESD), the item loadings range from 0.678 to 0.906, all of which are higher than their loadings with other constructs, indicating good discriminant validity. For instance, SESD1 has a loading of 0.832 with SESD, which is higher than its loadings with SL (0.311), ESDH (0.340), ESDP (0.245), PESD (0.468), and WESD (0.390).

For Perceived Pedagogical Content Knowledge About ESD (PESD), the item loadings range from 0.738 to 0.892, all of which are higher than their loadings with other constructs, confirming discriminant validity. For example, PESD1 has a loading of

0.791 with PESD, which is higher than its loadings with SL (0.329), ESDH (0.350), ESDP (0.195), SESD (0.488), and WESD (0.238).

Regarding Willingness to Implement ESD (WESD), the item loadings range from 0.731 to 0.948, all of which are higher than their loadings with other constructs, supporting discriminant validity. For instance, WESD1 has a loading of 0.831 with WESD, which is higher than its loadings with SL (0.531), ESDH (0.376), ESDP (0.389), SESD (0.353), and PESD (0.318).

Overall, the cross loadings in Table 31 demonstrate that all constructs demonstrate sufficient discriminant validity, as each item's loading with its assigned construct is higher than its loadings with other constructs. This further supports the robustness of the measurement model used in this study.

Table 31 Discriminant Validity (Cross Loadings)

	SL	ESDH	ESDP	SESD	PESD	WESD
SL1	**0.888**	0.507	0.458	0.318	0.394	0.495
SL2	**0.802**	0.428	0.435	0.294	0.379	0.446
SL3	**0.772**	0.430	0.379	0.286	0.370	0.448
SL4	**0.787**	0.467	0.377	0.283	0.330	0.468
SL5	**0.920**	0.510	0.452	0.364	0.428	0.528
SL6	**0.902**	0.529	0.426	0.358	0.393	0.511
SL7	**0.865**	0.509	0.435	0.314	0.342	0.507
SL8	**0.856**	0.486	0.377	0.380	0.407	0.493
SL9	**0.896**	0.514	0.433	0.324	0.386	0.550
SL10	**0.853**	0.469	0.396	0.343	0.344	0.584
SL11	**0.780**	0.461	0.332	0.338	0.382	0.424
SL12	**0.823**	0.495	0.398	0.329	0.372	0.410
SL13	**0.802**	0.458	0.415	0.301	0.344	0.442
SL14	**0.726**	0.430	0.351	0.264	0.301	0.427
ESDH1	0.471	**0.839**	0.343	0.383	0.393	0.360

	SL	ESDH	ESDP	SESD	PESD	WESD
ESDH2	0.491	**0.868**	0.367	0.353	0.413	0.397
ESDH3	0.516	**0.871**	0.389	0.320	0.367	0.423
ESDP1	0.405	0.346	**0.816**	0.222	0.251	0.283
ESDP2	0.350	0.303	**0.735**	0.171	0.231	0.317
ESDP3	0.330	0.284	**0.688**	0.165	0.244	0.261
ESDP4	0.347	0.326	**0.712**	0.183	0.202	0.294
SESD1	0.311	0.340	0.245	**0.832**	0.468	0.390
SESD2	0.333	0.317	0.170	**0.832**	0.471	0.410
SESD3	0.305	0.263	0.216	**0.728**	0.442	0.297
SESD4	0.306	0.371	0.223	**0.731**	0.426	0.318
SESD5	0.226	0.319	0.117	**0.678**	0.351	0.300
SESD6	0.347	0.363	0.230	**0.899**	0.516	0.421
SESD7	0.326	0.331	0.244	**0.858**	0.495	0.381
SESD8	0.302	0.300	0.159	**0.792**	0.435	0.381
SESD9	0.268	0.275	0.145	**0.760**	0.444	0.332
SESD10	0.362	0.408	0.258	**0.906**	0.495	0.475
PESD1	0.329	0.350	0.195	0.488	**0.791**	0.238
PESD2	0.412	0.418	0.278	0.511	**0.892**	0.355
PESD3	0.338	0.355	0.215	0.426	**0.759**	0.234
PESD4	0.328	0.334	0.336	0.426	**0.799**	0.358
PESD5	0.359	0.378	0.237	0.489	**0.831**	0.272
PESD6	0.295	0.345	0.216	0.434	**0.769**	0.249
PESD8	0.401	0.384	0.256	0.394	**0.738**	0.223
PESD9	0.376	0.387	0.263	0.494	**0.885**	0.321
PESD10	0.357	0.298	0.252	0.430	**0.748**	0.258
PESD11	0.368	0.411	0.265	0.494	**0.847**	0.291
WESD1	0.531	0.376	0.389	0.353	0.318	**0.831**
WESD2	0.461	0.390	0.331	0.382	0.285	**0.845**

	SL	ESDH	ESDP	SESD	PESD	WESD
WESD3	0.519	0.456	0.337	0.433	0.326	**0.896**
WESD4	0.573	0.426	0.379	0.451	0.369	**0.948**
WESD5	0.516	0.419	0.349	0.433	0.310	**0.896**
WESD6	0.449	0.343	0.289	0.390	0.269	**0.818**
WESD7	0.393	0.327	0.289	0.345	0.216	**0.731**
WESD8	0.491	0.403	0.315	0.405	0.310	**0.884**
WESD9	0.486	0.448	0.354	0.362	0.305	**0.848**
WESD10	0.480	0.298	0.283	0.390	0.232	**0.801**

In summary, the discriminant validity of the constructs was assessed using three different methods for robustness: the Heterotrait-Monotrait (HTMT) ratio, the Fornell-Larcker criterion, and cross loadings. The HTMT ratio values were below the threshold of 0.85 or 0.90, indicating sufficient distinctiveness between constructs. The Fornell-Larcker criterion confirmed that each construct shared more variance with its assigned indicators than with other constructs. Cross loadings further validated that each item's loading with its assigned construct was higher than with other constructs. These comprehensive assessments support the validity of the measurement model.

4.1.6 Structural Model Assessment in PLS-SEM

Once the measurement models are validated, the structural model can be evaluated. This involves assessing the relationships among constructs and the overall predictive power of the model. Hair et al. (2020) provides a comprehensive framework for structural model assessment in PLS-SEM. The size and significance of the path coefficients are examined to test the hypothesized relationships among the constructs. Path coefficients, which are standardized values ranging from -1 to +1, indicate the strength and direction of relationships. Values closer to zero suggest weaker relationships, while those approaching the absolute value of one indicate stronger predictive relationships. This evaluation provides insights into the causal mechanisms underlying the structural model. The Smart-PLS's bootstrapping at a subsample of 5,000

was initiated to evaluate the proposed model significance and hypotheses assessment (Hair et al., 2019).

In addition to assessing path coefficients, the predictive power of the structural model is evaluated using the coefficient of determination (R^2). R^2 measures the proportion of variance in the dependent variables (endogenous constructs) explained by the independent variables (exogenous constructs). Higher R^2 values indicate greater explanatory power. However, R^2 should be interpreted cautiously, as its magnitude is influenced by the number of predictors in the model and the sample size. Adjusted R^2 is often reported alongside R^2 to account for these factors, providing a more reliable measure of predictive accuracy.

The effect size (f^2) is another important metric used to assess the contribution of each independent construct to the model. This involves systematically removing each predictor from the model and comparing the resulting R^2 values. Effect sizes are categorized as small (0.02 to 0.15), medium (0.15 to 0.35), or large (above 0.35), based on established guidelines (Cohen, 1988). The effect size provides a nuanced understanding of the relative importance of individual predictors.

Finally, the predictive relevance of the model is assessed using the Q^2 statistic, obtained through a technique known as blindfolding. A Q^2 value greater than zero indicates that the model has meaningful predictive relevance, with higher values reflecting stronger predictive power. Q^2 values of 0.25 and 0.50 are interpreted as medium and large predictive relevance, respectively. By rigorously evaluating the structural model using these metrics, researchers can establish the validity of their findings and ensure that the model provides meaningful insights into the research questions. This comprehensive approach underscores the robustness of PLS-SEM as a methodological tool for analyzing complex theoretical frameworks.

Additionally, mediation analysis in PLS-SEM explores how an independent variable influences a dependent variable through a mediator, revealing the underlying mechanism of their relationship. This involves testing the direct effect between the variables and the indirect effect through the mediator using bootstrapping, a robust

method for assessing significance. If both effects are significant, partial mediation is present; if only the indirect effect remains significant, full mediation occurs. The Smart-PLS's bootstrapping at a subsample of 5,000 was initiated to evaluate the proposed model significance and hypotheses assessment (Hair et al., 2019).

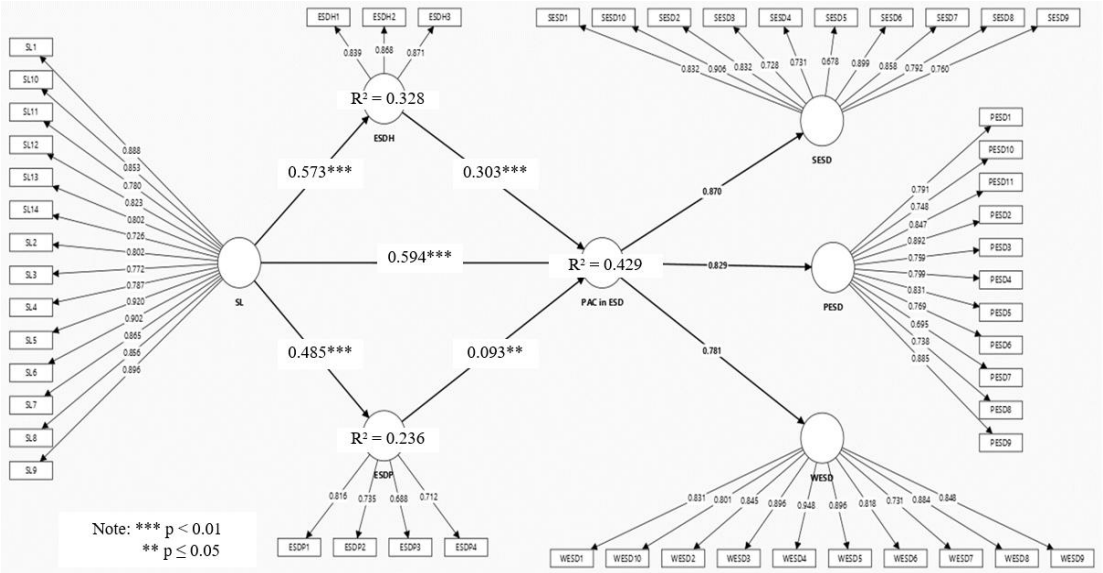

Figure 5 Structural Model

Note: SL=Sustainable Leadership, ESDH=Education for Sustainable Development-Holism, ESDP= Education for Sustainable Development-Pluralism, PAC in ESD=Professional Action Competence in ESD, SESD= Self-Efficacy regarding ESD, PESD= Perceived Pedagogical Content Knowledge About ESD, WESD= Willingness to implement ESD.

Structural Model Assessment

The research hypotheses explore the relationships between sustainable leadership, ESD-Holism, ESD-Pluralism, and professional action competence in ESD among pre-service teachers. Figure 5 shows the paths of the research structural model. The assessment of the research hypotheses reveals significant findings as shown in

Table 44. Hypothesis H1, which posits that sustainable leadership positively influences ESD-Holism, is supported (β=0.573; t-value=13.264; p-value=0.000), indicating a strong and significant relationship at the 0.01 level. This suggests that as sustainable leadership practices increase, the integration of environmental, social, and economic dimensions of sustainability issues in the classroom also increases. This integration encompasses a focus on the past, present, and future aspects of these issues, as well as their local, regional, and global impacts. Consequently, students experience a more comprehensive and interconnected approach to sustainability education, known as ESD-Holism, which enhances their understanding and engagement with sustainability principles. Similarly, Hypothesis H2, proposing that sustainable leadership positively influences ESD-Pluralism, is supported (β=0.485; t-value=10.559; p-value=0.000), confirming a significant relationship at the 0.01 level. This suggests that as sustainable leadership practices increase, there is a significant increase in ESD-Pluralism. This reveals when teachers invest more in teaching through pluralism by allowing different viewpoints and opinions to be addressed, encouraging critical reflection on what is being learned, and enabling students to participate in decision-making regarding classroom topics, students report more frequent sustainability behaviors. This comprehensive approach not only enriches the learning environment but also fosters a deeper understanding and commitment to sustainable practices among students. Hypothesis H3, which proposes that ESD-Holism positively influences pre-service teachers' professional action competence in ESD, is statistically significance (β=0.303; t-value=5.912; p-value=0.000), indicating a significant relationship at the 0.01 level. This reveals that a higher emphasis on holistic sustainability approaches enhances pre-service teachers' professional action competence to apply sustainability principles in their future teaching. Hypothesis H4, proposing that ESD-Pluralism positively influences pre-service teachers' professional action competence in ESD, is supported (β=0.093; t-value=1.960; p-value=0.050), demonstrating significance at the 0.05 level. This suggest that fostering diverse perspectives and participatory decision-making also contributes to teachers' competence in ESD.

Mediation Effect Assessment

The mediating effect analysis further investigates the relationships among the research constructs. The direct effect of sustainable leadership on professional action competence in ESD (H5) is statistically significant (β=0.594; t-value=15.046; p-value=0.000), indicating a strong relationship at the 0.01 level. This indicates that as sustainable leadership practices increase, there is a corresponding increase in the professional action competence of pre-service teachers in Education for Sustainable Development (ESD). This relationship suggests that when university leaders prioritize sustainability through social, environmental, and ethical responsibilities, innovation, clear communication, and student welfare, pre-service teachers become more capable and confident in applying sustainability principles in their teaching. Consequently, this enhanced competence enables them to effectively integrate ESD into their future classrooms, fostering a more sustainable and informed generation of students. The indirect effect analysis reveals that ESD-Holism statistically significant partially mediates the relationship between sustainable leadership and professional action competence in ESD (H6), with (β=0.174; t-value=5.160; p-value=0.000), confirming significance at the 0.01 level. This indicates that sustainable leadership enhances professional action competence in Education for Sustainable Development (ESD) through its positive impact on ESD-Holism. As sustainable leadership practices increase, they foster a more integrated approach to sustainability in the classroom, encompassing environmental, social, and economic dimensions. This holistic approach not only considers the past, present, and future aspects of sustainability issues but also their local, regional, and global impacts. Consequently, pre-service teachers develop a deeper understanding and greater competence in applying sustainability principles in their teaching, thereby enhancing their professional action competence in ESD. Additionally, ESD-Pluralism partially mediates the relationship between sustainable leadership and professional action competence in ESD (H7), with (β=0.045; t-value=1.894; p-value=0.058), indicating significance at the 0.10 level. This indicates that sustainable leadership influences professional action competence in Education for

Sustainable Development (ESD) through its effect on ESD-Pluralism. As sustainable leadership practices increase, they foster a classroom environment where diverse viewpoints and opinions are encouraged, critical reflection on learning is promoted, and students are actively involved in decision-making processes. This pluralistic approach not only enriches the educational experience but also enhances pre-service teachers' ability to apply sustainability principles effectively in their teaching, thereby improving their professional action competence in ESD.

In summary, the hypotheses demonstrate that sustainable leadership plays a crucial role in enhancing both ESD-Holism and ESD-Pluralism, which in turn positively impact pre-service teachers' professional action competence in Education for Sustainable Development (ESD). As sustainable leadership practices increase, the integration of holistic sustainability approaches encompassing environmental, social, and economic dimensions, as well as their past, present, and future aspects also increases. Simultaneously, the promotion of diverse perspectives and critical reflection within the classroom environment is enhanced. This dual enhancement leads to a higher competence among pre-service teachers in applying sustainability principles in their future teaching, thereby fostering a more comprehensive and effective approach to sustainability education. The research hypotheses were all statistically significantly supported at different conventional significance levels, with H1, H2, H3, H5, and H6 supported at the 0.01 level, H4 at the 0.05 level, and H7 at the 0.10 level.

Table 32 Assessment of Research Hypotheses

Path	Coefficient	S.D.	*T*-value	*P*-value
(H1) SL -> ESDH	0.573	0.043	13.264	0.000
(H2) SL -> ESDP	0.485	0.046	10.559	0.000
(H3) ESDH -> PAC in ESD	0.303	0.051	5.912	0.000
(H4) ESDP -> PAC in ESD	0.093	0.047	1.960	0.050
Mediating Effect Analysis				

Path	Coefficient	S.D.	*T*-value	*P*-value
Direct Effect				
(H5) SL -> PAC in ESD	0.594	0.039	15.046	0.000
Indirect Effect				
(H6) SL -> ESDH -> PAC in ESD	0.174	0.034	5.160	0.000
(H7) SL -> ESDP -> PAC in ESD	0.045	0.024	1.894	0.058

Structural Model Metrics Assessment

In addition to assessing path coefficients, the predictive power of the structural model is evaluated using the coefficient of determination (R^2), which measures the proportion of variance in the dependent variables (endogenous constructs) explained by the independent variables (exogenous constructs). Higher R^2 values indicate greater explanatory power. The effect size (f^2) is another important metric used to assess the contribution of each independent construct to the model, involving the systematic removal of each predictor from the model and comparing the resulting R^2 values. Effect sizes are categorized as small (0.02 to 0.15), medium (0.15 to 0.35), or large (above 0.35), based on established guidelines (Cohen, 1988). Finally, the predictive relevance of the model is assessed using the Q^2 statistic, obtained through a technique known as blindfolding. A Q^2 value greater than zero indicates that the model has meaningful predictive relevance, with higher values reflecting stronger predictive power.

Goodness of Fit (GoF) in Partial Least Squares Structural Equation Modeling (PLS-SEM) is a measure used to evaluate the model's overall fit. It combines both the measurement and structural model assessments into a single index. The GoF index was introduced by Tenenhaus et al. (2005). The Goodness-of-Fit (GoF) index is calculated as the square root of the product of the average R^2 (AvgR^2) and the average AVE (AvgAVE).

Explanatory Power and Predictive Relevance

According to Table 33, for Sustainable Leadership (SL), the Average Variance Extracted (AVE) is 0.698, which exceeds the recommended threshold of 0.50, confirming strong convergent validity. SL significantly explains 33% of the variance in ESD-Holism (ESDH) (R^2=0.33), a medium effect, with medium predictive relevance (Q^2=0.28). The AVE for ESDH is 0.739, further affirming its strong convergent validity. Similarly, SL explains 24% of the variance in ESD-Pluralism (ESDP) (R^2=0.24), with medium predictive relevance (Q^2=0.19) and an acceptable AVE of 0.546, indicating moderate convergent validity.

For Professional Action Competence in ESD (PAC in ESD), the model demonstrates a medium level of explanatory power (R^2=0.43), meaning SL, ESDH, and ESDP collectively explain 43% of the variance in PAC in ESD. Predictive relevance for PAC in ESD is also medium (Q^2=0.32). Subconstructs of PAC in ESD, namely Self-Efficacy Regarding ESD (AVE=0.648), Perceived Pedagogical Content Knowledge About ESD (AVE=0.637), and Willingness to Implement ESD (AVE=0.725), all exhibit strong convergent validity, as their AVE values significantly exceed the threshold of 0.50.

On average, the model explains 33% of the variance in the endogenous constructs (AvgR^2=0.33) and achieves an average AVE of 0.666, indicating strong convergent validity across constructs.

Goodness-of-Fit (GoF) and Overall Model Robustness

The Goodness-of-Fit (GoF) index, calculated as the square root of the product of AvgR^2 and AvgAVE, is 0.469, classified as large. This indicates that the model has a high level of overall fit, combining robust explanatory power and predictive capabilities. These results highlight the strength of the model in explaining and predicting key constructs related to SL and ESD.

Path-Specific Effect Sizes

The analysis of effect sizes (f^2) provides additional insights into the relative importance of SL and its associated constructs. The path from SL to ESDH has a large effect size (f^2=0.489), indicating a substantial contribution of SL to fostering a

holistic approach to ESD. The relationship between SL and ESDP shows a medium effect size (f^2=0.308), indicating a meaningful influence on pluralistic aspects of ESD.

For PAC in ESD, the direct path from SL exhibits a medium effect size (f^2=0.148), revealing the importance of SL as a predictor of professional competence in the context of ESD. However, indirect pathways reveal smaller contributions: the path from ESDH to PAC in ESD has a small effect size (f^2=0.104), and the path from ESDP to PAC in ESD has a small effect size (f^2=0.011).

Table 33 Summary of Structural Model Metrics

Construct/Path	R^2	Q^2	AVE	f^2
Sustainable Leadership (SL)			0.698	
SL -> ESDH				0.489
SL -> ESDP				0.308
SL -> PAC in ESD				0.148
ESD-Holism (ESDH)	0.33	0.28	0.739	
ESDH -> PAC in ESD				0.104
ESD-Pluralism (ESDP)	0.24	0.19	0.546	
ESDP -> PAC in ESD				0.011
Professional Action Competence in ESD (PAC in ESD)	0.43	0.32	0.456	
Self-Efficacy Regarding ESD			0.648	
Perceived Pedagogical Content Knowledge About ESD			0.637	
Willingness to Implement ESD			0.725	

Construct/Path	R^2	Q^2	AVE	f^2
Averages and GoF	R^2		AVE	
Average of R^2	0.33			
Average of AVE			0.666	
GoF=$\sqrt{}$ (Avg R^2 × Avg AVE) = 0.469				

In conclusion, these findings emphasize the varying degrees of influence that SL and its associated constructs exert on key aspects of ESD. While SL emerges as a significant driver of both ESDH and PAC in ESD, the indirect pathways through ESDH and ESDP reveal more modest contributions. This suggests that SL is a critical factor for advancing ESD outcomes but that its impact through intermediary constructs like ESDH and ESDP may require further development or complementary strategies.

By focusing on strengthening both direct and indirect pathways, institutions can leverage SL more effectively to foster holistic, pluralistic, and actionable approaches to ESD. The model's strong explanatory power, predictive relevance, and overall fit underline its robustness as a framework for understanding the complex interplay between SL, ESD constructs, and PAC in ESD.

4.1.7 Conclusion of Research Hypotheses

In conclusion, the research hypotheses demonstrate that sustainable leadership positively influences ESD-Holism (H1). Sustainable leadership positively influences ESD-Pluralism (H2). Additionally, ESD-Holism positively impact pre-service teachers' professional action competence in ESD (H3). ESD-Pluralism positively impact pre-service teachers' professional action competence in ESD (H4). Sustainable leadership also directly enhances professional action competence in ESD (H5). Furthermore, ESD-Holism partially mediate the relationship between sustainable leadership and professional action competence in ESD (H6). ESD-Pluralism partially

mediate the relationship between sustainable leadership and professional action competence in ESD (H7). All the 7 research hypotheses were supported. Table 46 demonstrates the conclusion of research hypotheses.

Table 34 Conclusion of Research Hypotheses

No.	Research Hypotheses Statement	Decision
H1	Sustainable leadership will positively influence ESD-Holism.	Supported
H2	Sustainable leadership will positively influence ESD-Pluralism.	Supported
H3	ESD-Holism will positively influence pre-service teachers' Professional Action Competence in ESD.	Supported
H4	ESD-Pluralism will positively influence pre-service teachers' Professional Action Competence in ESD.	Supported
H5	Sustainable leadership will positively influence the professional action competence of pre-service teachers in Education for Sustainable Development (ESD).	Supported
No.	Research Hypotheses Statement	Mediation
H6	ESD-Holism will mediate the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD).	Partial Mediation
H7	ESD-Pluralism will mediate the relationship between sustainable leadership and professional action competence in Education for Sustainable Development (ESD).	Partial Mediation

4.2 Qualitative Research Findings

4.2.1 Overview of Qualitative Research

Building on literature review and quantitative research, the qualitative research conducted in-depth interviews with 15 experts with experience in ESD,

teaching, research, and practice to further explore the factors influencing and pathways for improving pre-service teachers professional action competence in ESD. Employing a thematic analysis approach, the interview data was coded, categorized, and compared, ultimately yielding core themes.

The in-depth interview included 15 interviewees during the qualitative interview phase, including frontline teachers in teacher education programs, heads of teacher education programs, leaders of education colleges, internship supervisors for pre-service teachers, and professors with experience in ESD research. The diverse backgrounds of the interviewees not only ensured that the study could examine the current status and challenges of ESD competency development in pre-service teachers from different perspectives and roles, but also helped to validate and supplement the mechanisms revealed by the quantitative research (PLS-SEM). In addition, this diverse background not only reflects the diverse nature of the interviewees but also provides a solid foundation for the subsequent thematic analysis. Horizontally, this study encompassed diverse disciplines such as language, humanities, science, and the arts. Vertically, it included frontline teachers, department leaders, and academic experts, forming a three-dimensional perspective on ESD teacher education. In compliance with the ethical protocols for in-depth interviews and to guarantee the anonymity of the 15 participating experts, all personally identifiable information, including institutional affiliations, has been withheld. Participants are denoted pseudonymously as "E" followed by a numerical identifier (e.g., E1, E2…E15), and this nomenclature is used exclusively hereafter. Specifically, the interviewee group comprised the following categories:

1. Frontline Teachers (E1–E6): Teachers from six disciplines, including English, Mathematics, Physics, Chemistry, Biology, and Fine Arts, who have long explored how to integrate ESD concepts into their respective disciplines through frontline teaching and curriculum development. For instance, an English teacher (E1) hosted a "Green Campus" English speech contest, integrating environmental issues with cross-cultural communication; a chemistry teacher (E4) led the development of a "Green Chemistry" course and promoted green laboratory management; and a biology teacher

(E5) led students in real-world projects such as water quality monitoring and wetland protection.

2. Professional Leadership Group (E7–E9): This group includes leaders of the three teacher education programs: elementary education, early childhood education, and pedagogy. They primarily focus on the overall layout and curriculum implementation of ESD within the teacher education system. For instance, the elementary education leader (E7) actively promoted World Environment Day activities and incorporated them into the teacher education curriculum; the early childhood education leader (E8) collaborated with the local environmental protection bureau to emphasize the integration of early childhood education and sustainable development in holiday and community projects.

3. Faculty Leadership Group (E10–E11): This group includes deans and vice deans of the Faculty of Education. Interviewees in this leadership group are responsible for institutional support and cross-school collaboration at the macro level. The Dean of the School of Education (E10) has participated in the UNESCO Asia-Pacific Centre's Sustainable Education Project, bringing his international collaboration experience to local institutions. The Vice Dean of the School of Education (E11) focuses on systematically integrating ESD elements into the school's curriculum and teaching quality assurance system.

4. Internship Supervisors (E12–E13): These include internship supervisors from the School of Educational Sciences and the Department of Chinese Language and Literature. They are deeply involved in the practical aspects of teacher training. For example, E12 focuses on integrating mental health and environmental education, designing a "Green Campus Psychological Adjustment" activity; E13 guides teacher training students in developing environmental-themed essays, local cultural preservation, and school-based green reading activities during their internships.

5. Academic Researchers (E14–E15): These include professors of educational psychology and educational technology, both of whom have long engaged in ESD research. The professor of educational psychology (E14) emphasized the

importance of focusing on both the cognitive (professional knowledge and curriculum design ability) and emotional (values, attitudes, and implementation intention) dimensions of pre-service in order to enhance their overall professional action competence; the professor of educational technology (E15) focused on how to use information technology and digital platforms to promote innovation in ESD teaching.

Table 35 Overview of In-depth Interview Respondents

No.	Major/Department	ESD-Related Experience Notes
E1	English Teacher Education Major	Responsible for the teaching of cross-cultural understanding and environmental issues in English education courses, and hosted the "Green Campus" English Speech Competition.
E2	Mathematics Teacher Education Major	Engaged in mathematics education research for a long time and has incorporated ESD-related issues into mathematical modeling.
E3	Physics Teacher Education Major	Lead the development of the course "Integration of Clean Energy and Physics Teaching".
E4	Chemistry Teacher Education Major	Lead the development of the "Green Chemistry" course and promote green management in laboratories.
E5	Biology Teacher Education Major	Lead the development of the "Ecology and Sustainable Development" course and lead students to participate in water quality monitoring and wetland protection projects.
E6	Fine Arts Teacher Education Major	Lead the development of the "Art and Sustainable Development" curriculum and promote the "Community Art + Environmental Education" project.

No.	Major/Department	ESD-Related Experience Notes
E7	Head of the Department of Elementary Education	Organized several "World Environment Day" themed educational activities and was responsible for the design and implementation of ESD teacher education courses.
E8	Head of the Department of Early Childhood Education	Cooperate with the local Environmental Protection Bureau to organize environmental protection activities on June 5th, Environment Day.
E9	Head of the Department of Education	The education major course includes a module integrating educational principles and ESD.
E10	Dean of the School of Education	Responsible for matters concerning Education for Sustainable Development with the UNESCO Asia-Pacific Centre.
E11	Vice Dean of the School of Education	Responsible for teaching and embedding ESD elements into the course syllabus.
E12	Internship Supervisor at the School of Educational Sciences	Curriculum design and campus sustainable practice activities that combine mental health and environmental protection.
E13	Internship Supervisor at the Department of Chinese Language and Literature	Guide trainee teacher trainees to carry out environmental theme writing, local cultural protection projects and school green reading activities.
E14	Psychology Teacher	The research focuses on the psychological mechanisms of sustainable development of education.
E15	Educational Technology Teacher	Main research focus on promotes ESD teaching through information technology and digital platforms.

4.2.2 Overview of Qualitative Research Analysis Methodology

The qualitative research analysis methodology adhered to the thematic analysis method proposed by Braun and Clarke (2006), systematically analyzing interview data through a six-stage process. The goal was to extract underlying themes from the expert interview texts that reflected the core implications of Education for Sustainable Development (ESD), which in turn complementing and expanding upon the previous quantitative research findings using PLS-SEM at both theoretical and empirical levels. The specific process included: familiarizing with the interview text data and establishing a holistic understanding; conducting preliminary coding based on the research questions, literature review and quantitative variables; searching for and categorizing potential themes; reviewing the themes for logical consistency and empirical support; and finally finalizing the theme names and writing a comprehensive analysis report.

4.2.3 Preliminary Coding, Theme Refinement, Naming of the Theme

This study employed the thematic analysis method developed by Braun and Clarke (2006) to systematically analyze transcripts of in-depth interviews. First, the researcher transcribed the interview recordings verbatim and familiarized with the text through repeated readings. During this process, the researcher adhered closely to the theoretical framework underlying the research design, adopting a top-down analysis approach. The coding phase then began, identifying and analyzing meaningful elements within the text. This process, coding is not limited to individual sentences; it can be performed on a line or paragraph basis. Coding can be done directly on a semantic level to identify the interviewee's speech, or on an interpretive level to capture the underlying meaning. Whether coding individual words or complete sentences, the core goal of coding is to uncover key concepts within the text.

After completing the initial coding phase, the researcher grouped similar or overlapping codes into preliminary themes. Through the analysis of interview data from 15 experts, 14 Preliminary Themes were summarized, namely: Interdisciplinary Integration, Ecological Awareness/Environmental Perspectives, Integrating ESD Concepts into Instructional Design, Cultural Diversity, Participatory Teaching Strategies,

Autonomous, Critical, and Consultative Education, Leadership Effect, Institutional Support, Community Collaboration, Teaching Knowledge and Skills, Self-Efficacy, Teaching Willingness and Motivation, Teacher Education Curriculum Reform, and Professional Growth Mechanism (Table 36). On this basis, the researcher further refined the themes. By comparing relevant literature and theory, the researcher consolidated the 14 preliminary themes into six main themes: Holism and Systems Thinking in ESD, Pluralism in ESD Pedagogy, Sustainable Leadership for ESD Implementation, Components of ESD Competence (corresponding to the core constructs of the quantitative research), ESD-Centric Curriculum Reform, and Continuous Professional Growth in ESD (Table 37). This process ensured the thematic structure had greater theoretical support and explanatory power.

Finally, the researchers defined and named the identified main themes. Based on a comprehensive review of relevant theory and literature, the research clarified the scope and connotation of each theme and assigned it a scholarly name. The definitions and scope of each theme are detailed in Table 38.

Table 36 Coding Classification into Preliminary Themes

Preliminary Themes	Coding
Interdisciplinary Integration	Introducing environmental issues into writing courses while training language expression and sustainable thinking; integrating pollution control and carbon emission calculations into mathematical modeling classes; introducing renewable energy cases into energy conversion experiments; considering environmentally friendly material substitution in chemical reaction experiments; taking students to wetland biodiversity monitoring and connecting them to the community economy; using waste materials to create art, combining science and art; promoting interdisciplinary integrated courses; closely integrating educational theory and practice; and linking disciplines with sustainable development.
Ecological Awareness/Environmental Perspectives	The World Environment Day themed debate raised global and local awareness; classroom experiments compared solar energy and hydropower, guiding thinking about green and sustainable energy choices; plastic degradation cases prompted reflection on the relationship between humans and nature; wetland protection activities reflected the interdependence between humans and nature; the smart campus energy-saving simulation system supported digital energy-saving analysis; a campus water and energy conservation action plan was developed; and an eco-literature writing project combined culture and ecology.

Preliminary Themes	Coding
Integrating ESD Concepts into Instructional Design	Bilingual environmental writing assignments; a mathematical modeling competition incorporating sustainability issues; an energy simulation project combining physics and geography; a special course on green chemistry; designing an ecological civilization education program; an environmental art exhibition; a joint course integrating classroom and community; and a Green Reading Month combining literary creation with environmental education.
Cultural Diversity	Cross-cultural comparisons guide respect for diverse values; introduce minority economic data into statistical cases; integrate minority art with environmental protection concepts; emphasize respect for diverse cultures in the multi-ethnic context of Yunnan; promote multicultural exchange through information technology; and respect the diversity of ethnic languages, literature, and ecological cultures in the classroom.

Preliminary Themes	Coding
Participatory Teaching Strategies	Conduct decision-making simulations in energy-related classrooms; collaborate in lab groups to explore green chemistry methods; participate in wetland scientific research with teachers and students; create community murals; participate in community environmental protection summer camps; experience value conflicts in Model United Nations debates; and participate in group discussions and writing in ecological literature workshops.
Autonomous, Critical, and Consultative Education	Classroom negotiation to determine writing topics related to environmental ecology; discussing environmental solutions in group research; students and the community negotiate environmental protection plans; negotiating themes with ethnic minority residents during mural creation; promoting cross-cultural negotiation through a mental health and environmental summer camp; collaborating with ethnic minority elementary schools to develop digital stories; resolving value conflicts through negotiation during classroom debates; and the importance of fostering critical reflection in pedagogy.

Preliminary Themes	Coding
Leadership Effect	Teachers set an example by their own environmental protection actions; guide students to participate in social statistics services; take students to energy science exhibitions; participate in community environmental protection activities to influence students; teachers take the lead in ecological volunteer services; participate in environmental art exhibitions; the dean presides over green, environmental protection, and sustainable education forums; the dean actively participates in campus environment day activities to inspire students.
Institutional Support	The school encourages the integration of ESD related research and teaching; promotes the construction of energy and environmental laboratories; supports green chemistry experimental projects; establishes ecological education scholarships; funds environmental art practice; incorporates ESD into the college's compulsory modules; the national teacher education standards clearly define the status of ESD; leaders share the belief in sustainable education; promotes resource integration and provides practical opportunities; policies support project courses and psychological empowerment; and curriculum policies encourage the integration of classroom and environmental practice.

Preliminary Themes	Coding
Community Collaboration	Participate in local environmental data collection; collaborate with power companies to conduct energy education; collaborate with community businesses on waste treatment research; collaborate with local environmental protection bureaus to participate in Environment Day activities; provide school-based psychological support and social welfare activities; and promote green culture and conduct ecological research in the community.
Teaching Knowledge and Skills	Chemistry emphasizes green chemistry, biology emphasizes ecological monitoring, and art emphasizes environmental art. Teachers' understanding of sustainable development education varies and requires training. Students need to strengthen their understanding of economic and social dimensions. Primary school environmental protection class meetings are a successful practice.

Preliminary Themes	Coding
Self-Efficacy	Real sustainable development teaching cases are needed to improve confidence in sustainable development teaching; real educational situations can cultivate ability; allowing teacher trainees to see their teachers successfully implement sustainable development education in the classroom can improve their confidence; psychological safety and positive emotions can enhance interdisciplinary confidence; teacher guidance and clear tasks can enhance confidence in sustainable development education actions
Teaching Willingness and Motivation	A sense of mission and responsibility are key drivers; establishing research centers, a sense of mission and responsibility are key drivers; establishing research centers plays a demonstration role; value recognition and a sense of responsibility are the main drivers; new technologies and social recognition enhance motivation; environmental protection and a sense of responsibility for cultural heritage enhance motivation; and cultivating sustainable development values is crucial.

Preliminary Themes	Coding
Teacher Education Curriculum Reform	Establish compulsory modules and interdisciplinary courses; add sustainable development education theory courses and interdisciplinary teams; courses take into account both cognitive and emotional dimensions; adopt dual paths of digitalization and sustainability; and carry out project practice combining literature and ecological themes.
Professional Growth Mechanism	Long-term training and peer support; establish a teacher development and peer support mechanism; promote international exchanges and local linkages; high-level teachers need to balance cognition and emotion and have action; high-level teachers need to have digital literacy and interdisciplinary capabilities.

Table 37 Themes Refinement

Main Themes	Sub-Themes
Holism and Systems Thinking in ESD	Interdisciplinary Integration
	Ecological Awareness/Environmental Perspectives
	Integrating ESD Concepts into Instructional Design
Pluralism in ESD Pedagogy	Cultural Diversity
	Participatory Teaching Strategies
	Autonomous, Critical, and Consultative Education
Sustainable Leadership for ESD Implementation	Leadership Effect
	Institutional Support
	Community Collaboration
Components of ESD Competence	Teaching Knowledge and Skills
	Self-Efficacy
	Teaching Willingness and Motivation
ESD-Centric Curriculum Reform	
Continuous Professional Growth in ESD	

Table 38 Definition and Naming of the Themes

Main Themes	Meaning and Purpose
Holism and Systems Thinking in ESD	Holism and Systems Thinking in ESD emphasizes the interdisciplinary and cross-dimensional integration of ESD, enabling teacher trainees to understand the interdependence of the environment, society, and economy and implement systematic sustainable education in their teaching. This program encompasses three sub-themes: 1) Interdisciplinary Integration: Promoting the integration of different disciplines with sustainable development issues and cultivating systems thinking. 2) Ecological Awareness/Environmental Perspectives: Strengthening teacher trainees' understanding of the interdependence between humans and nature. 3) Integrating ESD Concepts into Instructional Design: Embedding ESD concepts into instructional design and classroom tasks. Holism and Systems Thinking in ESD aims to enhance teacher trainees' interdisciplinary perspectives and systems thinking skills, enabling them to grasp the holistic connection between knowledge and values in their teaching. Holism and Systems Thinking in ESD help teacher education transcend the limitations of a single discipline and achieve the integration of disciplinary knowledge, sustainable values, and practical action.

Main Themes	Meaning and Purpose
Pluralism in ESD Pedagogy	Pluralism in ESD Pedagogy emphasizes respect for diverse perspectives and cultural backgrounds in ESD instruction, encourages critical reflection and consultative learning, and fosters a shared understanding of diverse values. Its content includes three sub-themes: 1) Cultural Diversity: Focuses on cross-cultural understanding and ethnic diversity; 2) Participatory Teaching Strategies: Employs collaborative inquiry and simulations to enhance student engagement; and 3) Autonomous, Critical, and Consultative Education: Cultivates consultation, debate, and critical thinking skills in the classroom and community. Pluralism in ESD Pedagogy aims to guide teacher trainees in respecting diverse values in their teaching and foster dialogue and co-construction among students. Pluralism in ESD Pedagogy helps pre-service teachers promote inclusive education and sustainable values in multiethnic and multicultural settings.
Sustainable Leadership for ESD Implementation	Sustainable Leadership emphasizes that leaders and teachers in educational institutions provide assurance and support for the implementation of ESD and the development of ESD competencies in teacher trainees through value guidance, institutional development, and social collaboration. This approach encompasses three sub-themes: 1) Leadership Effect: Teachers and administrators role model through actions and values. 2) Institutional Support: Ensuring ESD advancement through policies, curriculum, and resources. 3) Community Collaboration: School leaders actively collaborate with local governments, businesses, and social organizations to implement ESD. Sustainable Leadership aims to establish a systematic ESD promotion mechanism through the joint efforts of leadership and teachers. Sustainable Leadership ensures that ESD education can move from concept to institutionalization and practice, fostering a sustainable development education ecosystem.

Main Themes	Meaning and Purpose
Components of ESD Competence	Components of ESD Competence refers to pre-service teacher's comprehensive ability to translate ESD concepts into teaching practice, encompassing three aspects: knowledge, confidence, and motivation. Specifically, it encompasses three sub-themes: 1) Teaching Knowledge and Skills: Mastering pedagogy that integrates disciplines with ESD. 2) Self-Efficacy: Developing the confidence to implement ESD in the classroom. 3) Teaching Willingness and Motivation: A sense of responsibility and mission drives ESD instruction. The purpose of Components of ESD Competence is to cultivate teachers who can truly implement ESD. Components of ESD Competence is a key indicator of the effectiveness of ESD teacher education. Pre-service teachers require more than simply teaching them "what sustainable development is" (knowledge). It also requires them to "be able to teach" (skills) and, more importantly, to "be willing and courageous to teach" (willingness to act).
ESD-Centric Curriculum Reform	The ESD-Centric Curriculum Reform emphasizes the systematic integration of ESD concepts into the teacher education curriculum, making it a core module rather than an add-on. The reform aims to create a curriculum structure aligned with the Sustainable Development Goals and ensure that teacher trainees gain exposure to and understanding of ESD across all disciplines. The reform promotes a shift in the education system from traditional knowledge transfer to a focus on both values and competencies, empowering future teachers to address global and local challenges.

Main Themes	Meaning and Purpose
Continuous Professional Growth in ESD	Continuous Professional Growth in ESD emphasizes that pre-service teachers continuously learn ESD concepts and methods throughout their pre-service and in-service education, enabling lifelong growth. The program aims to establish a continuous training system from pre-service teacher to in-service teacher, ensuring that teachers' ESD competence are constantly updated. Continuous Professional Growth in ESD adapts to rapidly evolving global and local sustainability issues, keeping teachers' teaching cutting-edge and proactive. Continuous Professional Growth in ESD encompasses pre-service education, in-service training, educational research, and international exchange.

4.2.4 Summarize of Qualitative Research

Holism and Systems Thinking in ESD

Holism and Systems Thinking in ESD emphasizes the comprehensive integration of the three dimensions of environment, society, and economy in the educational process, guiding learners to understand and address sustainable development issues from multiple perspectives, spanning time and space. In teacher training, holism is not only an educational concept but also a practical teaching approach, requiring teachers to organically integrate subject knowledge with the diverse goals of sustainable development, which in turn cultivating students' systems thinking and interdisciplinary problem-solving skills. The significance of Holism and Systems Thinking in ESD lies in helping pre-service teachers transcend the limitations of single-disciplinary knowledge in their teaching and learning, learning to consider the relationship between education, society, and nature from a systems perspective.

Based on the in-depth interview, holism and systems thinking in ESD has the following three sub-themes:

1) Interdisciplinary integration: This refers to breaking down disciplinary boundaries in curriculum and teaching, and combining sustainable development issues in environmental, social and economic dimensions with disciplinary knowledge.

> *"I believe that interdisciplinary integration in ESD cannot be limited to textbooks. I personally lead students to wetland ecosystems to conduct on-site biodiversity monitoring and record changes in species distribution and abundance. This is not only to teach biological knowledge, but more importantly, I guide students to interview local fishermen and residents to explore how wetland health affects fishery resources and ecotourism. This will effectively connect environmental issues with socioeconomic dimensions and help them understand that conservation and development are not contradictory, but can be synergistic." (E5)*
>
> *"In my art class, interdisciplinary integration is a core. I have been organizing the 'Waste to Treasure' art workshop guides students in collecting various discarded plastics, paper, and fabrics from everyday life. This process itself is a vivid environmental education lesson. During the creative process, we not only explore color, form, and aesthetics, but also delve into the sources, degradation processes, and environmental impacts of these materials, integrating artistic expression with scientific understanding. Ultimately, each student's work tells a sustainable development story about consumption, waste, and rebirth. (E6)*

2) Ecological awareness/environmental concepts: refers to strengthening teachers and students' overall understanding of the relationship between humans and nature, the operation of ecosystems and sustainable resource utilization in education.

> *"In my English teaching, I design an all-English classroom debate competition every year around the annual theme of World Environment Day, such as 'ecosystem restoration.' I require my teacher trainees to not only collect and demonstrate global data in English, but also to conduct in-depth research on the specific manifestations and impacts of this environmental issue locally. This process forces them to systematically understand the profound connection between global environmental issues and local actions through*

language application, thus going beyond superficial knowledge and building a holistic understanding of the relationship between humans and nature." (E1)

3) Integrating ESD concepts into teaching design: This means that teachers consciously integrate the concept of sustainable development into their teaching design and transform it into specific teaching objectives, content and activities.

"I believe that integrating ESD into art instruction shouldn't just be conceptual, but should involve designing specific art practice tasks. Therefore, I've explicitly included the 'Rebirth of Waste' environmental art exhibition as a core project in my new semester's teaching plan. In this project, students first research the current state of waste disposal in their community, then collect waste materials as creative media, and ultimately work in groups to create an art installation designed to spark public reflection on the environment. The entire project closely integrates environmental awareness, critical thinking, and artistic expression, ensuring that the concept of sustainable development becomes an actionable and measurable teaching objective, rather than just an empty slogan." (E6)

Overall, the core role of Holism and Systems Thinking in ESD is reflected in three aspects: interdisciplinary integration, ecological awareness/environmental concepts, and the integration of ESD concepts into teaching design. At the interdisciplinary integration level, holism requires teachers to transcend the limitations of single-disciplinary knowledge and help students understand the complexity of sustainable development issues through the integration of multiple disciplines. At the level of ecological awareness and environmental concepts, holism emphasizes that students should have the ability to understand the relationship between humans and nature, global and local interactions, and intergenerational responsibility, which in turn establishing long-term sustainable values. At the level of teaching design integration, holism guides teachers to systematically embed sustainable development elements into courses and classroom activities, so that teaching activities are not limited to knowledge transfer, but also promote the joint development of students' abilities and values.

Pluralism in ESD Pedagogy

Pluralism in ESD Pedagogy emphasizes respect for different cultures, viewpoints, and value systems in the educational process, and promotes an open and inclusive attitude among students through critical thinking and active participation. Pluralism in ESD Pedagogy focuses on whether teachers allow different viewpoints to be expressed in the classroom, whether they guide students to reflect critically on what they have learned, and whether they provide space for students to participate in topic selection and decision-making. Through diversity training, pre-service teachers classroom autonomy, critical reflection skills, and curriculum innovation capabilities are enhanced, laying the foundation for them to become "action-oriented sustainable educators" in the future. This concept is particularly important in the practice of teacher education in the multi-ethnic areas of Yunnan, because the diverse cultural background is both an educational resource and a key environment for improving pre-service teachers' cultural sensitivity and critical thinking.

Based on the in-depth interview, pluralism in ESD pedagogy has the following three sub-themes:

1) Cultural Diversity: Emphasizes respect, understanding, and integration of different nationalities, cultures, and values, avoids a single perspective, and cultivates students' cross-cultural understanding and empathy.

> *"When I teach ecology, I place particular emphasis on exploring local case studies. Agricultural ecosystems like the Hani Rice Terraces in Yunnan are excellent examples of the deep integration of culture and environment…Through this case study, students can transcend a purely biological perspective and see how different ethnic groups use unique cultural methods to understand and maintain ecological balance. This allows them to truly learn to respect cultural diversity and cultivate cross-cultural empathy and understanding." (E5)*

2) Participatory Teaching Strategies: emphasize students' active participation and cooperation in the learning process, and achieve knowledge construction and value judgment through experiential and inquiry-based learning.

> *"In my instructional design, I place particular emphasis on engaging students in the process of knowledge formation…Students were required to work in groups to collect local data on traffic flow, waste sorting…select appropriate statistical models…they learned to listen, debate, and reach consensus through collaborative inquiry, forming rational value judgments on sustainable development issues." (E2)*

3) Autonomous, Critical, and Consultative Education: Emphasizes joint decision-making and value coordination through consultation and dialogue in classroom and community practice, and cultivates students' civic awareness, critical thinking, and consultative skills.

> *"In my English teaching, I first guide students into groups to research local and global environmental issues they care about. Then, I organize class debates and discussions, allowing each student to fully present their reasons. Finally, through democratic voting, we collectively decide on the most representative writing topic. This process strengthens their English expression skills, and allows them to experience firsthand how to reach consensus through rational dialogue and value coordination, effectively cultivating their critical thinking and the ability to negotiate and make decisions as global citizens." (E1)*

Pluralism plays a crucial role in Education for Sustainable Development (ESD). First, it emphasizes respect and understanding for diverse cultures and values, helping students develop cross-cultural understanding and inclusive thinking during their learning process, which in turn better navigating the complex social and cultural issues involved in sustainable development. Second, through participatory teaching strategies, diversity encourages students to collaborate, explore, and experience in authentic contexts, enabling them to actively participate in knowledge construction and learn to negotiate and judge amidst value conflicts. Third, pluralism advocates for

classroom autonomy, critique, and deliberation, providing students with opportunities to participate in decision-making. This not only enhances learning agency but also fosters a sense of civic responsibility and social engagement. Thus, pluralism is not only an educational philosophy but also a practical teaching approach to fostering action and critical thinking.

Sustainable Leadership for ESD Implementation

Sustainable leadership is the core guarantee for promoting holistic and pluralistic approaches. It encompasses more than administrative initiatives by management; it emphasizes the actions, systems, and collaboration of teachers and leaders to create a sustainable educational environment for pre-service teachers. The purpose of studying sustainable leadership is to explore how, through leadership modeling, institutional development, and community collaboration.

Based on the in-depth interview, sustainable leadership has the following three sub-themes:

1) Leadership Effect: Teachers and administrators demonstrate environmental values through practical actions.

> *“School leaders organize campus activities themed on sustainable development and integrate the promotion and demonstration of sustainable development values into the campus environment, allowing pre-service teachers to continuously immerse themselves in and perceive these values in their daily lives. Under the long-term influence of this atmosphere, they are more likely to form firm sustainable development values, which in turn strengthening their internal motivation and willingness to engage in sustainable development education in the future.” (E10)*
>
> *"Our school's leadership places a strong emphasis on demonstrating exemplary leadership through personal involvement. Deans and department heads not only approve activity plans but also participate substantively in various academic forums related to environmental protection and sustainable development. They also spearheaded campus cleanup and environmental initiatives on June 5th, Environment Day. Through this high level of visibility and engagement, they clearly convey the school's core values to the pre-service teachers. This proactive demonstration has greatly stimulated students' sense of*

identity and successfully encouraged more pre-service teachers to proactively participate in the planning and implementation of environmental initiatives." (E14)

2) Institutional Support: Implement ESD through school systems and policies.

"Integrating ESD concepts into teaching practice requires strong institutional and policy support at the college level. In recent years, our college has actively promoted green chemistry experiment reform…This institutional support provides a solid foundation for faculty innovation in teaching, enabling us to systematically design and implement experimental teaching plans that reduce pollution and focus on safety, effectively implementing the goals of sustainable development in professional practice." (E4)

" It is crucial for school leaders to identify with and lead by example regarding sustainable development education. Leaders with a sustainable development mindset will not only prioritize capacity building for frontline teachers in this area, but will also proactively provide relevant resources and training support, effectively promoting the implementation of sustainable development education." (E12)

3) Community Collaboration: University leaders strengthen cooperation between universities and local governments, businesses, and communities.

"In recent years, our school has actively promoted cooperation with local governments and communities, providing a rich practical platform for ESD teaching. This in-depth community collaboration allowing students to deeply experience the practical value of mathematical knowledge in understanding and solving sustainable development problems, greatly enhancing their learning motivation and sense of social responsibility." (E2)

"To effectively implement ESD, universities must proactively open their doors and collaborate with a wider range of social forces to educate students…This sustained and stable community collaboration provides students with authentic educational contexts and is an important way to cultivate the collaborative skills and community awareness necessary for future ESD teaching." (E8)

Sustainable leadership plays a top-level design and cultural guiding role in ESD. Leaders' exemplary role not only influences pre-service teachers' values but also internalizes ESD into the norm through systems and policies. More importantly, the extended impact of leadership, community collaboration can expand the boundaries of the classroom, allowing pre-service teachers to directly participate in social, environmental, and cultural practices, enhancing their sense of social responsibility and drive for action.

Components of ESD Competence

ESD Competence is a key indicator of whether pre-service teacher can truly implement the concept of sustainable development in their educational practice. It is not only an accumulation of knowledge and attitudes, but also a comprehensive reflection of action and practice. Components of ESD Competence consists of three closely linked dimensions: pedagogical knowledge and skills, self-efficacy, and teaching willingness and motivation. These three dimensions collectively determine whether pre-service teachers can effectively promote the concept and actions of sustainable development in their future teaching positions.

Based on the in-depth interview, Components of ESD Competence has summarized the following three sub-themes:

1) Teaching Knowledge and Skills: This dimension refers to the pre-service teacher's mastery of subject knowledge and ability to apply teaching methods in ESD teaching.

> *"I believe that for pre-service teachers to be competent in ESD teaching, simply possessing general educational technology theory is far from enough. More importantly, they need to have a deep understanding of the core issues in the three dimensions of sustainable development: the environment, the economy, and the society, and be able to organically integrate these interdisciplinary contents into the knowledge system of the subject they teach." (E13)*

2) Self-efficacy in ESD: This dimension emphasizes the confidence of pre-service teachers in implementing ESD teaching.

> *"To effectively enhance pre-service teachers' self-efficacy in ESD teaching, theoretical instruction alone is far from sufficient. They particularly need case studies and practical opportunities from real-world teaching situations. We should systematically establish a localized ESD teaching case library and organize teacher trainees to visit real classrooms in primary and secondary schools to analyze how frontline teachers design and implement sustainable development-themed teaching activities. When pre-service teachers can refer to these successful practices, personally apply them in their internships, and receive positive feedback, their confidence in their ability to teach ESD will be substantially enhanced." (E9)*

3) Willingness to Implement ESD: This dimension reflects the intrinsic motivation and incentive of normal school students to implement ESD teaching.

> *"I've discovered that what truly drives pre-service teachers to engage in ESD teaching practice is often not external assessment requirements, but rather their strong inner sense of mission and social responsibility. This internal motivation stems from their deep concern for global sustainable development issues and their belief in responsible education for future generations. When they view ESD teaching as an important way to contribute to social change and cultivate future citizens, they will develop a strong sense of value and a willingness to actively implement it." (E12)*

ESD Competence is key to truly implementing sustainable development education in teacher training. Specifically, pedagogical knowledge and skills provide the foundation, enabling teachers to understand how to implement practices; self-efficacy provides the confidence to dare to take action; and willingness and motivation to teach provide the internal driving force, enabling teachers to proactively pursue the initiative. Only by combining these three aspects can teacher trainees not only understand the concept of sustainable development but, more importantly, effectively apply it in their teaching. Therefore, the level of ESD professional action competence not

only reflects the learning progress of pre-service teachers themselves, but also directly reflects the quality of teacher training at teacher training institutions and the overall emphasis on the Sustainable Development Goals within the education system. Only when pre-service teachers not only learn how to teach, but also have the confidence to teach and the willingness to teach, can schools cultivate talents who are truly committed to sustainable development education and provide society with future teachers who are motivated and responsible.

Additionally, the qualitative research identified two other themes relevant to developing pre-service teachers' ESD competencies: ESD-Centric Curriculum Reform and Continuous Professional Growth in ESD.

The ESD-Centric Curriculum Reform emphasizes the systematic integration of ESD concepts into the teacher education curriculum, making it a core module rather than an add-on. The reform aims to create a curriculum structure aligned with the Sustainable Development Goals and ensure that teacher trainees gain exposure to and understanding of ESD across all disciplines. The reform promotes a shift in the education system from traditional knowledge transfer to a focus on both values and competencies, empowering pre-service teachers to address global and local challenges.

> *"Curriculum design must adhere to the principle of integrating both cognitive and emotional dimensions. It should not simply focus on explaining concepts, but should also emphasize guiding values and cultivating teaching abilities. Specifically, in addition to teaching sustainable development knowledge, it should also utilize emotionally engaging teaching methods such as role-playing, ecological experiences, and community service to help teacher trainees internalize sustainable development values while mastering the practical skills of designing ESD teaching activities and guiding students' value reflection. This will truly achieve the unity of knowledge and action, laying a solid foundation for them to address sustainable development challenges in the real world in the future." (E14)*

Continuous Professional Growth in ESD emphasizes that pre-service teachers continuously learn ESD concepts and methods throughout their pre-service and in-service education, enabling lifelong growth. The program aims to establish a continuous training system from teacher trainee to in-service teacher, ensuring that teachers' ESD competencies are constantly updated. Continuous Professional Growth in ESD adapts to rapidly evolving global and local sustainability issues, maintaining teachers' pedagogical advancement and initiative. Continuous Professional Growth in ESD encompasses pre-service education, in-service training, educational research, and international exchange.

> *"To achieve continuous professional growth in the field of ESD, we cannot rely solely on concentrated training during the teacher training phase. Instead, we must establish a development system that covers teachers throughout their entire career. We are committed to establishing a regular teacher development training mechanism and a stable peer support network. For example, we regularly hold ESD workshops, establish cross-school teaching and research communities, and encourage experienced and novice teachers to pair up to reflect on and improve their ESD teaching practices. Through this systematic support, teachers can continuously acquire the latest sustainable development education concepts and methods, continuously optimize their teaching behaviors through communication and collaboration, and truly achieve ESD capacity development from pre-service to post-service, throughout the professional life cycle of teachers." (E8)*

In conclusion, the qualitative in-depth interview results of this study further enriched and deepened the findings of the quantitative research, revealing that the development of ESD competence among pre-service teachers presents multi-dimensional thematic characteristics. To be more specific, the qualitative data analysis condensed four core themes that are highly consistent with the quantitative research: (1) Holism and Systems Thinking in ESD, which emphasizes interdisciplinary integration, systematic understanding, and the cultivation of ecological awareness, which is consistent with the results of the ESD holistic dimension in the quantitative research; (2) Pluralism in ESD Pedagogy, which involves cultural sensitivity, participatory teaching,

and consultation, which echoes the measurement of the ESD pluralistic dimension in the quantitative research; (3) Sustainable Leadership for ESD Implementation, which reflects leadership demonstration, institutional support, and community collaboration, confirming the importance of institutional and leadership factors to the effectiveness of ESD education in the quantitative results; (4) Components of ESD Competence, which covers teaching knowledge, self-efficacy, and implementation willingness, which is highly consistent with the Professional Action Competence and its three sub-variables of Self-Efficacy Regarding ESD, Perceived Pedagogical Content Knowledge About ESD, and Willingness in Implementing ESD in the quantitative research. Additionally, the qualitative research also discovered two important themes that the quantitative research did not cover: (5) ESD-Centric Curriculum Reform, which emphasizes the systematic integration of sustainable development into the curriculum system, making it a core module of teacher education rather than an additional content; and (6) Continuous Professional Growth in ESD, which highlights the continuous learning, training, and updating mechanism of pre-service teacher and in-service teachers before and after service. These two dimensions have expanded the understanding of ESD competence building, indicating that relying solely on classroom and short-term interventions is difficult to fully support the long-term growth of normal students, and a more systematic guarantee is needed through curriculum system and continuous development mechanism.

CHAPTER 5
CONCLUSION AND DISCUSSION

5.1 Summary of Key Findings

This dissertation employed mixed research methods, combining quantitative and qualitative research, to systematically analyze the impact pathways of sustainable leadership, ESD holism, and ESD pluralism on pre-service teachers' competence in Education for Sustainable Development (ESD). Quantitative research, the first phase of this study, using partial least squares structural equation modeling (PLS-SEM), found that sustainable leadership had a significant positive impact on ESD holism, ESD pluralism, and ESD professional action competence. In addition, ESD holism and pluralism significantly predicted pre-service teacher's professional action competence in Education for Sustainable Development (ESD). Furthermore, mediation analysis revealed that ESD holism and pluralism partially mediated the impact of sustainable leadership on pre-service teacher's professional action competence in Education for Sustainable Development (ESD). Moreover, the quantitative research confirmed that professional action competence in Education for Sustainable Development (ESD) is a second order construct that comprises of three sub-constructs: Self-Efficacy regarding ESD; Perceived Pedagogical Content Knowledge About ESD; and Willingness to implement ESD.

In the qualitative research section, the qualitative data for this study were gathered through semi-structured, in-depth interviews. Participants (N=15) were purposively sampled from various stakeholders in Yunnan Province, including normal university teachers, department heads, university leaders, internship supervisors, and ESD research experts. Thematic analysis identified six core themes: (1) Holism and Systems Thinking in ESD; (2) Pluralism in ESD Pedagogy; (3) Sustainable Leadership for ESD Implementation; and (4) Components of ESD Competence which corresponded to the quantitative research constructs, and (5) ESD-Centric Curriculum Reform and (6) Continuous Professional Growth in ESD which emerged as novel factors.

When the qualitative and quantitative results are compared (Table 39), a high degree of consistency is observed across four key themes: ESD holistic, ESD pluralism, sustainable leadership, and ESD competence. This consistency not only strengthens the credibility of the research conclusions but also further demonstrates that the multidimensional nature of ESD competency development is a stable phenomenon. In addition, the qualitative research revealed two key dimensions not captured by the quantitative research: ESD-centric curriculum reform and continuous professional growth in ESD. This complementary finding highlights the importance of institutional dimensions and teacher development mechanisms, demonstrating that the development of ESD competency in teacher education students relies not only on classroom instruction and individual motivation but also requires long-term institutional support and professional development pathways.

Thus, this research's Quantitative + Qualitative Complementary model demonstrates three key values: First, the quantitative research provides a macro-level path relationship and structural model; second, the qualitative research deepens the understanding of the core variables, revealing specific practical contexts and case studies for strategies development; and third, the qualitative research adds new dimensions, furthering the understanding of the ESD competency development of pre-service students. This provides a solid theoretical basis and practical implications for subsequent strategy development to enhance pre-service teacher's ESD competence.

Table 39 Correspondence between Quantitative and Qualitative Findings

Qualitative Themes	Qualitative Sub-themes/Scope	Correspondence with Quantitative Research Variables and Results	Explanation
Holism and Systems Thinking in ESD	Interdisciplinary Integration, Ecological Awareness/Environmental Perspectives, Integrating ESD Concepts into Instructional Design	Corresponding to ESD Holism in Quantitative Research	Qualitative research complements more specific cases (such as interdisciplinary project learning, environmental day activities, and green campus practices) and concretizes the holistic measurement results in quantitative research.

Qualitative Themes	Qualitative Sub-themes/Scope	Correspondence with Quantitative Research Variables and Results	Explanation
Pluralism in ESD Pedagogy	Cultural Diversity, Participatory Teaching Strategies, Autonomous, Critical, and Consultative Education	Corresponding to ESD Pluralism in Quantitative Research	Qualitative research revealed the unique challenges and practices in Yunnan's multi-ethnic context (such as the integration of ethnic culture and ecology, and pre-service teacher's consultation in curriculum design), confirming and expanding the quantitative findings.
Sustainable Leadership for ESD Implementation	Leadership Effect, Institutional Support, Community Collaboration	Corresponding to Sustainable Leadership in quantitative research, and influencing ESD competence through the mediating effects of Holism and Pluralism	The qualitative research provides richer empirical details, such as Deans' participation in Environment Day activities, policy support for interdisciplinary platforms, and cooperation with local environmental protection bureaus, which further explain the quantitative path relationships.

Qualitative Themes	Qualitative Sub-themes/Scope	Correspondence with Quantitative Research Variables and Results	Explanation
Components of ESD Competence	Teaching Knowledge and Skills, Self-Efficacy, Teaching Willingness and Motivation	Corresponding to Professional Action Competence in ESD (second-order factor) in quantitative research	The qualitative results revealed details such as the sources of motivation (sense of responsibility, value identification) and ways to enhance confidence (real cases and teacher and student role models), enriching the structural model of the quantitative research.
ESD-Centric Curriculum Reform	Curriculum Reform: Integrating ESD into the mandatory curriculum	Not covered by quantitative research (new findings)	Supplementary findings indicate that the development of ESD competence among pre-service teacher cannot rely solely on individuals and teaching strategies, but requires curriculum and institutional support, which is a core issue at the educational reform level.
Continuous Professional Growth in ESD	Continuous ESD competence training	Not covered by quantitative research (new findings)	Supplementary findings: The study emphasizes that teacher education requires continuous support throughout pre-service and post-service periods, echoing the concept of lifelong learning and providing direction for the long-term cultivation of "sustainable educators with action competence."

5.2 Integrated Discussion of Findings

5.2.1 The Influence of Sustainable Leadership on ESD-Holism

The study's findings strongly support the positive relationship between sustainable leadership and ESD-Holism, consistent with prior research emphasizing the role of school leadership in embedding sustainability principles into educational practices (e.g., Abidin et al., 2023; Qablan et al., 2023; Verhelst et al., 2023; Zachariou & Kadji-Beltran, 2009). In the phase 1: quantitative research, sustainable leadership, as perceived by pre-service teachers, refers to university leaders' actions and values that support sustainability through social, environmental, and ethical responsibilities, innovation, clear communication, and prioritizing student welfare and educational values over profit. This type of leadership emphasizes the interconnectedness of various dimensions of sustainability, including environmental, social, and economic aspects. By adopting a holistic perspective, sustainable leaders ensure that their actions and decisions consider the long-term impacts on all these dimensions, fostering a comprehensive approach to sustainability. This aligns with the principles of ESD-Holism, which seeks to integrate these diverse dimensions into educational practices, promoting a broad and interconnected understanding of sustainability issues among students.

In phase 2, the qualitative research, several college leaders and academic leaders emphasized the critical role of sustainable leadership in promoting holistic ESD. For instance, one interviewed school leadership expert (E10) noted, *"Without top-level design and policy guidance at the college level, individual faculty efforts are often fragmented and struggle to achieve a holistic effect."* This echoes the emphasis on interdisciplinary and cross-field integration in ESD Holism. Faculty members (E3) also emphasized that leadership support can better integrate interdisciplinary issues such as clean energy and green technology into their academic curriculum, which in turn promoting holistic ESD practice. This demonstrates that sustainable leadership not only provides resources and policy support but also shapes the direction and vision for ESD holistic development.

Sustainable leaders' focus on integrating environmental, social, and economic dimensions into educational processes directly aligns with the construct of holism in ESD. Leaders who prioritize sustainability create a culture that encourages interdisciplinary thinking and the incorporation of local, regional, and global sustainability issues within curricula. This alignment enhances pre-service teachers' perception of the holistic integration of sustainability dimensions, fostering a comprehensive understanding of interconnected sustainability challenges.

Social Influence Theory provides further insight into this relationship, highlighting the importance of leaders as influential role models who guide and shape organizational values. According to Kelman's (1974) Social Influence Theory, under the context of the current research, sustainable leaders act as influencing agents who deliberate strategies to promote behavioral or attitudinal congruency in line with sustainability values. Through compliance, identification, and internalization, these sustainable leaders cultivate a positive orientation among educators and students, enhancing their predisposition toward adopting ESD-Holism. Sustainable leaders' actions serve as cues for educators to adopt holistic teaching practices, reinforcing norms that prioritize sustainability in teaching and learning. By fostering a supportive environment, sustainable leaders reduce barriers to implementing holistic ESD approaches, such as resistance to curriculum changes or limited resources.

From the perspective of Social Influence Theory, the impact of sustainable leadership on ESD-Holism can be attributed to leaders' ability to serve as role models, shaping norms and values within their institutions. By emphasizing the interconnectedness of environmental, social, and economic dimensions, leaders instill a holistic mindset in educators and students alike. For instance, sustainable leaders who advocate for interdisciplinary approaches and demonstrate the integration of sustainability across curricula effectively influence pre-service teachers' perceptions of ESD-Holism. These leaders reinforce the importance of addressing sustainability issues at multiple levels: local, regional, and global and across temporal dimensions, thereby fostering a more comprehensive understanding of sustainability (Sinakou et al., 2019).

In addition, sustainable leadership plays a pivotal role in advancing ESD by fostering environments that emphasize holistic approach (Verhelst et al., 2023). Sustainable leadership entails the strategies, values, and actions leaders adopt to prioritize sustainability, focusing on social, environmental, and ethical responsibilities (Qablan et al., 2023). Leaders who adopt this approach facilitate participatory decision-making, support experiential learning, and create opportunities for teachers and students to engage actively in sustainability projects. For instance, school principals and other educational leaders support ESD implementation by encouraging collaboration, fostering a participative culture, and providing resources for sustainability education (Müller et al., 2020).

Previous research has shown that challenges like limited administrative skills, lack of resources, and resistance to change can make it hard for sustainable leadership to be effective in Education for Sustainable Development (ESD) (Kadji-Beltran et al., 2013; Filho et al., 2020). Addressing these barriers is important for improving professional skills in ESD among pre-service teachers, who often have positive attitudes towards sustainability but need more training in teaching skills and self-confidence (Palomino et al., 2022). Good sustainable leadership can help overcome these challenges. It involves guiding and using school resources to support ESD (Dries et al., 2023; Verhelst et al., 2023). Studies have highlighted the value of sustainable leadership, whether from school leaders or teacher leaders, in supporting school policies towards ESD (Abidin et al., 2023; Dries et al., 2023). School leaders can give teachers the freedom to take on roles that inspire and motivate others in ESD leadership (Dries et al., 2023). Both teachers and school leaders agree that it is the responsibility of school leaders to provide the right resources at the right time and place to support ESD (Dries et al., 2023). A clear vision of ESD within the school helps other teachers see ESD as part of their job (Dries et al., 2023). Sustainable leadership, school resources, and their relationship in supporting ESD are key to an effective ESD school (Dries et al., 2023; Verhelst et al., 2023). Efficient time management helps in teaching and learning

for ESD in a way that includes different subjects and perspectives (Dries et al., 2023; Mogren & Gericke, 2017).

Sustainable leadership significantly contributes to fostering ESD-Holism by integrating environmental, social, and economic dimensions into educational practices. Leaders who prioritize sustainability emphasize long-term development goals that align with holistic education principles (Abidin et al., 2023). School leaders play a pivotal role in interpreting education policies related to sustainability, facilitating comprehensive approaches to sustainable development (Zachariou & Kadji-Beltran, 2009). These practices resonate with Social Influence Theory's assertion that behaviors deeply rooted in personal values yield stronger long-term commitments (Kelman, 1958). By leveraging their influence, sustainable leaders create opportunities for pre-service teachers to engage with holistic perspectives, enhancing their readiness and motivation to implement ESD principles (Zachariou & Kadji-Beltran, 2009).

5.2.2 The Influence of Sustainable Leadership on ESD-Pluralism

The quantitative research confirms that sustainable leadership significantly influences ESD-Pluralism. This finding aligns with existing literature that highlights the role of participatory leadership styles in fostering pluralistic teaching practices (Müller et al., 2020). In the current research, sustainable leadership, as perceived by pre-service teachers, refers to university leaders' actions and values that support sustainability through social, environmental, and ethical responsibilities, innovation, clear communication, and prioritizing student welfare and educational values over profit. This type of leadership emphasizes the interconnectedness of various dimensions of sustainability, including environmental, social, and economic aspects. By adopting a holistic perspective, sustainable leaders ensure that their actions and decisions consider the long-term impacts on all these dimensions, fostering a comprehensive approach to sustainability. Pluralism, a key dimension of ESD, measures the degree to which teachers foster discussions, address varying viewpoints, and involve students in topic selection (Andersson, 2017; Boeve-de Pauw et al., 2015; Sinakou et al., 2019). Pluralism promotes the inclusion of diverse perspectives, critical reflection, and

participatory decision-making on sustainability topics. Sustainable leaders who value inclusivity and innovation enable educators and students to collaboratively address sustainability challenges through participatory decision-making processes (Boeve-de Pauw et al., 2015). Incorporating pluralism in communication facilitates the inclusion of diverse perspectives, making it easier to involve different viewpoints (Verhelst et al., 2023).

In phase 2, the qualitative research revealed that faculty members generally agreed that the attitude and openness of college leadership directly impacted the implementation of pluralism teaching practices. For instance, an art teacher (E6) stated, *"Leaders support us in integrating community art with environmental education, enabling students to understand sustainable development from diverse cultural and social perspectives."* Meanwhile, the head of the elementary education department (E7) noted, *"When implementing environmental education, we must integrate the voices of diverse stakeholders, including schools, families, communities, and local governments. School leaders are able to effectively negotiate relevant collaborations with the community and local governments."* These perspectives demonstrate that sustainable leadership can foster an atmosphere supportive of diverse dialogue and multi-stakeholder collaboration, providing a solid institutional foundation for pluralistic ESD practices.

From the perspective of Kelman's Social Influence Theory (1953), leaders' behaviors and communication styles act as mechanisms for social learning, enabling educators to internalize and adopt pluralistic practices. According to Kelman's (1974) Social Influence Theory, sustainable leaders act as influencing agents who deliberate strategies to promote behavioral or attitudinal congruency in line with sustainability values. Through compliance, identification, and internalization, these leaders foster a positive orientation among educators and students, enhancing their predisposition toward adopting ESD-Pluralism. Sustainable leaders' emphasis on inclusive dialogue and critical thinking provides educators with the confidence and institutional support necessary to address controversial topics and incorporate diverse perspectives into

their teaching (Verhelst et al., 2023). Sustainable leadership's statistically significant positive effect on ESD-Pluralism can be understood through the lens of participative decision-making and inclusive practices. Leaders who encourage open dialogue, value diverse perspectives, and promote critical reflection create environments conducive to pluralistic education. Social Influence Theory suggests that such behaviors enhance perceived legitimacy and trust in leadership, motivating educators to adopt pluralistic approaches in their teaching. This includes addressing varying viewpoints on sustainability issues, fostering critical discussions, and involving students in decisions regarding the curriculum. Consequently, pre-service teachers exposed to such leadership are more likely to perceive ESD as a dynamic and participatory process. A pluralistic way of communicating positively impacts a school's efforts toward ESD by presenting opportunities to start a dialogue with and among students. This approach also increases the opportunity to involve students in critical decision-making (Verhelst et al., 2021). Pluralistic communication that involves relevant stakeholders can facilitate this critical decision-making process. Including relevant stakeholders in the process allows ideas and initiatives to grow and mature, which is important for ESD. Additionally, when stakeholders participate in decision-making, a sense of ownership can be established (Verhelst et al., 2021).

Thus, sustainable leadership significantly impacts ESD-Pluralism by fostering an environment where diverse perspectives are valued and participatory decision-making is encouraged. This approach not only enriches the educational experience but also enhances the effectiveness of ESD by promoting inclusivity and critical engagement with sustainability topics. This comprehensive approach ensures that sustainability is taught in a way that addresses its environmental, social, and economic dimensions, which are essential for professional competence in ESD.

In addition, sustainable leadership plays a pivotal role in advancing ESD by fostering environments that emphasize pluralistic approach (Verhelst et al., 2023). Sustainable leadership entails the strategies, values, and actions leaders adopt to prioritize sustainability, focusing on social, environmental, and ethical responsibilities

(Qablan et al., 2023). Leaders who adopt this approach facilitate participatory decision-making, support experiential learning, and create opportunities for teachers and students to engage actively in sustainability projects. For instance, school principals and other educational leaders support ESD implementation by encouraging collaboration, fostering a participative culture, and providing resources for sustainability education (Abidin et al., 2023; Müller et al., 2020; Verhelst et al., 2023).

Although prior research has shown that challenges like limited administrative skills, lack of resources, and resistance to change can make it hard for sustainable leadership to be effective in Education for Sustainable Development (ESD) (Kadji-Beltran et al., 2013; Filho et al., 2020). Addressing these barriers is important for improving professional skills in ESD among pre-service teachers, who often have positive attitudes towards sustainability but need more training in teaching skills and self-confidence (Palomino et al., 2022). Good sustainable leadership can help overcome these challenges. It involves guiding and using school resources to support ESD (Dries et al., 2023). Studies have highlighted the value of sustainable leadership, whether from school leaders or teacher leaders, in supporting school policies towards ESD (Dries et al., 2023). School leaders can give teachers the freedom to take on roles that inspire and motivate others in ESD leadership (Dries et al., 2023). Both teachers and school leaders agree that it is the responsibility of school leaders to provide the right resources at the right time and place to support ESD (Dries et al., 2023). A clear vision of ESD within the school helps other teachers see ESD as part of their job (Dries et al., 2023). Sustainable leadership, school resources, and their relationship in supporting ESD are key to an effective ESD school (Dries et al., 2023). Efficient time management helps in teaching and learning for ESD in a way that includes different subjects and perspectives (Dries et al., 2023; Mogren & Gericke, 2017).

Sustainable leadership promotes ESD-Pluralism by creating environments that encourage diverse perspectives and critical reflection on sustainability issues. Leaders who value inclusivity and innovation enable students and educators to collaboratively address sustainability challenges through participatory decision-making

processes (Abidin et al., 2023). The concept of pluralism aligns with Kelman's (1958) identification and internalization processes, where individuals adopt behaviors or attitude consistent with intrinsic values and beliefs. Sustainable leaders influence this adoption by fostering positive orientations and reducing psychological resistance to diverse viewpoints (Kelman, 1974). For instance, sustainable leaders guide educators in integrating multiple perspectives into the curriculum, promoting collaborative learning and critical engagement with sustainability topics (Zachariou et al., 2013). These efforts align with ESD-Pluralism's aim of enabling students to critically reflect on sustainability issues, ensuring the relevance and inclusivity of educational practices.

5.2.3 The Influence of ESD-Holism on Professional Action Competence in ESD

The quantitative research findings of this study reveal a significant positive relationship between ESD-Holism and Professional Action Competence (PAC) in Education for Sustainable Development (ESD), reinforcing previous research that links holistic educational approaches to enhanced teaching outcomes (Boeve-de Pauw et al., 2015; Singh-Pillay, 2023). ESD-Holism, as a teaching approach, integrates the environmental, social, and economic dimensions of sustainability, fostering a comprehensive understanding of global challenges among pre-service teachers.

In phase 2, the qualitative research, normal university teachers generally emphasized that holistic curriculum design significantly enhances the professional action competence of pre-service teacher. For example, a chemistry teacher (E4) noted, *"In the Green Chemistry course, students not only learned knowledge but also implemented sustainable principles in laboratory practice. This practical experience has boosted their confidence in future teaching."* In addition, a biology teacher (E5) used water quality monitoring and wetland protection projects to allow pre-service teachers to practice ESD holism in real-world situations, transforming this into concrete teaching and research action competence. This demonstrates that ESD Holism can closely integrate theory and practice, promoting the growth of pre-service teacher's professional action competence.

Holistic education enables pre-service teachers to perceive and address sustainability issues in an interconnected manner, promoting systems thinking and long-term solutions. For example, Boeve-de Pauw et al. (2015) highlighted that educators who employ holistic teaching approaches provide their students with a deeper understanding of sustainability by linking local and global perspectives and examining temporal connections between past, present, and future. These practices are vital in fostering teachers' ability to embed sustainability principles into diverse educational contexts.

The relationship between ESD-Holism and Professional Action Competence (PAC) in Education for Sustainable Development (ESD) can also be contextualized within the broader framework of professional competence, which comprises self-efficacy, pedagogical content knowledge, and willingness to act. Holistic ESD approaches have been shown to enhance self-efficacy by empowering teachers with the confidence to engage in sustainability-related teaching activities (Zachariou & Kadji-Beltran, 2009). Similarly, integrating environmental, social, and economic dimensions into teaching improves pedagogical content knowledge, enabling teachers to design and deliver interdisciplinary and participatory learning experiences (Mogaji & Newton, 2020).

Kelman's (1974) Social Influence Theory provides a theoretical lens through which to understand the influence of holistic approaches on Professional Action Competence (PAC) in Education for Sustainable Development (ESD). In the current research context, leaders and educators who model and promote holistic sustainability principles act as influential agents, guiding pre-service teachers to internalize these values. Internalization, a process where individuals adopt behaviors or attitude consistent with deeply held beliefs, is crucial in fostering long-term professional competence. By embedding holistic practices into teacher training, educators help pre-service teachers align their intrinsic values with their professional actions, ensuring sustained commitment to ESD (Kelman, 1974).

Additionally, experiential and project-based learning opportunities inherent in holistic approaches have been shown to enhance teachers' willingness to implement sustainability education (Sass et al., 2022; Sinakou et al., 2019). These experiences allow pre-service teachers to engage directly with sustainability challenges, fostering a sense of agency and purpose. For instance, interdisciplinary projects that connect local and global sustainability issues help teachers understand the interconnected nature of these challenges, thereby enhancing their motivation to address them in their teaching practices.

Thus, ESD-Holism significantly contributes to developing pre-service teachers' Professional Action Competence by integrating sustainability's multidimensional aspects into pedagogical practices. Pre-service teachers exposed to holistic ESD approaches demonstrate enhanced self-efficacy, stronger pedagogical knowledge, and greater willingness to act, ensuring their readiness to address sustainability challenges in their professional roles (Abidin et al., 2023).

5.2.4 The Influence of ESD-Pluralism on Professional Action Competence in ESD

The quantitative research revealed that ESD-Pluralism positively influence pre-service teacher's Professional Action Competence (PAC) in ESD. Pluralism within Education for Sustainable Development (ESD) emphasizes the integration of diverse perspectives, critical reflection, and participatory decision-making, which are essential for navigating the complexity of sustainability issues. This approach equips future educators with the competencies necessary to implement sustainability principles effectively, aligning with research that highlights the transformative potential of pluralistic education (Isac et al., 2022). ESD-Pluralism nurtures critical thinking and inclusivity by encouraging learners to explore multiple viewpoints and engage in critical dialogue (Boeve-de Pauw et al., 2015). This pedagogical ethos ensures that no single perspective dominates, fostering the critical evaluation of alternative views and collaborative problem-solving.

In phase 2, the qualitative research revealed that respondents generally noted that exposure to pluralistic cultures and multidimensional ESD teaching methods can help pre-service teacher develop more inclusive and creative teaching practices. For instance, a Chinese language and literature intern instructor (E13) noted, *"When students try to integrate essay topics with environmental protection and local cultural preservation, they not only improve their writing skills but also develop cross-disciplinary problem-solving skills."* An educational psychology researcher (E14) further noted that pluralism helps pre-service teacher understand that ESD is not simply about imparting knowledge, but rather a comprehensive process involving psychology, society, and values. Therefore, qualitative research also supports the view that ESD pluralism is an important factor to foster ESD competence.

Kelman's (1958) Social Influence Theory provides a theoretical lens to understand how ESD-Pluralism influences the development of Professional Action Competence (PAC) in Education for Sustainable Development (ESD). According to Social Influence Theory, leaders shape behaviors and attitudes through compliance, identification, and internalization. In the context of ESD, sustainable leaders who model pluralistic approaches act as role models and change agents, inspiring teachers to adopt similar practices. Initially, compliance may result from external incentives or policies promoting pluralistic teaching. Over time, identification with these values fosters alignment with the leader's vision. Finally, internalization occurs when pluralistic principles resonate with teachers' personal values, leading to lasting integration of ESD-Pluralism into their professional identity. By fostering participatory learning environments, ESD-Pluralism empowers pre-service teachers to address sustainability challenges collaboratively and critically. This teaching approach nurtures their ability to facilitate inclusive discussions, guide decision-making, and address controversial topics constructively. As such, pluralism enhances their self-efficacy and pedagogical competence, ensuring they are equipped to translate sustainability principles into actionable teaching strategies. The transformative power of pluralistic teaching is

evident in its ability to prepare educators to guide students toward understanding and solving real-world sustainability challenges (Davlembayeva & Papagiannidis, 2024).

Thus, ESD-Pluralism is crucial in developing pre-service teachers' Professional Action Competence (PAC) in Education for Sustainable Development (ESD) by integrating diverse perspectives, fostering critical reflection, and promoting participatory decision-making. By empowering educators to address sustainability comprehensively, pluralistic approaches prepare them to inspire and guide future generations in adopting sustainable practices. This integration of pluralism into pedagogical practices contributes to a more sustainable and inclusive educational paradigm, ensuring that both teachers and students are equipped to tackle the complexities of a rapidly changing world.

5.2.5 The Influence of Sustainable Leadership on Professional Action Competence in ESD

The quantitative research revealed that sustainable leadership positively influence pre-service teachers' Professional Action Competence (PAC) for Education for Sustainable Development (ESD). Sustainable leadership, as perceived by pre-service teachers, embodies the actions and values of university leaders committed to promoting sustainability. These leaders prioritize social, environmental, and ethical responsibilities, foster innovation, maintain transparent communication, and emphasize student welfare and educational excellence over financial motives. This form of leadership provides a foundation for embedding sustainability into the institutional culture and pedagogy. Sustainable leadership operates through strategic management practices, inspiring commitment, and fostering participative processes that align with the goals of ESD (Qablan et al., 2023). By articulating a clear vision and integrating sustainability into decision-making frameworks, leaders establish an institutional ethos where sustainability becomes a shared value (Müller et al., 2020; Verhelst et al., 2023). These efforts create an environment where educators and students are motivated and equipped to engage with sustainability challenges, thus directly enhancing the Professional Action Competence (PAC) for Education for Sustainable Development (ESD) of pre-service teachers.

In phase 2, the qualitative research revealed that leadership support was considered a crucial condition for the development of ESD professional action competence among pre-service teacher. For instance, the Associate Dean of the School of Education (E11) emphasized, *"By incorporating ESD elements into the curriculum, we ensure that pre-service teacher have opportunities to engage with and practice the concept of sustainable development in every course."* Furthermore, the Director of the Early Childhood Education Program (E8) stated that leadership-driven school-local collaborations (such as joint activities with the Environmental Protection Agency) enable students to gain practical experience and enhance their sense of responsibility. This demonstrates that leadership enhances pre-service teacher's ESD competence through institutional arrangements and resource integration.

The impact of sustainable leadership on Professional Action Competence (PAC) for Education for Sustainable Development (ESD) can be understood through Kelman's (1958) Social Influence Theory. Leaders act as influential agents, facilitating the internalization of sustainability values among pre-service teachers. This internalization process, which aligns individual values with institutional goals, fosters long-term professional competence by linking intrinsic motivation with actionable teaching practices (Kelman, 1974). Through clear communication of sustainability objectives and the encouragement of innovative pedagogical methods, sustainable leaders significantly enhance teachers' self-efficacy (Abidin et al., 2023), pedagogical knowledge, and willingness to implement ESD principles.

Social Influence Theory provides a valuable explanation theory for examining how leadership fosters Professional Action Competence (PAC) for Education for Sustainable Development (ESD). It highlights the interplay of group norms, shared values, and individual agency in competence development. Sustainable leaders establish a sense of collective identity and shared purpose, which enhances pre-service teachers' dispositions into observable competencies (Shephard, 2022). By fostering participatory environments, these leaders enable pre-service teachers to develop the cognitive, affective, and motivational dimensions of competence necessary for

addressing sustainability challenges (Brundiers et al., 2020). Furthermore, sustainable leaders influence the motivational and volitional aspects of competence. They bridge the gap between knowledge acquisition and practical application by fostering both the willingness and capability to act. This is critical for pre-service teachers who may possess theoretical understanding but lack the motivation to engage in meaningful sustainability practices. By addressing this gap, sustainable leadership ensures that latent dispositions are transformed into actionable competencies, leading to tangible outcomes in sustainability education (Jensen & Schnack, 1997; Shephard, 2022).

Thus, sustainable leadership is a pivotal factor in cultivating Professional Action Competence among pre-service teachers in ESD. Through the mechanisms of Social Influence Theory, leaders inspire the internalization of sustainability values, enhance self-efficacy, and motivate meaningful engagement with sustainability education. By fostering an institutional culture that prioritizes sustainability, leaders empower educators to implement ESD principles effectively, preparing them to address global challenges and contribute to a sustainable future.

5.2.6 The mediating role of ESD-Holism between Sustainable Leadership and Professional Action Competence in ESD

The quantitative research highlights the mediating role of ESD-Holism as a pathway through which sustainable leadership enhances Professional Action Competence (PAC) in Education for Sustainable Development (ESD). The findings address a notable gap in empirical research, shedding light on the mechanisms by which sustainable leadership influences pre-service teachers' PAC through a holistic educational framework.

ESD-Holism integrates the environmental, social, and economic dimensions of sustainability, fostering an interconnected understanding of these domains. Leaders who emphasize holistic approaches indirectly enhance pre-service teachers' Professional Action Competence (PAC) in Education for Sustainable Development (ESD) by promoting comprehensive and systemic thinking in sustainability education. This aligns with prior research, which highlights the transformative potential of holistic

frameworks in cultivating the competencies required for addressing sustainability challenges (Brandt et al., 2022).

In phase 2, the qualitative research, several respondents explicitly stated that sustainable leadership may doesn't directly shape student motivation, but rather works through holistic curriculum and program design. For example, a physics teacher (E3) noted, *"Faculty-level support has enabled us to integrate new energy teaching and experiments, giving students greater confidence in applying this knowledge in future teaching."* This suggests that leadership, by promoting the integration of holistic educational content, provides students with a more systematic learning and practice path, which in turn enhancing their ESD professional action competence.

The mediating role of ESD-Holism is deeply rooted in Kelman's Social Influence Theory (SIT), which identifies three stages of influence, namely compliance, identification, and internalization (Kelman, 1974). These stages provide a theoretical lens to understand how sustainable leadership fosters changes in pre-service teachers' attitudes and behaviors:

Compliance: At the initial stage, leaders establish policies, frameworks, or incentives to encourage teachers to adopt ESD-Holism. For example, mandatory professional development programs focusing on sustainability principles compel educators to align their practices with organizational goals. While this stage often involves external motivation, it sets the foundation for deeper engagement with ESD principles.

Identification: Leaders who embody holistic sustainability practices serve as role models, inspiring pre-service teachers to emulate their behavior. For instance, sustainable leaders who integrate multidimensional sustainability into their decision-making can foster a sense of shared purpose among teachers. This identification with leaders promotes the adoption of ESD-Holism as a means of maintaining alignment with the values and vision of the organization.

Internalization: The most profound level of influence occurs when pre-service teachers adopt ESD-Holism as a core part of their professional identity. This internalization is facilitated by leaders who prioritize holistic education, enabling teachers to integrate sustainability principles into their teaching practices authentically. Once internalized, these values drive long-term behavior change, ensuring that sustainability remains central to teachers' pedagogical approaches.

The mediating role of ESD-Holism also bridges the gap between leadership initiatives and classroom outcomes. By emphasizing the interconnectedness of sustainability dimensions, holistic approaches enhance pre-service teachers' pedagogical content knowledge and self-efficacy in implementing ESD principles. This finding aligns with research suggesting that educators who adopt holistic frameworks are better equipped to address complex sustainability issues (Andersson, 2017). Moreover, the Social Influence Theory clarifies how leaders' influence cascades through structured and organic processes, ultimately translating into classroom practices that reflect the principles of ESD-Holism.

From a practical perspective, the integration of Social Influence Theory provides valuable insights into the pathways by which sustainable leadership fosters Professional Action Competence (PAC) in Education for Sustainable Development (ESD). Compliance through policies ensures initial alignment with organizational goals, while identification and internalization facilitate sustained behavior change and deeper commitment to sustainability values. This progression highlights the importance of sustainable leadership not only as a directive force but also as a transformative influence that empowers teachers to internalize and enact holistic sustainability principles.

Thus, ESD-Holism mediates the relationship between sustainable leadership and pre-service teachers' Professional Action Competence (PAC) in Education for Sustainable Development (ESD) by operationalizing Social Influence Theory's stages of compliance, identification, and internalization. Leaders who emphasize ESD-Holism create a structured yet adaptable framework that integrates sustainability's

environmental, social, and economic dimensions into teaching practices. This holistic approach equips pre-service teachers with the skills, knowledge, and values necessary to confidently address sustainability challenges in their future careers.

5.2.7. The mediating role ESD-Pluralism between Sustainable Leadership and Professional Action Competence in ESD

The quantitative research highlights the mediating role of ESD-Pluralism in connecting sustainable leadership with Professional Action Competence (PAC) in Education for Sustainable Development (ESD). ESD-Pluralism, characterized by the integration of diverse perspectives and participatory decision-making, significantly enhances educators' abilities to implement inclusive and action-oriented teaching practices (Axeithioti & Sinakou, 2021; Boeve-de Pauw et al., 2015).

In phase 2, the qualitative research also revealed that ESD pluralism plays a mediating role between sustainable leadership and ESD competence. For example, an art teacher (E6) noted, *"With the support of leadership, we can collaborate with the community to help students see the diverse possibilities of integrating art and environmental protection."* An educational technology researcher (E15) also emphasized that the introduction of digital platforms enables pre-service teachers to learn and apply ESD in diverse contexts. This diverse learning experience translates into more innovative action. Therefore, ESD pluralism is a key mediating mechanism for the transformation of leadership into action competence.

Social Influence Theory (Kelman, 1974) provides a robust framework for understanding how ESD-Pluralism mediates this relationship. According to Social Influence Theory, leaders influence individuals through three mechanisms: compliance, identification, and internalization. In the context of ESD, sustainable leaders foster environments that encourage pluralistic values and behaviors, guiding educators through these stages of influence. Initially, educators may comply with pluralistic teaching practices to meet institutional or leadership expectations. For example, leaders who emphasize inclusivity and provide resources for pluralistic education create a structure where compliance is rewarded. As educators interact more closely with these leaders, they begin to identify with the values and practices promoted, aligning their

teaching approaches with those modeled by their leaders. The final stage, internalization, occurs when educators fully adopt pluralistic practices because these approaches resonate with their personal values and beliefs about education and sustainability (Kelman, 1974; Davlembayeva & Papagiannidis, 2024).

By fostering environments that prioritize dialogue, inclusivity, and diverse perspectives, sustainable leaders indirectly enhance pre-service teachers Professional Action Competence (PAC) in Education for Sustainable Development (ESD). Through pluralism, pre-service teachers engage in critical reflection, collaborative decision-making, and problem-solving, all of which are essential components of professional action competence (Abidin et al., 2023; Müller & Qablan, 2023). These practices align with the holistic and participatory goals of ESD, enabling educators to address sustainability challenges comprehensively.

Furthermore, Social Influence Theory can explain how pluralistic practices reduce resistance to change by facilitating identification and internalization. Leaders' emphasis on inclusivity encourages educators to adopt sustainability-focused behaviors as part of their professional identity. When pre-service teachers identify with their leaders' commitment to sustainability, they are more likely to incorporate these values into their future teaching. Internalization ensures that pluralistic approaches become deeply embedded in their practices, leading to sustained professional growth and the effective implementation of ESD principles (Kelman, 1974; Axeithioti & Sinakou, 2021).

The mediating role of ESD-Pluralism also highlights its contribution to the holistic development of sustainability competencies. Leaders who promote pluralistic approaches not only facilitate compliance with institutional goals but also empower educators to critically engage with diverse perspectives, fostering deeper understanding and action-oriented learning. This dynamic supports the development of professional action competence by equipping educators with the skills, knowledge, and attitudes needed to address the multifaceted dimensions of sustainability (Boeve-de Pauw et al., 2015; Iqbal & Ahmad, 2020).

Thus, the findings affirm that ESD-Pluralism mediates the relationship between sustainable leadership and professional action competence in ESD by leveraging the principles of Social Influence Theory. Sustainable leaders who champion pluralism cultivate environments where educators progress from compliance to internalization, enabling them to adopt pluralistic teaching methods that align with ESD's goals. This type of sustainable leadership allows pre-service teachers to experience ESD-Pluralism more deeply in the classroom, thereby enhancing their Professional Action Competence (PAC) in Education for Sustainable Development (ESD).

5.3 Theoretical Implications

This study makes significant theoretical contributions to the fields of Sustainable Leadership and Education for Sustainable Development (ESD) by elucidating the mediating roles of ESD-Holism and ESD-Pluralism. The findings provide new insights into how sustainable leadership practices within teacher training institutions influence the professional action competence of pre-service teachers in ESD.

Firstly, the research enhances the theoretical understanding of Sustainable Leadership by demonstrating its indirect effects on professional action competence through ESD-Holism and ESD-Pluralism. This study proposes a comprehensive model in which sustainable leadership not only directly influences ESD but also enhances pre-service teachers' professional action competence by fostering holistic and pluralistic educational approaches. This model introduces a fresh perspective on how leadership practices in educational settings shape teachers' abilities to engage with sustainability education, thereby expanding the theoretical framework of sustainable leadership.

Secondly, the study refines the conceptual framework of ESD by integrating both holistic and pluralistic approaches as essential mediators between leadership and teacher competence. ESD-Holism, which encompasses the environmental, social, and economic dimensions of sustainability, and ESD-Pluralism, which incorporates diverse perspectives and values, are shown to be critical pathways through which sustainable leadership impacts professional action competence. This integration helps develop a

more nuanced understanding of how sustainability principles can be effectively embedded into teacher training, thereby advancing the theoretical discourse on ESD.

Moreover, the research addresses a notable gap in the literature by providing empirical evidence on the mediating effects of ESD-Holism and ESD-Pluralism. Previous studies have largely focused on the direct effects of leadership on sustainability practices, with limited attention to the specific mechanisms through which leadership influences teacher competence. By highlighting the mediating roles of ESD-Holism and ESD-Pluralism, this study offers a deeper theoretical understanding of the processes through which sustainable leadership fosters professional action competence in ESD.

Furthermore, the study contributes to the theoretical development of professional action competence in ESD under the context of teacher training institutions by clarifying the roles of self-efficacy, perceived pedagogical content knowledge, and willingness to implement ESD. The findings suggest that sustainable leadership, through its influence on ESD-Holism and ESD-Pluralism, enhances these dimensions of professional action competence, thereby providing a comprehensive theoretical model that links leadership practices to teacher competence in sustainability education.

In summary, this research makes substantial theoretical contributions by expanding the understanding of sustainable leadership and its impact on professional action competence in ESD. By integrating holistic and pluralistic approaches as mediators, the study provides a robust theoretical framework that elucidates the pathways through which sustainable leadership influences teacher competence. These theoretical insights not only advance the academic discourse on ESD but also offer valuable directions for future research in the field.

5.4 Integrated Strategy Development to Enhance ESD Competence

This dissertation aimed to explore strategies for developing ESD competence among pre-service teachers. Combining the results of quantitative and qualitative research, it clearly demonstrates that sustainable leadership not only directly impacts and increases the frequency of pre-service teacher's exposure to ESD holism and pluralism but also, through ESD holism and pluralism as a partial mediator, promotes

pre-service teachers' professional action competence in ESD. Additionally, qualitative findings from expert interviews further reveal specific pathways and strategies insights in curriculum design, social practice, interdisciplinary collaboration, and contextual experience. Therefore, this research proposes the following multi-dimensional strategic development implications, aiming to provide theoretical and practical references for ESD education reform in teacher training institutions and the development of ESD competence among pre-service teachers.

Following the development of the 16 integrated strategies to enhance ESD competence of pre-service teachers, to further enhance the rigor and practical value of the research findings, this study fed back the resulting strategy framework to the 15 experts who participated in the second phase of qualitative research, conducting a strategy validation/member checking process. This process aimed to re-examine and refine the strategies' relevance to reality, feasibility, and contextual suitability. During the strategy validation process, experts provided specific feedback on the rationality and operability of each strategy from the perspectives of teacher education practice, curriculum implementation conditions, the current state of teacher development, and the needs of regional sustainable development. The researchers systematically analyzed the experts' opinions and, based on this, appropriately adjusted and optimized the wording, implementation paths, and key content of some strategies, thereby ensuring that the strategy system more realistically reflects the actual context of ESD capacity building in teacher education institutions. This closed-loop process of strategy feedback and expert confirmation effectively enhances the credibility and dependability of the strategy development process, ensuring that the strategies proposed in the research not only originate from theoretical deductions based on quantitative models and qualitative thematic analyses, but also undergo practical testing and recognition by professionals with extensive experience in Education for Sustainable Development. Simultaneously, this process further strengthens the overall integrity and internal consistency of the research design using a mixed-methods approach, enabling strategy development to form a systematic research logic chain from "data—interpretation—practical verification."

The specific of the 16 integrated strategies to enhance ESD competence of pre-service teachers are presented as follows:

5.4.1 Leveraging the leadership effect of educators: strengthening value guidance and behavioral modeling

Through the role models of teachers and managers, normal school students can experience the connotation and expression of ESD leadership in a real environment.

- Systematically carry out "ESD Leadership Model Case Teaching" in normal universities, and invite primary and secondary school principals, teaching researchers and front-line teachers who have outstanding performance in sustainable development education to share their experiences and demonstrate how they promote ESD practice through curriculum reform, campus actions and social cooperation.

- Clearly require university teachers, educational mentors, and internship instructors to demonstrate ESD behavior in their teaching and management, such as taking the lead in low-carbon office work, participating in sustainable campus construction, and clearly conveying ESD values in teaching guidance.

5.4.2 Strengthen institutional support for institutions and build a systematic guarantee for the development of ESD

Provide stable institutional support for the ESD competence development of pre-service teachers from multiple aspects including policies, curriculum and resources.

- Strategic recommendations: Promote normal universities to explicitly incorporate ESD into teacher training programs, curriculum quality standards and teaching evaluation systems, establish compulsory ESD modules, and stipulate ESD competency requirements that must be achieved for graduation.

- Strategic recommendations: Establish an ESD teaching resource support platform, develop and share ESD interdisciplinary teaching case libraries, activity design templates and practice guidance manuals, and provide funding and facility support for pre-service teachers to conduct ESD practical research.

5.4.3 Establish a mechanism for cultivating teacher leadership

Integrate leadership elements into the teacher training process to help them become active promoters of ESD in schools in the future.

- Strategic recommendations: Set up a special topic of "Educational Leadership and Change Management" in the teacher education curriculum to cultivate normal students' ESD project design, team collaboration and organizational mobilization capabilities, so that they understand how to promote the implementation of ESD inside and outside the school from the perspective of teachers.

- Strategic recommendations: Organize pre-service teachers to carry out "campus ESD micro-actions", such as planning and implementing garbage sorting promotion projects, organizing sustainable consumption advocacy activities, etc., to train their leadership awareness and organizational skills through actual planning and implementation.

5.4.4 Promote interdisciplinary integrated teaching

Help pre-service teachers break down disciplinary barriers, understand the inherent connections between multi-dimensional issues such as environment, society and economy, and develop the ability to systematically analyze and solve sustainability problems.

- Strategic recommendations: Establish interdisciplinary project modules in teacher education courses, such as offering comprehensive topics such as "Sustainable Urban Development" and "Global Climate Change and Local Responses," requiring pre-service teachers to collaboratively apply multidisciplinary knowledge such as geography, science, society, and economics to jointly design and present solutions.

5.4.5 Integrating ESD concepts into teaching design

Guide pre-service teachers to consciously integrate the concept of sustainable development when designing their teaching, and transform systems thinking into practical classroom practice.

- Strategic Recommendation: Conduct "ESD Teaching Design Workshops" using project-based learning (PBL) and situational tasks as the main methods to train pre-service teachers to design teaching plans that integrate

multidisciplinary perspectives and are close to real-world issues, such as "How to Reduce Campus Carbon Footprint" and "Designing a Zero Waste Sports Meet."

- Strategic recommendations: Develop and promote ESD teaching resource libraries and case libraries, provide cross-disciplinary integrated teaching design templates and typical lesson examples, and help pre-service teachers integrate sustainable concepts into specific subjects, such as analyzing ecological literature in Chinese classes and modeling resource allocation issues in mathematics classes.

5.4.6 Promote participatory teaching strategies

Cultivate the ability of pre-service teachers to use participatory methods such as collaboration, experience and simulation to carry out ESD teaching, ensuring that students from different backgrounds can participate equally.

- Strategic recommendations: Encourage pre-service teachers to experiment with project-based collaborative learning in microteaching and internships, organize group research, debates, and co-construct solutions around sustainable development issues (such as fair trade and water resource allocation), and enhance their ability to organize diverse dialogues in practice.

5.4.7 Developing autonomous, critical and consultative educational skills

Guide pre-service teachers to master how to cultivate students' critical thinking, negotiation awareness and collective action through classroom and community practice.

- Strategic Recommendation: Include a “Critical Thinking and Value Negotiation” training session in teacher training courses. By analyzing controversial sustainability issues (such as climate change responsibility), students can learn how to guide discussions, manage conflicts, and promote consensus.

- Strategic recommendations: Encourage pre-service teachers to design consultative learning projects that engage with the community. For example, organize students to discuss solutions to local environmental problems with community representatives, learn to coordinate diverse interests in real-world scenarios, and promote sustainable actions.

5.4.8 Promote the reconstruction of the teacher education curriculum system with ESD

Systematically integrate the ESD concept into the entire process of teacher training, and make it a core component of teacher education in various disciplines, rather than additional content.

- Strategic recommendations: Make ESD a compulsory module for teacher education majors and develop interdisciplinary comprehensive courses, such as offering a compulsory general education course "Foundations of Sustainable Development Education" and a series of courses on "Subject ESD Teaching Methods";

- Strategic recommendations: Integrate cognitive and emotional dimensions into curriculum design, not only imparting knowledge about sustainable development, but also guiding pre-service teachers to internalize sustainable development values through emotionally engaging teaching methods such as role-playing, ecological experiences, and community service.

- Strategic recommendations: Emphasize competence orientation, help pre-service teachers master the practical ability to design ESD teaching activities and guide students to reflect on their values, and lay the foundation for them to cope with real sustainable challenges in the future.

5.4.9 Strengthen ecological awareness and environmental concepts

Enhance pre-service teachers' understanding of the interdependence between human and nature, and establish educational values of respecting and adapting to nature.

- Strategic recommendations: Organize ecological experience and field trips, such as leading pre-service teachers to nature reserves, eco-villages, or urban wetlands to observe biodiversity in real environments and explore the balance between ecosystem service functions and human activities.

- Strategic recommendations: Incorporate ecological ethics and environmental philosophy into general education and education courses, and guide pre-service teachers to think about the place of humans in nature and the responsibilities they should bear through discussions of classic texts and case studies.

5.4.10 Strengthen practical experience and successful feedback to enhance ESD teaching self-efficacy

Through progressive practice and positive incentives, enhance the confidence of pre-service teachers in conducting ESD teaching.

- Strategic recommendations: Establish a three-stage practice system of "micro-teaching-educational internship-practical teaching" to allow pre-service teachers to gradually transition from simulated teaching to the implementation of ESD content in real classrooms, and receive specific feedback and encouragement from tutors at each stage.

- Strategic recommendations: Organize pre-service teachers to participate in ESD practice projects in primary and secondary schools, such as assisting in the development of environmental protection clubs and sustainable development theme class meetings, so that they can accumulate successful experience in a supportive environment and gradually enhance their teaching confidence.

5.4.11 Inspire a sense of responsibility and mission, and cultivate intrinsic motivation for ESD teaching

Through value guidance, role modeling and meaning construction, to strengthen the intrinsic motivation of pre-service teachers to engage in sustainable development education and realize their continuous commitment to "willingness to teach".

- Strategic recommendations: Integrate mission education into the entire process of teacher training, and help them understand the social significance of ESD teaching and the role responsibilities of teachers through activities such as sharing of outstanding teacher cases, educational ethics seminars, and debates on sustainable development values.

- Strategic recommendations: Build a dialogue platform between normal school students and ESD practice role models (such as outstanding frontline teachers and social environmental activists), stimulate their emotional identification and behavioral imitation through real stories, and form their career vision of "I want to be such a teacher."

5.4.12 Promote social collaboration and expand ESD practice platforms and networks

Through continuous cooperation between colleges and universities and governments, enterprises and social organizations, provide pre-service teachers with opportunities to participate in real ESD practices.

- Strategic recommendations: Normal universities should establish educational cooperation networks with local governments, environmental protection organizations, corporate social responsibility departments, etc., jointly develop ESD internship bases for normal students, and organize them to participate in regional sustainable development projects, such as regional environmental education publicity and campus carbon neutrality actions.

- Strategic Recommendation: Encourage pre-service teachers to participate in ESD social service projects under the guidance of their schools, such as designing sustainable development workshops for the community and assisting local schools in developing ESD curriculum.

5.4.13 Building an interdisciplinary teaching, research and practice community

Break the boundaries of university disciplines, connect the practical scenarios of primary and secondary schools, and provide a systematic learning and practice environment for pre-service teachers.

- Strategic recommendations: Establish a "university-primary and secondary school" ESD collaborative teaching and research mechanism, organize normal school students and primary and secondary school teachers to jointly carry out interdisciplinary teaching seminars and collaborative lesson preparation, and improve overall teaching design capabilities in practice.

- Strategic recommendations: Encourage pre-service teachers to participate in sustainable campus action projects, such as participating in the planning of campus ecological landscapes, organizing environmental protection public welfare advocacy activities, etc., so that they can experience the relationship between individual actions and systemic change through real participation.

5.4.14 Strengthening understanding of cultural diversity

Help pre-service teachers recognize, respect and integrate diverse cultures and ethnic perspectives, and be able to carry out ESD teaching in a multicultural context.

- Strategic recommendations: Open a special module on "Cultural Diversity and Sustainable Development", introduce cases such as ethnic minority ecological wisdom and local environmental knowledge, and guide pre-service teachers to compare the differences in values on nature, resources and development among different cultures.

- Strategic recommendations: Organize pre-service teachers to participate in multicultural education experience activities, such as visiting multi-ethnic schools and international schools, collecting ethnic cultural narratives, and conducting cross-cultural cooperation projects to enhance pre-service teachers' perception and empathy of cultural differences.

5.4.15 Create a diverse educational practice community to promote reflection and professional growth

Establish a long-term mechanism to support pre-service teachers in practicing, reflecting and learning in different cultural backgrounds.

- Strategic recommendations: Encourage pre-service teachers to conduct educational internships in multi-ethnic regions, international projects, or schools with outstanding cultural diversity, to personally experience and try to implement ESD teaching in complex cultural environments, and write reflective reports to deepen their understanding of pluralistic teaching.

5.4.16 Build an ESD continuous professional growth system

Establish an ESD support mechanism throughout the entire process of teachers' professional development, and promote teachers' lifelong learning and capacity updating.

- Strategic recommendations: Establish a regular ESD teacher development mechanism, such as holding regular ESD workshops and establishing a cross-school teaching and research community to promote collaborative reflection and

improvement of teaching practices among teachers in primary, secondary, and university levels;

- Strategic recommendations: Establish a "mentor pairing" system to encourage experienced ESD practitioners to work with novice teachers to jointly conduct instructional design and action research, thereby enhancing professional inheritance and peer support;

- Strategic recommendations: Expand channels that combine international exchanges with local practices, support teachers' participation in international ESD projects and cooperation, and deepen collaboration with local primary and secondary schools, communities, and environmental organizations to promote the localization of global experience.

Table 40 Integrated Strategic Recommendations for Enhancing ESD Competence among Pre-service Teachers

Core Strategies	Goal	No.	Strategic Focus	Core Objective
Core Strategy 1: Driving Sustainable Leadership and Institutional Governance	Establish a systematic and robust policy and organizational culture to support education for sustainable development (ESD)	1	Leveraging the leadership effect of educators	Enhance ESD leadership modeling and value guidance
		2	Strengthen institutional support for ESD development	Provide institutional guarantees for ESD competence development
		3	Establish a mechanism for cultivating teacher leadership	Develop future teachers' ESD leadership and change management skills
Core Strategy 2: Elevating Curriculum and	By integrating across disciplines,	4	Promote interdisciplinary integrated teaching	Break disciplinary barriers for systems thinking and

Core Strategies	Goal	No.	Strategic Focus	Core Objective
Pluralistic Instructional Innovation	reform the learning management system to make it more comprehensive and diversified			problem-solving
		5	Integrating ESD concepts into teaching design	Translate ESD concepts into classroom practice
		6	Promote participatory teaching strategies	Enhance engagement through participatory methods
		7	Develop autonomous, critical and consultative skills	Cultivate critical thinking and collective action skills
		8	Reconstruct teacher education curriculum system with ESD	Integrate ESD across curriculum systems and disciplines
Core Strategy 3: Strengthening Action Competence through Ecological Experiences	Develop self-efficacy and a sense of responsibility through practical application in real-world environments	9	Strengthen ecological awareness and environmental concepts	Cultivate respect for nature and ecological ethics
		10	Strengthen practical experience and feedback	Boost confidence through practice and feedback
		11	Inspire responsibility and intrinsic	Strengthen motivation and

Core Strategies	Goal	No.	Strategic Focus	Core Objective
			motivation	sense of mission in ESD teaching
Core Strategy 4: Building Collaborative Ecosystems and Professional Growth Networks	Promote collaboration among universities, schools, and communities to support ongoing learning and professional development in the field of ESD	12	Promote social collaboration and expand practice networks	Enable practical collaboration between academia, government, and society
		13	Build interdisciplinary teaching, research and practice community	Link universities and schools for real ESD collaboration
		14	Strengthen understanding of cultural diversity	Promote multicultural understanding in ESD contexts
		15	Create diverse educational practice community	Encourage reflection and growth through diverse experiences
		16	Build ESD continuous professional growth system	Foster lifelong ESD learning and professional development

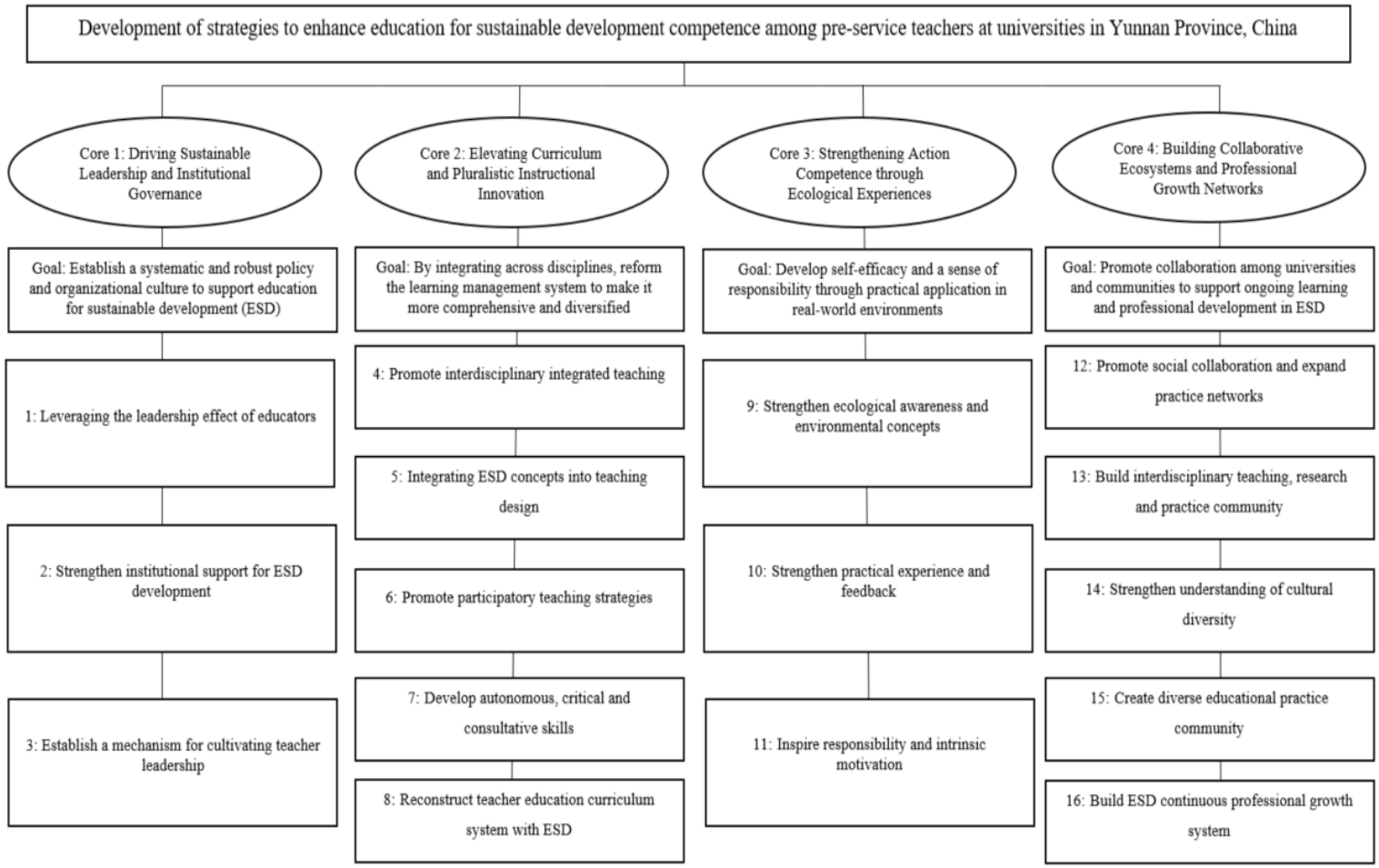

Figure 6 An Infographic Framework of the Integrated Strategies for Enhancing ESD Competence among Pre-service Teachers

5.6 Limitations and Future Research

This study, while providing valuable insights into the influence of sustainable leadership on professional action competence in Education for Sustainable Development (ESD), has several limitations that should be acknowledged.

Firstly, the study is geographically limited to Yunnan Province, China. While this region provides a unique context for examining the integration of ESD in teacher training, the findings may not be generalizable to other regions or countries with different educational systems and cultural contexts. Future research should consider replicating this study in diverse geographical settings to enhance the generalizability of the results.

Secondly, Longitudinal studies are needed to explore the causal pathways through which sustainable leadership influences professional action competence in ESD over time.

Thirdly, the study focuses on the mediating roles of ESD-Holism and ESD-Pluralism. While these constructs are critical for understanding the integration of sustainability principles in teacher training, other potential mediators or moderators, such as institutional support, teacher motivation, or external policy influences, were not examined. Future research should explore these additional factors to provide a more comprehensive understanding of the mechanisms through which sustainable leadership impacts ESD.

Furthermore, this current research used a non-probability sampling method to collect primary data from target samples, which may limit the generalizability of the findings to the broader population. As the sampling technique relied on the selection of participants based on convenience or specific inclusion criteria rather than random selection, there is a potential for sampling bias. This could result in the sample not being fully representative of the overall population of interest, potentially affecting the validity of the conclusions. Future studies may benefit from employing probability sampling methods to enhance the representativeness of the sample and the robustness of the results.

Building on the findings and limitations of this study, several avenues for further research and recommendations can be proposed.

Firstly, future research should replicate this study in different geographical and cultural contexts to examine the generalizability of the findings. Comparative studies across regions or countries can provide insights into how different educational systems and cultural factors influence the integration of ESD in teacher training.

Secondly, longitudinal studies are needed to explore the causal relationships between sustainable leadership, ESD-Holism, ESD-Pluralism, and professional action competence in ESD. Such studies can provide a deeper understanding of how these relationships evolve over time and the long-term impact of sustainable leadership on teacher competence in sustainability education.

Thirdly, exploring other potential mediators or moderators, such as institutional support, teacher motivation, and external policy influences, can provide a more holistic understanding of the factors that influence the integration of ESD in teacher training. This research can inform the development of targeted interventions and support mechanisms to enhance the effectiveness of ESD programs.

Furthermore, future studies may benefit from employing probability sampling methods to enhance the representativeness of the sample and the robustness of the results. By adopting techniques such as simple random sampling, stratified sampling, or cluster sampling, researchers can ensure that every individual within the target population has an equal chance of being selected. This approach would reduce potential sampling bias and provide a more accurate representation of the population, thereby increasing the generalizability of the findings.

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