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Teacher Readiness for Implementing Sustainable Education

A Comparative Synthesis of Predictive Factors Across Diverse Educational Contexts

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Abstract

Teacher readiness is a critical determinant of effective implementation of Education for Sustainable Development (ESD) across global educational systems. This study synthesizes evidence from ten international studies involving more than 7,000 teachers to examine the factors that predict readiness for sustainable education and how these predictors vary across different contexts. Using a systematic semantic search, screening, and structured data extraction process, the review identifies four overarching domains shaping readiness: individual characteristics, knowledge and skills, attitudes and environmental commitment, and institutional and system-level factors. Findings reveal that demographic variables such as age, gender, and teaching experience exert limited influence, while disciplinary background, sustainability knowledge, and technological–pedagogical competence demonstrate stronger predictive power. Notably, self-efficacy and personal engagement in sustainable behaviors emerge as dominant predictors, especially in systems with greater ESD maturity. Institutional conditions—including leadership support, resource availability, school culture, and policy alignment—further moderate the translation of individual readiness into classroom practice. The review highlights significant gaps, particularly the absence of studies comparing high-performing and low-performing systems directly, and the inconsistent provision of discipline-specific professional development. The study concludes by emphasizing the need for a holistic, context-sensitive approach to strengthening teacher readiness as a foundation for advancing sustainable education globally.

Keywords: *Comparative Education; Education For Sustainable Development (ESD); Institutional Support; Professional Development; Self-Efficacy; Sustainability Education; Teacher Readiness*

Introduction

Global efforts to advance sustainability have intensified demands on education systems, placing teachers at the forefront of curriculum transformation. As schools worldwide integrate Education for Sustainable Development (ESD), teachers' readiness has become a critical determinant of successful implementation. Teacher readiness encompasses a combination of knowledge, skills, attitudes, and institutional support that enables educators to translate sustainability principles into effective pedagogical practices. Recent comparative analyses highlight that readiness is shaped by complex interactions between individual capabilities and contextual factors, making it a central topic in sustainability education research.

Sustainability education has emerged as a fundamental component of contemporary curricula, aiming to equip learners with the knowledge, skills, and values necessary to address global challenges

such as climate change, biodiversity loss, and resource depletion [1], [2]. As societies worldwide recognize the urgency of sustainable development, education systems are increasingly integrating sustainability principles into teaching and learning processes [3]. Central to this integration are teachers, whose readiness and pedagogical competence significantly determine the success of sustainability education initiatives [4].

Despite growing global awareness, teacher readiness in sustainability education remains inconsistent across contexts. Many educators lack adequate understanding of sustainability concepts, face challenges in translating theory into pedagogical practice, and often receive insufficient institutional support [5]. Limited access to resources, inadequate professional development, and the absence of assessment tools for evaluating teacher preparedness further exacerbate these challenges.

The relevance of this study is further underscored by the United Nations Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 13 (Climate Action), which emphasize the transformative role of education in achieving sustainable futures. However, educational systems often lack the infrastructure, pedagogical frameworks, and qualified personnel required to operationalize these goals effectively [6]. Additionally, the rapid advancement of educational technology has created both opportunities and challenges for sustainability education. While digital tools can enhance learning engagement and accessibility, disparities in technological competence and access persist among educators, particularly in developing contexts [5]. This digital divide underscores the need for teacher training programs that integrate both sustainability competencies and digital literacy [7].

Moreover, sustainability education demands a holistic, interdisciplinary approach that encompasses environmental, social, and economic dimensions of sustainable development [8]. Teachers must cultivate students' critical thinking, problem-solving, and collaboration skills through pedagogies that transcend disciplinary silos [9]. However, many teacher education programs remain fragmented, offering limited opportunities for experiential and systems-based learning.

This study thus contributes to ongoing global efforts to strengthen Education for Sustainable Development (ESD) by developing an empirical tool for measuring and enhancing teacher readiness. The Teacher Readiness not only supports evidence-based decision-making for policymakers and institutions but also aligns with international agendas promoting sustainability-oriented pedagogy. By empowering educators with measurable insights into their preparedness, teacher readiness can foster systemic improvements in sustainability education, thereby advancing global sustainability goals.

The relevance of teacher readiness for sustainable education lies in its direct influence on curriculum delivery, student engagement, and long-term educational outcomes. Studies consistently show that when teachers possess strong self-efficacy, adequate sustainability knowledge, and institutional support, they are more capable of embedding sustainability concepts into classroom instruction. Conversely, insufficient training, limited resources, and weak policy alignment can hinder even the most motivated teachers. Existing literature identifies several key dimensions of teacher readiness. First, knowledge and competencies remain foundational. In developing ESD contexts. Second, self-efficacy (teachers' confidence in their ability to teach sustainability) is often the most significant

determinant in more mature systems with established ESD infrastructure. Third, *personal engagement in sustainable behaviors functions as a powerful mediator between knowledge and practice. Teachers who personally practice sustainability are more likely to integrate it into their teaching, demonstrating a strong link between lived experience and pedagogical implementation.

Despite this growing body of research, several gaps remain. One prominent gap concerns the lack of comparative studies examining teacher readiness across different system performance levels. Although researchers have investigated urban versus rural schools, private versus public institutions, and national differences, no studies directly compare high-performing and low-performing systems using standardized educational performance metrics. This gap limits understanding of how system-level capacity moderates individual-level predictors of readiness. Given that education systems differ widely in infrastructure and support, this gap presents a critical barrier to forming generalizable conclusions about global teacher readiness.

Given these gaps, the importance of studying teacher readiness is twofold. First, it provides actionable insights for policymakers seeking to enhance ESD implementation across diverse educational settings. Second, it enriches theoretical frameworks describing how personal, institutional, and systemic factors interact to shape teacher preparedness. The systematic review of comparative studies emphasizes that readiness is not merely an individual trait but a context-dependent construct influenced by institutional capacity, resource availability, and professional development structures.

Therefore, the objective of this study is to develop a comprehensive understanding of teacher readiness for implementing sustainable education by synthesizing existing research and examining the interplay between individual, institutional, and systemic factors. Specifically, this study aims to identify dominant predictors of readiness, explore how these predictors vary across different contexts, and highlight gaps in current research that must be addressed to support global ESD goals. By grounding this investigation in empirical evidence from multiple countries and education levels, this study contributes to a more nuanced understanding of readiness and provides a foundation for future comparative research.

Materials and Methods

A. Paper Search Strategy

This study began with an extensive semantic search to identify the most relevant literature on teacher readiness for implementing sustainable education curricula. Using the Elicit academic search engine (which integrates over 138 million papers from Semantic Scholar and OpenAlex) the query “What factors predict teacher readiness for implementing sustainable education curricula in comparative analysis between high-performing and low-performing educational systems?” was executed. This semantic search approach was chosen because it captures conceptually relevant papers rather than relying solely on keyword matching, making it particularly effective for multidimensional constructs such as teacher readiness, sustainability education, and comparative system performance.

From this process, the 50 most relevant studies were retrieved. These papers spanned diverse methodological traditions and educational contexts, enabling a comprehensive foundation for subsequent screening. The broad scope ensured inclusion of studies addressing teacher attributes (e.g.,

knowledge, self-efficacy), institutional dynamics (e.g., resources, leadership), and system-level characteristics (e.g., urban–rural differences, public–private distinctions). While no study explicitly categorized systems as high-performing or low-performing, the search captured papers involving varied system capacities, resource levels, and policy environments, which contributed to later contextual analysis.

Table 1. Paper Search Summary

Component	Description
Search Engine	Elicit (Semantic Scholar + OpenAlex)
Query Used	"What factors predict teacher readiness for implementing sustainable education curricula…?"
Database Size	138+ million academic papers
Retrieval Method	Semantic search
Papers Retrieved	50 most relevant results
Purpose	Identify broad literature on predictors of teacher readiness and comparative contexts

B. Screening Procedures

After retrieval, all 50 papers were screened using predefined inclusion criteria to ensure alignment with the study's purpose. Screening focused on eight essential dimensions. First, papers had to involve teachers as participants, either in-service or pre-service, within K–12 or higher education contexts. Second, the study needed to involve a sustainable education intervention, including ESD, environmental education, green curriculum delivery, or climate education. Third, the paper must assess teacher readiness outcomes, such as preparedness, willingness, attitudes, self-efficacy, or barriers to curriculum implementation.

Additionally, only studies incorporating comparative elements (such as differences between educational systems, school types, or regions) were included, as these indirectly informed system performance variations. Accepted papers had to employ recognized research designs such as quantitative, qualitative, mixed-methods, or systematic review. Studies also needed to occur in formal educational environments, involve direct teacher participation, and meet peer-review publication standards.

Screening followed a holistic judgment approach. Studies were not required to meet every criterion rigidly; rather, decisions were made based on overall relevance and contribution. This process yielded a curated set of studies that allowed robust cross-contextual analysis of teacher readiness factors within varied institutional and systemic landscapes.

Table 2. Screening Criteria Summary

Criterion	Requirement
Teacher Population	Teachers involved as key participants
Sustainable Education Focus	ESD, environmental education, green curriculum
Teacher Readiness Outcomes	Self-efficacy, attitudes, preparedness, barriers
Comparative Elements	School/system/regional comparisons
Study Design	Quantitative, qualitative, mixed, or systematic review
Educational Context	Formal schooling or teacher education settings
Teacher Involvement	Direct involvement in data collection
Publication Quality	Peer-reviewed works only

C. Data Extraction and Coding

Data extraction was conducted using a structured protocol applied uniformly to each included paper. A large language model was instructed to extract specific data columns representing contextual, conceptual, methodological, and empirical aspects of teacher readiness research. First, extraction captured educational system context, including country, system characteristics (urban/rural, resources), and comparative dimensions. Second, details on readiness definitions were recorded, including theoretical frameworks, measurement tools, and constructs such as self-efficacy, change readiness, and competence.

Third, extraction documented the sustainability education type, identifying whether studies addressed ESD, EfS, climate education, interdisciplinary integration, or subject-specific implementations. Fourth, all predictive factors examined in each paper were identified, covering teacher characteristics, knowledge, attitudes, professional development, institutional structures, and policy environments.

Extraction also included key predictive relationships, specifying significant predictors, effect directions, relative strengths, and moderating variables. Sample characteristics—such as sample size, teaching level, experience, and demographic features—were also recorded. Finally, methodological features were extracted, including design, instruments, analytical approaches, and validation procedures. This systematic extraction allowed consistent synthesis across diverse studies and supported a structured comparative analysis of readiness predictors.

Table 3. Data Extraction Categories

Category	Examples of Extracted Elements
Educational System Context	Country, resources, urban/rural, school type
Readiness Definition	Self-efficacy, change readiness, competence frameworks
Sustainability Education Type	ESD, EfS, climate education, interdisciplinary models
Predictive Factors	Knowledge, attitudes, PD, institutional support
Predictive Relationships	Significant predictors, correlations, moderators
Sample Characteristics	Size, teaching level, experience, demographics
Methodological Approach	Surveys, interviews, PCA, Q-methodology, regression

Results

A. Characteristics of Included Studies

The review included 10 studies examining teacher readiness for sustainable education implementation across diverse educational contexts. Studies were conducted in Sweden, Qatar, Germany, Indonesia, Finland, Germany and USA, Colombia, Malaysia, Vietnam, andmultiple countries through a systematic review. Educational levels ranged from primary through higher education, with the majority focusing on secondary and teacher education programs.

Studies conceptualized teacher readiness through a variety of theoretical perspectives. The most common approach positioned self-efficacy as the central construct, referring to teachers' confidence in their ability to deliver sustainability-related instruction. For example, in the German context, self-efficacy was assessed using an eight-item scale complemented by a three-item action-efficacy measure. Similarly, the multi-country study involving Indonesia, Malaysia, and Vietnam introduced a

comprehensive ICTeEfS self-efficacy scale consisting of three dimensions (competence, reflective practices, and transformative teaching beliefs) which demonstrated strong reliability with a Cronbach's alpha of 0.84.

Table 3. Summary of Included Studies

Author, Year of Study	Country/Region	Sample Size	Educational Level	Study Design	Sustainability Education Type
Borg et al., 2012 [10]	Sweden	3,229 teachers from 224 schools	Upper secondary	Survey	Education for Sustainable Development (ESD)
Bruder et al., 2023 [11]	Qatar	965 teachers	Preparatory and secondary	Survey	ESD and Global Citizenship Education (GCED)
Daumiller et al., 2025 [12]	Germany	419 teachers	Primary and secondary	Cross-sectional survey with network analysis	ESD
Anwar et al., 2025 [13]	South Sumatra, Indonesia	232 biology teachers	Secondary (biology education)	Descriptive–comparative quantitative	ESD
Uitto et al., 2017 [14]	Finland	442 teachers from 49 schools	Lower secondary	Survey	Sustainability Education (SE)
Brandt et al., 2022 [15]	Germany and USA	76 students (Germany)	Higher education (pre-service teachers)	Mixed-methods comparative case study	ESD
Raman et al., 2022 [16]	18 countries	27 publications	Teacher education	Systematic review	ESD
Du et al., 2022 [17]	Colombia	25 university teachers	Higher education	Mixed-methods using Q methodology	ESD
Ghazali et al., 2024 [18]	Indonesia, Malaysia, Vietnam	1,815 teachers	Primary (majority)	Survey with principal component analysis	Education for Sustainability (EfS)
Zguir et al., 2022 [19]	Qatar	157 Grade 8 teachers	Secondary (Grade 8)	Mixed-methods	ESD

Other studies adopted multi-dimensional readiness frameworks. The Qatar study conceptualized readiness through the interconnected dimensions of alignment, capabilities, and engagement. Meanwhile, the German–American comparative study used an ESD-specific professional action competence framework, integrating sustainability-related content knowledge, pedagogical content knowledge, and motivational factors. In Indonesia, the examination of biology teachers' readiness drew on the Technological Pedagogical Content Knowledge (TPACK) model, incorporating indicators such as commitment to ESD, conceptual understanding, attitudes, technological skills, and inquiry-based competencies.

In Colombia, teacher readiness was understood as change readiness, reflecting beliefs about the suitability, support, and significance of proposed educational changes. This framework encompassed intrapersonal (cognitive and affective), relational (interpersonal), and environmental (contextual) dimensions. Additionally, the systematic review characterized teaching readiness as comprising three

key domains: professional knowledge and practice, professional engagement, and self-management, highlighting the multifaceted nature of readiness across diverse educational settings.

Discussion

A. Individual Teacher Characteristics

Individual characteristics showed varied predictive patterns across the included studies. Age, for example, demonstrated a small but positive effect on ESD implementation. Finnish teachers showed a slight increase in sustainability-related teaching with age [14], a pattern echoed in Germany where older teachers reported higher implementation frequencies [12]. Gender, however, consistently showed no significant relationship with teacher readiness across Finland, Germany, Indonesia–Malaysia–Vietnam, and Qatar [11], [12], [14], [18].

Teaching experience produced counterintuitive findings. In Indonesia, novice teachers with fewer than ten years of experience scored higher on multiple readiness dimensions than their more experienced counterparts [13]. In the Indonesia–Malaysia–Vietnam dataset, although 40% of teachers had over 15 years of experience, teaching experience was not a significant predictor of ICTeEfS self-efficacy [18]. These findings suggest that years of teaching alone do not translate into readiness without sustained professional development.

Subject area also played a substantial role. Swedish science teachers relied heavily on fact-based, lecture-oriented traditions [10], while social science teachers showed greater alignment with ESD pedagogies. Notably, 41% of Swedish language teachers reported not teaching sustainability at all [10]. Finnish teachers exhibited distinct disciplinary clusters, with holistic sustainability integration most common in biology, geography, and history [14]. In Qatar, readiness varied significantly based on subject specialization and teaching area [11].

B. Knowledge and Skills Dimensions

Across contexts, sustainability-related knowledge consistently emerged as one of the strongest predictors of readiness. In the Indonesia–Malaysia–Vietnam study, knowledge of sustainability accounted for 24.5% of the variance in ICTeEfS self-efficacy; the largest predictor in their model [18]. In contrast, German findings emphasized that teachers' personal engagement in sustainable behaviors exerted stronger influence than formal sustainability knowledge measured through testing [12]. These results suggest that knowledge is essential in early-stage ESD systems, while personal ecological commitment becomes more influential in mature systems.

Technological skills showed mixed patterns. ICT knowledge accounted for only 3% of explained variance in ICTeEfS self-efficacy [18]. Indonesian biology teachers demonstrated strong ESD commitment but moderate conceptual understanding, with technological and inquiry-related competencies rated lowest [13]. Many teachers lacked experience integrating ICT effectively, creating a pedagogical gap despite their familiarity with basic digital tools.

Pedagogical knowledge also varied. The German–American comparative study found that ESD-specific coursework improved content and pedagogical content knowledge, with the 4Cs framework (personal, professional, social, and structural connections) most strongly associated with competence

development [15]. Swedish teachers identified a lack of subject-specific examples and insufficient expertise as major barriers to integrating sustainability across disciplines [10].

C. Attitudes and Environmental Commitment

Attitudinal factors and personal ecological behaviors played central roles in shaping readiness. German network analysis identified self-efficacy as the strongest predictor of implementation (edge weight = 0.30), followed by private environmental engagement (edge weight = 0.16) [12]. These findings indicate that teachers' personal commitment to sustainability can be more influential than formal knowledge, leading to more authentic and consistent classroom integration. Self-efficacy also showed a negative association with eco-anxiety, suggesting that teachers who feel more capable of teaching sustainability experience less stress related to environmental issues [12].

In Colombia, readiness was conceptualized through the lens of change readiness, emphasizing personal learning and conviction as core components. Teachers highlighted four central readiness dimensions: personal learning, improved teaching performance, application of professional development to practice, and student engagement [17].

Professional development also contributed substantially to readiness. Indonesian teachers who received environmental education training demonstrated higher readiness levels [13]. The systematic review further underscored the importance of technology-enhanced transformative learning experiences, although predictive pathways were not quantified [16]. Swedish studies additionally emphasized discipline-specific professional development, noting that general sustainability training was insufficient without tailored examples and support [10].

D. Institutional and System-Level Factors

Institutional and system-level contexts strongly shaped readiness outcomes. In Qatar, teachers from private schools reported significantly higher alignment, capability, and engagement with ESD/GCED than those in public schools, although overall readiness was high across both groups (~80%) [11]. The extent of school involvement in sustainability initiatives was a significant predictor of readiness in this context [19].

Geographic setting produced notable disparities. In the Indonesia–Malaysia–Vietnam study, urban teachers demonstrated higher ICTeEfS self-efficacy than rural teachers, reflecting differences in access to resources, infrastructure, and institutional support [18]. School type, however, was not a significant predictor in Germany, nor was teacher professional status [12]. Similarly, Finnish findings indicated that school type and location did not significantly affect readiness [14].

Institutional support structures played a pivotal yet inconsistent role. In Colombia, teachers described their readiness as largely confined to micro-level teaching practices due to limited institutional capacity for broader change [17]. Weak institutional policy alignment and insufficient leadership support were repeatedly identified as barriers. Swedish teachers emphasized the need for school management to create structured collaboration opportunities for ESD implementation [10]. In Qatar, teachers called for stronger alignment between national ESD policies and classroom-level application [11].

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Conclusion

This review demonstrates that teacher readiness for implementing sustainable education is a multidimensional construct shaped by the interplay of individual characteristics, professional competencies, personal commitment, institutional support, and broader systemic factors. Across diverse educational contexts, readiness cannot be attributed to a single predictor; rather, it emerges from a combination of knowledge, attitudes, skills, and enabling conditions within teachers' working environments.

At the individual level, mixed patterns regarding age, experience, and gender highlight that demographic factors alone do not determine readiness. Instead, disciplinary background, pedagogical beliefs, and professional identity show stronger influence on how teachers engage with sustainability content. Knowledge of sustainability and technological–pedagogical competence were found to be foundational, particularly in developing ESD contexts where baseline understanding varies widely. However, in more mature systems, personal environmental engagement and self-efficacy played a more decisive role than formal knowledge, indicating that teachers' lived practices and internal motivations are essential drivers of sustainable teaching behaviors.

The findings further underscore that readiness extends beyond individual capability to include institutional and systemic dimensions. Schools with stronger leadership, clearer policy alignment, and active involvement in sustainability initiatives foster higher levels of teacher readiness. Conversely, gaps in policy implementation, resource disparities—especially between urban and rural settings—and insufficient discipline-specific professional development continue to limit teachers' ability to translate readiness into practice. This highlights the importance of viewing readiness not solely as an individual responsibility but as a product of the wider educational ecosystem.

Ultimately, this review reveals that fostering teacher readiness for sustainable education requires a holistic and context-sensitive approach. Strengthening foundational sustainability knowledge, enhancing self-efficacy through authentic professional learning experiences, and promoting teachers' personal engagement with sustainable practices are critical individual-level strategies. At the institutional and system levels, ensuring coherent policies, providing adequate resources, and offering discipline-specific professional development are essential for enabling sustained ESD implementation. Addressing these interconnected areas will allow educational systems to build a more robust foundation for embedding sustainability into curricula and preparing learners for the complex global challenges ahead.

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