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Review

Pre-Service Teacher Action Competence in Education for Sustainable Development: A Scoping Review

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Abstract: To successfully implement Education for Sustainable Development (ESD) in schools, teachers require specific competences that enable them to integrate sustainability principles into their teaching. The development of these competences begins in the teachers' training programs, yet existing research on ESD competences of pre-service teachers remains fragmented, employing various conceptualizations and methodological approaches. This literature study systematically analyzes the research landscape on ESD competences by reviewing empirical studies published between 2007 and May 2024. The study identifies trends, focal areas, and research gaps. The results indicate that most studies focus on knowledge and motivational aspects, whereas action competence is underrepresented. Furthermore, the field is characterized by a prevalence of cross-sectional studies and self-assessment methods, limiting insights into long-term competence development. These findings highlight the need for more interdisciplinary, longitudinal, and comparative research to establish a more comprehensive understanding of how ESD competences develop and how they can be effectively fostered in teacher education. This review contributes to the literature by providing a structured synthesis of existing studies and by outlining future research directions.

Keywords: education for sustainable development; professional action competence; teacher education; pre-service teachers; review

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Academic Editor: Pedro Guilherme Rocha dos Reis

Received: 17 March 2025
Revised: 18 April 2025
Accepted: 20 April 2025
Published: 24 April 2025

Citation: Vidal, S.; Kuckuck, M. Pre-Service Teacher Action Competence in Education for Sustainable Development: A Scoping Review. *Sustainability* **2025**, *17*, 3856. https://doi.org/10.3390/su17093856

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1. Introduction

Sustainable development (SD) is one of the central challenges of the 21st century. It aims to balance ecological, economic, social, and political dimensions while developing long-term, viable solutions to global issues. Education for Sustainable Development (ESD) has been established as a policy response to these challenges and plays a key role in the Agenda 2030 and the 17 Sustainable Development Goals, specifically as outlined in Target 4.7 of SDG 4 [1]. ESD is relevant across all educational sectors and requires comprehensive integration into school education, where teachers play a crucial role.

Teachers not only shape learning environments but also significantly influence the quality and approach of instruction through their own competences [2–5]. To effectively initiate sustainability-oriented educational processes, teachers need specific competences that go beyond subject knowledge and include normative, systemic, and transformative dimensions. In this context, the concept of action competence has become increasingly relevant, as it captures not only cognitive but also motivational and volitional aspects of teachers' capacity to implement ESD in practice. Action competence can be defined as the ability and willingness to take reflective and value-based action in complex, real-world contexts. It integrates knowledge, attitudes, and the perceived capacity to act

into a coherent readiness for pedagogical implementation [6]. The development of these competences begins in the initial phase of teacher education. It is essential that pre-service teachers acquire the necessary skills and knowledge early in their training to integrate ESD effectively into their teaching and facilitate transformative learning processes [7]. An established theoretical framework for analyzing and operationalizing professional competences is the model of professional teaching competence proposed by Baumert and Kunter [8]. As already described by Shulman in 1986 [9], effective teaching requires not only subject knowledge but also pedagogical knowledge, and—most importantly—the ability to integrate both. According to the model by Baumert and Kunter, in addition to subject knowledge and pedagogical knowledge, teachers' professional competence also includes beliefs, motivational orientations, and self-regulation skills, all of which are crucial for successful teaching. In the context of ESD, this raises the question of how these dimensions are incorporated into teacher training and which specific ESD-related competences have been the focus of previous research [10,11].

Against this background, this scoping review systematically examines which ESD competences have been addressed in previous research on teacher education. The aim is to identify trends and existing research gaps, thereby providing a foundation for the further development of teacher education in the context of ESD. Given the central role of teachers in implementing ESD, this study seeks to contribute to a more robust empirical foundation for competency development in teacher education.

1.1. Context Setting

The aim of ESD is to enable learners to engage in critical reflection and make decisions that integrate the ecological, economic and social dimensions of sustainability. Teachers (educators) in particular act as key drivers of change in the process of achieving the Sustainable Development Goals (SDGs) [1]. They play a key role in supporting future generations in acquiring the (key-) skills required for sustainable development. However, teachers can only adequately fulfill this task if they are appropriately trained, i.e., if they have the necessary knowledge and skills for ESD-oriented teaching [12,13]. Various models and concepts that formulate, structure and categorize or organize the competences of (pre-service) teachers relevant to ESD have already been developed (e.g., [10,12,14–17]). These approaches draw on several theoretical and heuristic foundations to describe the ESD-related competences of teachers in different contexts.

The professional competence of teachers is crucial when it comes to the implementation and design of (ESD-oriented) lessons. The fact that competence has a strong influence on the design of lessons and the actions of teachers has already been investigated and proven many times [8,18]. More recent studies have now also attempted to embed the concept of teachers' professional competence in the context of ESD [10,14,19,20]. Thus, the concept of *Teachers' Professional Action Competence in Education for Sustainable Development* (e.g., [21–24]) is crystallizing more and more.

1.2. Teachers' Professional Action Competence in ESD

Action competence is a central concept in educational science though it is defined differently in various theoretical approaches. Basically, it describes the ability of individuals to act in complex situations in a reflective, goal-oriented and responsible manner. In the literature, competence to act is often understood as the interplay of knowledge, skills, motivation and values, with different models focusing on different aspects [6,25,26]. Some approaches see competence to act as the ability to make autonomous and reflective decisions in socially relevant contexts [27,28], whereas others place greater emphasis on the performative and social aspects, such as the ability to cooperate and communicate [29,30].

Especially in the context of transformative educational processes, action competence is often seen as the key to actively shaping social and ecological change [31,32].

In their analysis of various action competence concepts, Sass et al. [33] have shown that action competence can be understood both as an individual competence and as a pedagogical principle. This differentiation illustrates the complexity of the concept and shows that the development of action competence is not only a question of imparting knowledge, but also of promoting self-efficacy, the ability to reflect and social participation [25,26].

While the concept of competence to act in environmental and sustainability education is often referred to as 'Action Competence' [6,33], research in teacher education primarily draws on the model of 'Professional Action Competence' developed by Baumert and Kunter [8]. What both models have in common is that they understand action competence not only as a body of knowledge, but also as a dynamic interplay of various cognitive, motivational and reflective components. Sass et al. [33] identify four central dimensions of action competence: knowledge, commitment and passion, self-efficacy and critical reflection. These aspects can be linked to the components of Baumert and Kunter's model [8], which also has a multidimensional structure. For example, knowledge of sustainability issues corresponds to specialist knowledge, while the ability to reflect critically and commitment to sustainable development show parallels to professional convictions and motivational orientations. A decisive difference lies in the domain of application: while Sass et al. [33] interpret action competence as a general ability to actively shape social challenges, Baumert and Kunter [8] focus on the profession-specific action competence of teachers in the school context. Nevertheless, it makes sense to combine both approaches, especially when it comes to developing skills in the area of ESD. This is because teachers not only need specialist knowledge and subject-specific didactic knowledge in order to be able to teach sustainability-related topics competently, but they also need the ability to critically reflect on social challenges and a strong sense of self-efficacy, as is also emphasized in the model by Sass et al. [33].

Building on the profession-specific understanding of competence, Bertschy, Künzli and Lehmann [10] have further developed the model of Baumert and Kunter [8] for the requirements of ESD. They explicitly refer to the need for teachers to have subject-specific knowledge, didactic skills and the ability to enable learners to participate in society in a sustainable way. In their model, which is referred to as *ESD-Specific Professional Action Competence of Teachers in Kindergarten and Primary School* they emphasize two central aspects in particular:

1.2.1. Knowledge and Abilities

The model encompasses both the subject-specific knowledge (Content Knowledge, CK) and the didactic skills (Pedagogical Content Knowledge, PCK) that are necessary to effectively integrate complex, interdisciplinary sustainability topics into the classroom [10]. An understanding of systemic interrelationships and conflict perspectives in particular can be a key element in anchoring sustainable solutions to problems in education [21]. It is particularly important that teachers not only have knowledge about sustainability, but also a deep understanding of the connections between ecological, social and economic systems. This systemic perspective is crucial to enable students to understand the complex and ethically challenging problems of sustainable development and to develop solutions [10].

1.2.2. Motivational Beliefs

Teachers' motivational beliefs influence their engagement with ESD. Teachers must recognize sustainability as a key educational goal and understand their role in promoting sustainable thinking. Research shows that teachers who attribute high personal and profes-

sional relevance to ESD are more likely to integrate sustainability-related content into their teaching. This includes the belief that education can contribute to solving sustainability challenges and fostering responsible citizenship. The extent to which teachers see sustainability as part of their professional identity affects their willingness to prioritize it in their teaching [10].

Vukelić [11] takes up this model and expands it by emphasizing the importance of self-efficacy and the intention to implement ESD even more strongly. She argues that teachers need to develop a strong intention to act in order to be truly effective. This extension is based on social psychological theories that explain the reasons for people to actually implement an action (or not). Vukelić integrates three theoretical concepts in particular:

- The Norm Activation Model (NAM, [34]) demonstrates that people only decide to take action if they feel personally responsible and believe that their actions will have a positive impact. Vukelić transfers this to teacher education by showing that teachers only implement ESD if they feel responsible for sustainable education and are convinced that they can make a difference.
- The Expectancy-Value Theory (EVT, [35,36]) maintains that people only carry out an action if they (1) believe that they will be successful (self-efficacy) and (2) attach a high value to the action. Vukelić shows that teachers only implement ESD if they feel competent and recognize the relevance of ESD.
- The Theory of Planned Behavior (TPB, [37]) states that the best predictor of actual behavior is the intention to act. It is precisely this gap that Vukelić closes; she argues that knowledge and motivation only lead to actual implementation if teachers have a clear intention to integrate ESD in the classroom.

Vukelić defines the components of self-efficacy and willingness to act as follows:

1.2.3. Teacher Self-Efficacy for ESD

Self-efficacy refers to teachers' confidence in their ability to implement ESD effectively. Teachers with high ESD-related self-efficacy feel capable of designing lessons that integrate sustainability topics and apply appropriate pedagogical methods [11]. This conviction is shaped by personal experience, professional training, and institutional support. Studies indicate that teachers who believe in their competence to teach ESD are more likely to experiment with innovative methods and overcome challenges in implementation [22]. A lack of self-efficacy, on the other hand, is often linked to hesitancy in adopting new instructional approaches [11].

1.2.4. Willingness to Act

Willingness to act describes teachers' intention and readiness to integrate ESD into their teaching. Vukelić highlights that teachers who are willing to act see themselves as agents of change in education. This willingness is influenced by personal values, attitudes, and perceptions of professional responsibility [11]. Teachers who consider ESD important but lack a clear commitment to implementation may struggle to incorporate it into their teaching. Structural and institutional factors also play a role, as limited curricular flexibility and lack of resources can hinder even motivated teachers from putting ESD into practice [21].

Vukelić presents the three dimensions in her model—knowledge and abilities, motivational beliefs and willingness to act—as interconnected elements that define teachers' ability to implement ESD (see Figure 1). Her model illustrates how knowledge and abilities as well as the assessment of the value of ESD and the ascription of responsibility influence the intention of teachers to implement ESD in practice—mediated by confidence in their own effectiveness. This model emphasizes the central importance of self-efficacy, which

should be understood not only as a motivating force, but also as a condition for teachers' actual willingness to act.

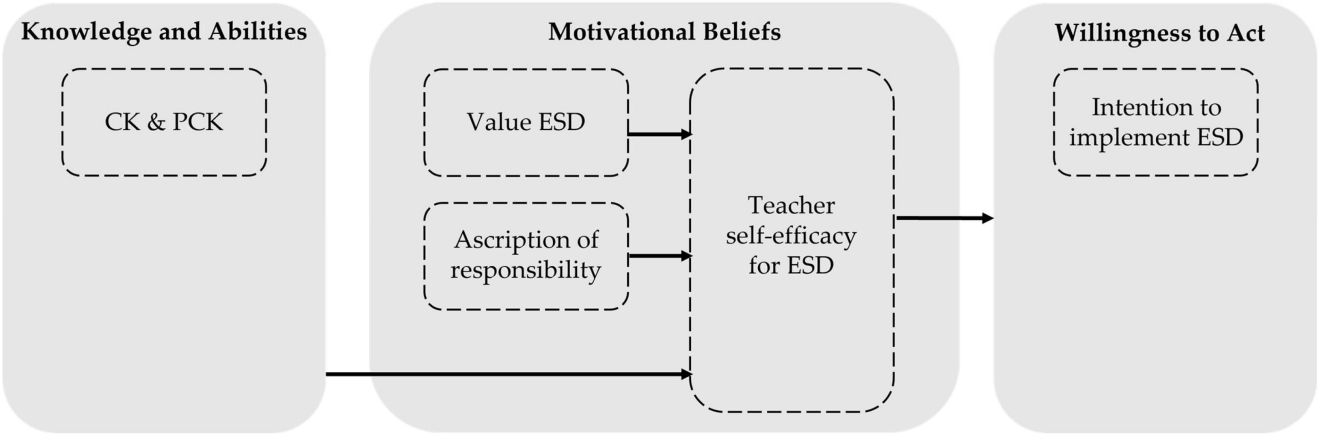


Figure 1. Model of teachers' competence in education for sustainable development (own illustration based on Vukelić, 2022 [11]).

The extension by Vukelić adds an important dimension to the existing model of Bertschy, Künzli and Lehmann by emphasizing the psychological mechanisms behind knowledge, self-efficacy and willingness to act. By incorporating aspects of NAM, EVT and TPB, she shows that the implementation of ESD is not only a question of subject knowledge and didactics, but that teachers also need a strong confidence in their own abilities as well as a clear intention to act.

This perspective is particularly relevant for teacher training, as it makes it clear that the promotion of ESD-specific professional competence must not only aim to impart knowledge and didactic skills, but also to strengthen the self-efficacy of pre-service teachers and support their intention to act.

1.3. Teacher Education for Sustainable Development (TESD)

As already shown, the successful implementation of ESD depends not only on knowledge and methodological skills, but also on motivational and volitional factors such as self-efficacy and intention to act [11]. Teacher training plays a central role here, as it has a significant influence on the development of these professional competences. Studies show that the training phase is a decisive formative phase for the acquisition of professional competences in general teacher education [38]. This phase is also regarded as central to the acquisition of ESD skills (e.g., [10,39,40]), but comprehensive empirical studies validating this connection are still lacking.

In order to strengthen the integration of ESD in teacher training and ensure that pre-service teachers acquire the necessary competences, corresponding educational offerings are increasingly being integrated into university teaching for teachers, for example in the form of curricular adaptations, subject-specific modules or interdisciplinary courses (e.g., [41–43]). However, in many countries, including German-speaking countries, ESD is still insufficiently anchored in teacher training programs [44].

In addition to curricular anchoring, the individual understanding of pre-service teachers about sustainability and ESD is also crucial [40,45]. Only if future teachers develop a differentiated understanding of sustainability will they be able to integrate these topics into their lessons in a reflective and practice-oriented manner [1,46,47]. It is not enough to view ESD solely as the transfer of knowledge—it must also be understood as the processual development of professional values, convictions and reflection skills. Dealing with one's own attitudes towards sustainability and ethical issues contributes to ensuring that (pre-

service) teachers not only master ESD in terms of content, but also see themselves in the role of multipliers for sustainable action [5]. This shows the relevance of the psychological components emphasized in Vukelić's model, where the expectation of self-efficacy is a central condition for the actual implementation of ESD [11].

Research on TESD examines how the necessary skills for the implementation of ESD can be developed in teacher education. Fischer et al. [46] summarize the research strands to date in five central categories:

- Designing learning environments
- Understanding learner attributes
- Measuring learning outcomes
- Promoting systems change
- Advancing visions for the field

Within these research perspectives, there are studies that deal with the ESD skills required by (pre-service) teachers (e.g., [12,14,16,24]) or investigate which influencing factors—such as attitudes or values—determine the ESD actions of (pre-service) teachers (e.g., [19,48]).

Despite the growing importance of ESD in teacher education, little is known about what specific skills, knowledge and understanding pre-service teachers actually possess. The existing theoretical frameworks and models that define and describe the ESD competences of (pre-service) teachers, as described above, have not yet been sufficiently tested and/or operationalized. To date, there are hardly any comprehensive empirical studies that systematically address the actual ESD competences and understandings of pre-service teachers. The reviews by Goller and Rieckmann [49], Lohmann et al. [50] and Singer-Brodowski et al. [51] provide an overview of previous work on ESD in teacher education or the ESD skills of ESD multipliers. They show that previous studies hardly focus on pre-service teachers as a target group, but rather tend to focus on specific dimensions such as specialist knowledge on ecological topics or methodological approaches to integrate sustainability into teaching without taking into account the broader development of skills and the associated attitudes of teachers. There is also a need for studies that not only measure teachers' knowledge and attitudes towards ESD, but also identify the factors that influence the development of ESD competences. Some studies have already attempted to capture these factors by investigating how, for example, teachers' own attitudes towards sustainability, their subject-specific training or the institutional framework conditions influence the development of ESD skills (see the results of the review by Goller and Rieckmann [49]). However, these empirical studies usually take only partial aspects into account, survey the competences of other target groups (e.g., teacher educators) and do not yet provide a complete record of the relevant influencing factors.

A particularly relevant review in this context is the work of Pegalajar-Palomino et al. [52], which analyzes empirical studies on the attitudes, competences and preparation of pre-service teachers for the implementation of ESD in the classroom. The authors evaluated empirical studies from the years 2010 to 2020 and identified a total of 21 studies that deal with the perception and implementation of ESD by pre-service teachers. It is clear that they predominantly have positive attitudes towards ESD, but often do not have the necessary professional skills to effectively integrate sustainability into the classroom. Furthermore, deficits in university education with regard to the promotion of these skills are emphasized.

The present review differs from the review by Pegalajar-Palomino et al. in some key aspects. Firstly, it provides a systematic overview on a sound theoretical basis, using Vukelić's model of professional competence [11] as a frame of reference. This enables a differentiated analysis of the studies in order to examine which competence dimensions have actually been recorded in previous research and to what extent they cover the full

range of competences required for ESD. In contrast, the analysis by Pegalajar-Palomino et al. is carried out without an explicit theoretical foundation and is primarily oriented towards general attitudes, social responsibility and educational aspects [52]. Secondly, the present review goes beyond a thematic synthesis by systematically examining which aspects of professional competence for ESD are actually taken into account in empirical studies. While Pegalajar-Palomino et al. primarily consider studies that address pre-service teachers' attitudes towards ESD as well as general aspects of competence such as social responsibility and environmental knowledge, there is no systematic analysis of the extent to which empirical studies capture different dimensions of professional competence for ESD. As this review does not assume a uniform conceptual basis for the competence areas under consideration, a comparative evaluation of the studies examined is made more difficult. The present review goes beyond this work by systematically analyzing which aspects of professional competence are considered in empirical studies examining pre-service teachers' ESD competences and to what extent they cover the spectrum of competence dimensions that are discussed in research as relevant for ESD. This not only provides an overview of existing studies, but also shows in which areas there are research deficits and which competence dimensions have not yet been adequately considered. Through this methodological and theoretical foundation, the present scoping review makes a significant contribution to research by enabling a more comprehensive and systematic analysis of the competence development of pre-service teachers in the field of ESD. This helps to identify existing research gaps, while providing a sound basis for future empirical studies on professional competence for ESD.

1.4. Aim of This Review

This review aims to provide a systematic overview of empirical studies on the competences and understanding of ESD among pre-service teachers. The ESD competence aspects examined in the studies are identified and categorized in relation to Vukelić's model. The aim is to analyze which competence dimensions have been the focus of empirical studies to date and which aspects have received less attention. This way, existing research priorities and potential research gaps are made visible and their significance for the further development of ESD competence research can be discussed.

The central research questions of this review are therefore:

1. What are the methodological and contextual characteristics of studies examining competences related to ESD of pre-service teachers?
2. Which aspects of ESD-related professional action competence are investigated in empirical studies on pre-service teachers, and to what extent do these studies cover the full range of the competence dimensions required for ESD?

2. Materials and Methods

2.1. Search Process and Criteria

This review follows the *PRISMA extension for scoping reviews* (PRISMA-ScR) guidelines [53]. A detailed Scoping Review Protocol was developed to ensure transparency in the methodological approach. The protocol outlines the essential steps, including the selection of databases and search strategies, the definition of inclusion and exclusion criteria, and the study selection process as documented in the PRISMA flow diagram (see Figure 2). The complete protocol is publicly available on the Open Science Framework (OSF; [https://osf.io/ga4ny/files/osfstorage/67cf1c6f7869cfe617bb330c], accessed on 17 March 2025). In addition, the completed PRISMA-ScR checklist is provided as Supplementary Materials.

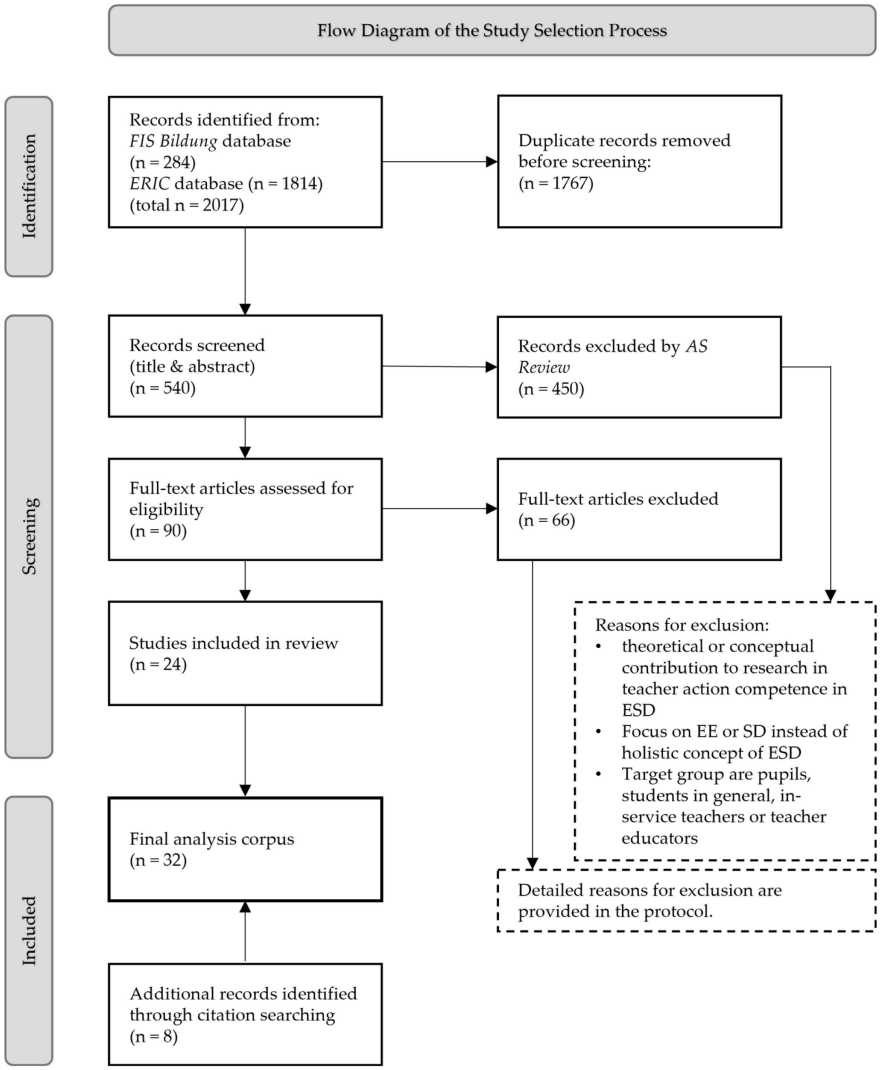


Figure 2. Flow diagram of the study selection process (according to PRISMA).

In a first step, suitable databases were selected for an electronic database search. To ensure international relevance and a focus on teacher education, the *ERIC* database was selected, particularly for English-language articles. The *FIS Bildung* database was selected for German-language articles, as apparently much research on the topic takes place in Germany. These databases are specific to educational research literature. No time limit was deliberately set as a filter for the year of publication. The search took place in May 2024; all studies published after this date are not included in the review.

The keywords for the research were determined from the three relevant concepts 'ESD', 'action competence' and 'teacher training'. In order to achieve the highest possible number of hits, keywords and various synonyms were determined for each concept [54]. The defined search terms were combined using Boolean operators (OR, AND) and partially truncated:

- Search String ERIC: ("education for sustainable development" OR esd OR "education for sustainability") AND (skills OR knowledge OR motivation OR attitudes OR beliefs OR self-efficacy OR understanding OR conceptions OR competences OR competencies OR readiness OR willingness OR intention) AND ("teacher education" OR "pre service teacher" OR "student teacher")
- Search String FIS Bildung: ("Bildung nachhaltige Entwicklung" OR bne OR "Bildung Nachhaltigkeit") AND (Kompetenzen OR Wissen OR Motivation OR Einstellungen

OR Überzeugungen OR Haltungen OR Verständnis OR Vorstellungen OR Präkonzepte OR Selbstregulation OR Selbstwirksamkeit OR Handlungsbereitschaft OR Bereitschaft OR Intention) AND Lehrerbildung OR Lehrkräftebildung OR Lehramtsstud* OR „angehende Lehr*“).

The hits identified on the basis of the search strategy were then checked using de-fined inclusion and exclusion criteria to ensure that only studies that are within the focus of this review were included. The most important criteria are shown in Table 1.

Table 1. Inclusion and exclusion criteria for study selection.

Criteria [1]	Included	Excluded
Publication Period	No restrictions	None
Language	English German	All other languages
Quality	Peer reviewed Not peer-reviewed	None
Type	Papers Journal articles Book chapters Monographs	Bachelor’s or Master’s theses Other formats (e.g., online-only HTML formats)
File type	Full-text available as pdf Print format	All other formats
Research type	Empirical	Theoretical Conceptual
Context	Pre-service teachers Education for Sustainable Development (ESD) Education for Sustainability (EfS) Professional competences	Pupils Teachers Environmental Education (EE) Sustainable Development (SD) Sustainability Isolated key competences without references to professional competence

[1] For detailed inclusion and exclusion criteria, see the protocol.

The database search yielded a total of 2017 hits. In the first step, 1477 duplicates were removed. The remaining hits were then screened in several steps. In order to make the large number of papers accessible for manual processing, the AI software *ASReview LAB* (Utrecht University—Version 1.5, [55]) was used, which facilitates and accelerates the screening process by means of active learning. The software screens titles and abstracts. By using the software, a further 450 papers were excluded from the review according to the criteria in Table 1. The 90 remaining articles were subjected to a full-text screening, in which all studies that did not meet the defined criteria (detailed inclusion and exclusion criteria are provided in the protocol) were finally eliminated. A total of 24 studies were defined as relevant for the review. During the full-text screening, further potentially relevant studies were identified in some citations and literature references. These were then checked and added to the final corpus in an additional step. As a result, eight additional studies were included in the review. The final analysis corpus thus comprises 32 studies from the period from 2007 to May 2024 (see Figure 2).

2.2. Data Analysis

As part of the scoping review, the relevant data of the 32 studies selected for the review were systematically documented in a table. Each study was given its own row in which specific characteristics were recorded in predefined columns. Missing information was marked accordingly as “unspecific” in order to present the data quality transparently. The

aim was to gain a comprehensive temporal, geographical and methodological overview of the empirical surveys on the topic.

The features of the table include:

- Publication year: Documents the publication year of the study in order to visualize trends or developments over time.
- Authors: Lists the authors of the study for identification.
- Country of Research: Records the location of the surveys to show the geographical distribution of existing studies.
- Methodology: Describes the methodological approach of the study, e.g., qualitative, quantitative or mixed methods.
- Participants' Field of Study and Training Phase: Documents the training phase and the subject areas studied by the participating pre-service teachers.
- Target School Level of the Participants: Describes the school level the participants are being trained to teach, e.g., primary, secondary education.

Categories of Teachers' Professional Action Competence in ESD

In order to adequately answer the research questions of the review, an analysis of the ESD-related competence aspects recorded in the studies was carried out. The aim was to assign each study to a competence category equivalent to a category in the Teacher Action Competence Model according to Vukelić [11]. This assignment is intended to show which ESD-related competences of pre-service teachers are the focus of previous research. The assignment of the studies to the categories was based on the competences explicitly formulated by the surveyed studies. The results of the analysis were then added to the table, complementing the previously documented data. The analysis of the competence aspects addressed in the studies was carried out using a simplified categorization, which was inductively based on the Vukelić model. Three main categories were formed on this basis (see Table 2). The categories developed are based on the competences described by Vukelić as essential (see Figure 1): 1. Knowledge and Abilities, 2. Motivational Beliefs and 3. Willingness to Act. As Vukelić also describes self-efficacy in particular as crucial for dealing with ESD, a separate sub-category was added for this competence, belonging to the Motivational beliefs category (2a. Self-efficacy). The category system is shown in Table 2 and contains the categories with a respective description and anchor examples from the studies.

Table 2. Category system of teachers' professional action competences in ESD.

	Category	Description	Example Quotes
1.	Knowledge and Abilities	Knowledge and understanding of ESD concepts as well as their didactic implementation	"identify knowledge and understanding about SD and ESD" [56] (p. 4); "The studied competencies consist of content knowledge (CK) [and] pedagogical content knowledge (PCK)" [19] (p. 1)
2.	Motivational Beliefs	Attitudes, beliefs and values in the context of ESD	"investigating of pre-service science teachers' beliefs on education for sustainable development" [57] (p. 1); "Pre-service teachers' attitudes toward education for sustainability" [48] (p. 1)
2a.	Self-efficacy	Confidence in teaching and applying sustainability principles	"self-efficacy beliefs of teaching ESD" [58] (p. 1); "assess primary school Teachers' Self-Efficacy" [59] (p. 1)
3.	Willingness to Act	Readiness to implement ESD in teaching practice	"pre-service teachers' intention of implementing ESD" [60] (p. 1); "the willingness to actively support and implement ESD" [19] (p. 1)

The assignment of the studies selected for the review to these categories was based on a review of the titles, abstracts and research questions of the studies. If there was insufficient information or ambiguity, the methodology and/or results section was consulted. Key terms and formulations were used that clearly refer to the respective aspects of competence:

- Title: Terms in the title that refer to specific aspects of competence (e.g., "knowledge", "beliefs", "skills") were taken into account in order to capture the thematic focus of the study.
- Abstracts: Abstracts were analyzed to identify key terms that indicate which aspects of competence were examined.
- Research questions: Research questions were included in order to gain additional information on the focus of the studies.
- Methodology/results section: The methodology and/or results section was specifically examined in regard to survey instruments or variables and to aspects of competence that were addressed or interpreted in the results.

A multiple assignment was only made if the studies explicitly surveyed several of the competence categories. Using this approach, the content could be recorded in a structured and comprehensible manner without having to carry out a detailed content analysis of the methodology or results of the studies. In the interests of intercoder reliability, as described by Mayring [61], the selected studies were reviewed by a second person. The results of this second review were compared with those of the first person in order to minimize potential discrepancies. In addition, the completed overview table was discussed with fellow researchers in order to check the completeness and appropriateness of the selection of characteristics and data presentation.

3. Results

The analysis of the 32 included selected studies provides a systematic overview of previous research approaches to ESD competences in teacher education. A wide range of thematic and methodological focuses, as well as geographical and temporal distributions, can be observed. The findings are presented in a structured narrative format throughout the results section. For an overall synthesis, all key results have been compiled in an overview table, presented as Table 3. The development and structure of this summary table are described in the methods section.

Table 3. Overview of included studies (sorted by date).

No.	Year	Authors	Country of Research	Methodology	Participants	Target School Level	Category
[62]	2007	Nikel	UK, Denmark, Germany	Mixed-methods, cross-sectional explorative	Pre-service teachers	Primary Lower secondary	1
[63]	2007	Winter and Firth	UK	Qualitative, explorative	Pre-service geography teachers	Secondary	1, 2
[64]	2011	Boon	Australia	Quantitative, descriptive	First year pre-service teachers	Primary Early childhood	1, 2
[65]	2012	Evans et al.	Australia	Qualitative, cross-sectional explorative	Pre-service teachers	Primary Secondary	1
[66]	2013	Burmeister and Eilks	Germany	Mixed-methods, cross-sectional descriptive	Pre-service chemistry teachers Trainee chemistry teachers	Secondary	1, 2
[67]	2013	Effeney and Davis	Australia	Quantitative, cross-sectional descriptive	Pre-service teachers	Primary	1, 2, 2a

Table 3. *Cont.*

No.	Year	Authors	Country of Research	Methodology	Participants	Target School Level	Category
[68]	2016	Buchholz et al.	Germany	Qualitative, descriptive	Pre-service teachers (Physics, Informatics)	Secondary	1, 2, 3, 4
[69]	2016	Evans et al.	Australia	Quantitative, quasi-experimental longitudinal	First year pre-service teachers	Early childhood Primary Middle school	2, 2a
[70]	2016	Soysal	Türkiye	Mixed-methods, cross-sectional descriptive	Fourth grade/senior pre-service classroom teachers	Primary Secondary	1, 2
[71]	2017	Andersson	Sweden	Quantitative, quasi-experimental cross-sectional	Pre-service teachers	Primary Secondary	2
[72]	2017	Hinz	Germany	Quantitative, cross-sectional descriptive	Pre-service teachers (Bachelor's, Master's, all subjects)	Primary Secondary	2
[48]	2017	Tomas et al.	Australia	Mixed-methods, quasi-experimental longitudinal	Pre-service teachers (Bachelor's)	Early childhood Primary	2, 2a
[57]	2018	Ates and Gül	Türkiye	Quantitative, cross-sectional descriptive	Pre-service science teachers (all grade levels)	Primary	2
[73]	2018	Bieniok and Hinz	Germany	Quantitative, cross-sectional explorative	Pre-service teachers	Unspecified	1, 2
[74]	2018	Gan and Gal	Israel	Quantitative, cross-sectional descriptive	Pre-service teachers (most second/third year)	Early childhood Primary	2, 2a
[75]	2018	Milama et al.	Indonesia	Quantitative, cross-sectional descriptive	Pre-service chemistry teachers (first, middle and final year)	Secondary	1, 2
[19]	2019	Brandt et al.	Germany, USA	Mixed-methods, quasi-experimental longitudinal	Pre-service teachers	Primary	1, 2, 3
[76]	2019	Dorn	Germany	Mixed-methods, quasi-experimental longitudinal	Pre-service teachers (general studies, Bachelor's)	Primary	2
[59]	2019	Malandrakis et al.	Greece	Quantitative, cross-sectional descriptive	Pre-service teachers (entry and exit level, Bachelor's)	Early childhood Primary	1, 2, 2a
[77]	2020	Baumann and Niebert	Switzerland	Qualitative, explorative	Pre-service geography teachers (Master's)	Secondary	1, 2, 4
[56]	2020	Bezeljak et al.	Austria, Slovenia	Mixed-methods, descriptive	Pre-service biology teachers (mostly 3rd and 4th year Bachelor's)	Secondary	1, 3
[60]	2021	Kang	South Korea	Other, explorative	Pre-service teachers	Secondary	3
[78]	2022	Ammoneit et al.	Germany	Quantitative, cross-sectional descriptive	Pre-service geography teachers	Secondary	1, 2
[79]	2022	Ferguson et al.	Jamaica	Mixed-methods, quasi-experimental longitudinal	Pre- and in-service teachers	Unspecified	1
[58]	2022	Handtke et al.	Germany	Quantitative, quasi-experimental longitudinal	Pre-service teachers (Bachelor's and Master's) In-service and trainee teachers	Unspecified school types Secondary	1, 2, 2a
[80]	2022	Vukelić	Croatia	Quantitative, cross-sectional descriptive	Pre-service teachers (humanities, natural sciences, arts education, social sciences)	Unspecified	2, 2a, 3

Table 3. *Cont.*

No.	Year	Authors	Country of Research	Methodology	Participants	Target School Level	Category
[81]	2023	Baumann et al.	Germany	Mixed-methods, quasi-experimental longitudinal	Pre-service teachers	Primary	1
[82]	2023	Bourn et al.	England, Türkiye, Pakistan	Mixed-methods, cross-sectional descriptive	Pre-service teachers	Primary Secondary	1
[4]	2023	Bröll and Haustein	Germany	Mixed-methods, cross-sectional descriptive	Pre-service teachers	Primary	1
[83]	2023	Dittmann-Zöllner et al.	Germany	Quantitative, cross-sectional explorative	Pre-service teachers (Bachelor's and Master's)	Unspecified	1
[3]	2023	Gaubitz	Germany	Qualitative, explorative	Pre-service teachers (general studies, Bachelor's)	Primary	1
[84]	2024	Nousheen et al.	Pakistan	Quantitative, cross-sectional descriptive	Pre-service teachers (Bachelor's and Master's)	Secondary	1, 2, 2a

3.1. Publication Period of the Selected Studies

The studies were published between 2007 and May 2024. The corpus does not entail any studies published in the years 2008 to 2010 and 2014 to 2015. Most studies were published in 2023 (n = 5) (see Figure 3). For the graphical representation, the number of published studies per 5-year period was chosen, starting with the year 2005 (beginning of the United Nations Decade of Education for Sustainable Development [85]).

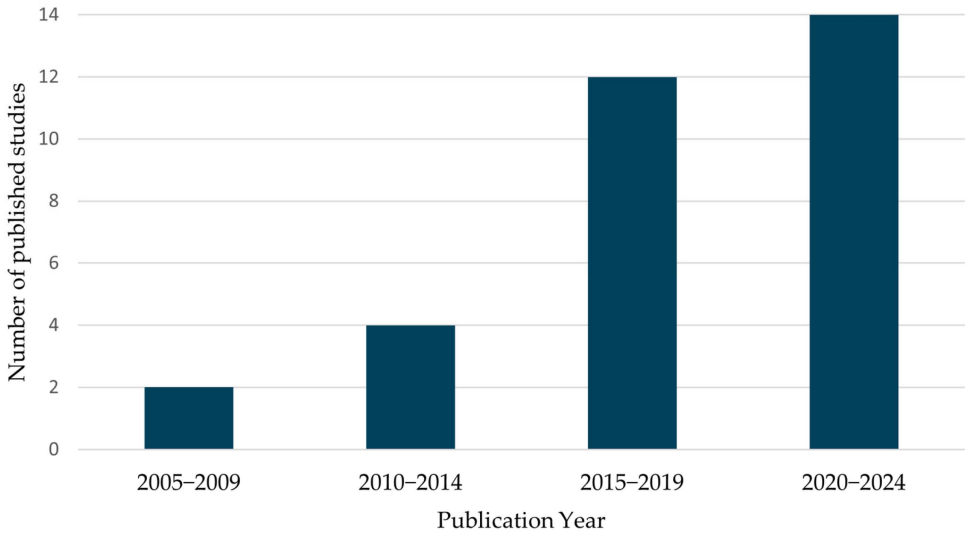


Figure 3. Number of published studies on ESD-related competences of pre-service teachers in 5-year intervals (total n = 32).

3.2. Geographical Distribution by Countries

Of the 32 included studies, 4 included data from several countries [19,56,62,82]. In total, the studies were published in 17 different countries. The geographical distribution of the studies shows clear regional differences, with a focus on Europe. Europe is the most strongly represented region with 23 studies. Within Europe, Germany alone accounts for 13 studies. Eight studies were conducted in Asia, with Türkiye accounting for the largest share with three studies. Australia is represented with five studies. Two studies were conducted in North America (see Figure 4).

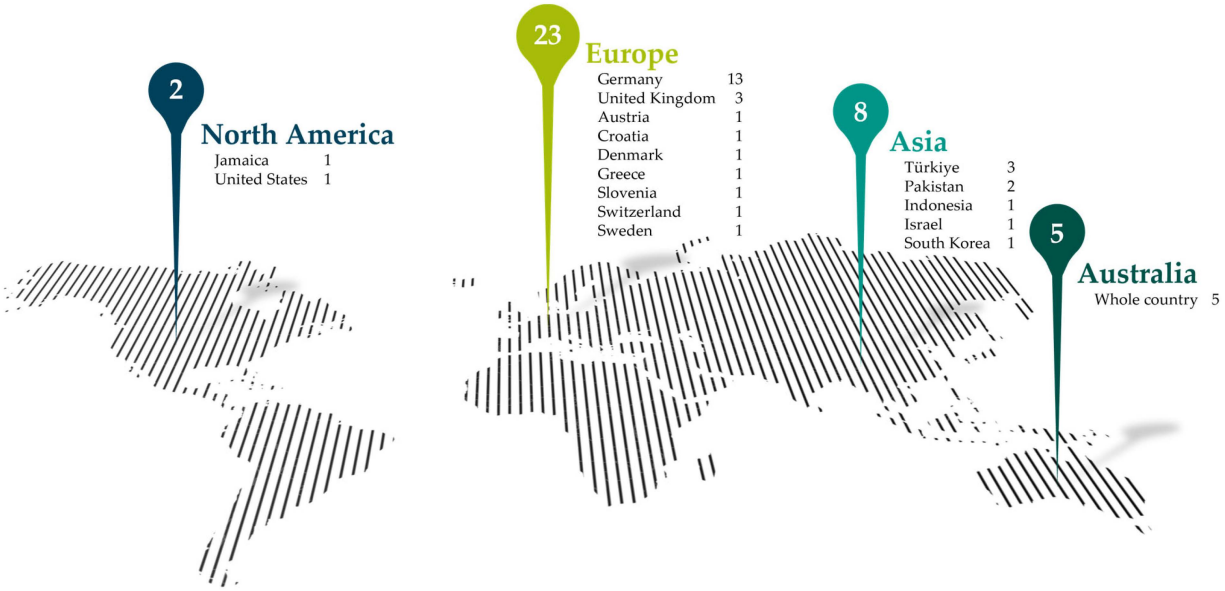


Figure 4. Geographical distribution of the selected studies.

3.3. Type of Research

The research designs and methods were taken from the article texts, where accessible. Where information was insufficient, the research methodology was inferred from the objectives of the studies, as described by Döring [86]. Table 4 shows the research designs and methods of each study.

Table 4. Research types of the selected studies.

Method	Design	References
Qualitative n = 5	cross-sectional explorative (n = 1)	[65]
	explorative (n = 3)	[3,63,77]
	descriptive (n = 1)	[68]
Quantitative n = 14	quasi-experimental longitudinal (n = 3)	[19,58,69]
	quasi-experimental cross-sectional (n = 1)	[71]
	cross-sectional descriptive (n = 9)	[57,59,67,72,74,75,78,80,84]
	descriptive (n = 1)	[64]
Mixed-Methods n = 12	quasi-experimental longitudinal (n = 4)	[48,76,79,81]
	cross-sectional explorative (n = 3)	[62,73,83]
	cross-sectional descriptive (n = 4)	[4,66,70,82]
	descriptive (n = 1)	[56]
Other n = 1	explorative (n = 1)	[60]

Quantitative approaches dominate with 14 studies, whereas qualitative methods are used in 5 studies and mixed-method designs in 12 studies. The study by Kang [60] cannot be assigned to either qualitative or quantitative methodology (fuzzy-set qualitative comparative analysis) [87].

Within the quantitative studies, nine are cross-sectional and descriptive. This design is typical for quantitative surveys [86]. There are also several cross-sectional studies within the other method groups. For example, 7 of 12 mixed-methods studies are cross-sectional and one qualitative study appears in a cross-sectional-explorative design. Longitudinal studies are only available in a quasi-experimental design and are represented to a lesser extent with a total of seven studies (including three quantitative and four mixed methods). It is striking that there was no intervention study among the studies included in the review before 2012. Moreover, almost all of the longitudinal studies evaluate an ESD intervention and collect data with pre- and post-tests (with the exception of the measurement instrument development by Handtke et al. [58], which used the longitudinal design to validate the instrument). These studies aim to record certain effects and/or impacts of the interventions on the ESD-related skills of pre-service teachers [88]. In addition to the study by Handtke et al., which aims to develop and validate a measurement instrument to record ESD-related self-efficacy, Malandrakis et al. [59] also developed a scale to assess ESD-related self-efficacy, although in a cross-sectional descriptive design to validate the instrument. The majority of the studies (n = 16) tend to be descriptive, while seven studies are exploratory in nature.

In summary, this distribution shows that research on ESD in teacher education has so far predominantly relied on cross-sectional studies and has a descriptive orientation. The evaluation of ESD interventions by means of pre- and post-tests also appears to be not uncommon. This format provides a good basis for evaluating interventions, while longitudinal studies independent of interventions could analyze long-term development. However, such studies are not yet available (see Figure 5).

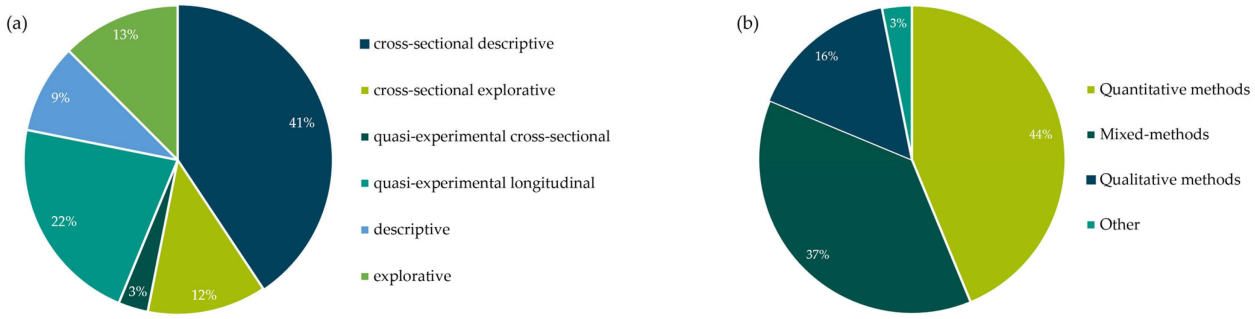


Figure 5. Overview of the research designs (**a**) and methods (**b**) used in the studies.

3.4. Overview of the Studies' Samples

In most of the studies, the training phases of the participants are not specified in more detail. In the studies that describe the sample in more detail, no clustering of specific groups can be identified. For example, five studies explicitly examine Bachelor's students [3,48,56,59,76], one study examines Master's students [77] and a further four studies look at both Bachelor's and Master's students [58,72,83,84]. There is also variance with regard to the educational progress of the pre-service teachers examined. Two studies focus more on first-year students [64,69], three studies focus more on students who have already progressed further [56,70,74] and another two explicitly examine students of all levels [59,75].

In addition, 12 studies specify the subjects studied by the participants, with natural science disciplines (e.g., "chemistry", "physics", "science", "biology", n = 5) dominating [56, 57,66,68,75]. Two studies examine pre-service teacher training in general studies for the

primary school [3,76] and a further two pre-service teachers of geography [63,77]. Two studies examine pre-service teachers of several or all subjects [72,80] and one study from Türkiye examines "pre-service classroom teachers" [70]. The remaining studies do not describe the sample in more detail. In addition, most of the studies specify the school levels for which the participants are being trained. A total of 11 studies examine pre-service teachers for primary education, 9 studies deal with students of secondary education, 7 studies include a mixture of both educational levels, and 5 studies do not provide any precise details. Some studies also include participants studying early childhood education. However, these were not considered further in this analysis, as Early Childhood Education is not considered to be part of the school education system in all countries.

3.5. Analyzed Competence Aspects

The results show that motivational aspects such as attitudes, beliefs and self-efficacy expectations have been investigated particularly frequently to date. A total of 23 of the 32 included studies survey motivational beliefs, of which 8 studies also examine the ESD-related self-efficacy expectations of pre-service teachers. Aspects of the "Knowledge and Abilities" category are also addressed in many studies (n = 20). In comparison, the category "Willingness to Act" is addressed less frequently (n = 8) (see Figure 6).

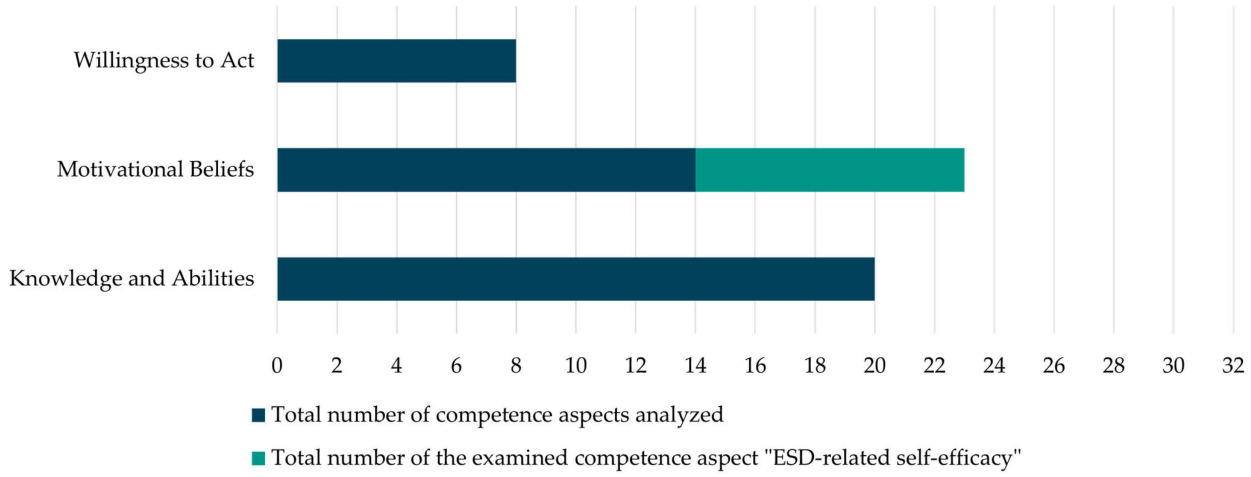


Figure 6. Distribution of the competence aspects examined in the studies (total n = 32).

Each of the corpus studies examines an individual number of aspects of competence. The distribution can be seen in Figure 7. Studies that only examine aspects from one category are marked in the diagram as 'single-category studies', studies that examine aspects from exactly two categories are marked as 'two-categories studies' and studies that examine aspects that can be assigned to all three categories are marked as 'three-categories studies'. The analysis shows that, of the 32 studies, most studies examined aspects from exactly one category (n = 16). Of these, 6 studies examined aspects assigned to the 'Knowledge and Abilities' category and 10 studies examined aspects assigned to the 'Motivational Beliefs' category. A total of 12 out of 32 studies surveyed aspects from exactly two categories. Note that the combination of aspects from the 'Knowledge and Abilities' category and 'Motivational Beliefs' (n = 8) occurs significantly more frequently than the combination of aspects from the "Knowledge and Abilities" category and 'Willingness to Act' (n = 3) or 'Motivational Beliefs' and 'Willingness to Act' (n = 1). Studies that address aspects of all categories occur least frequently (n = 3).

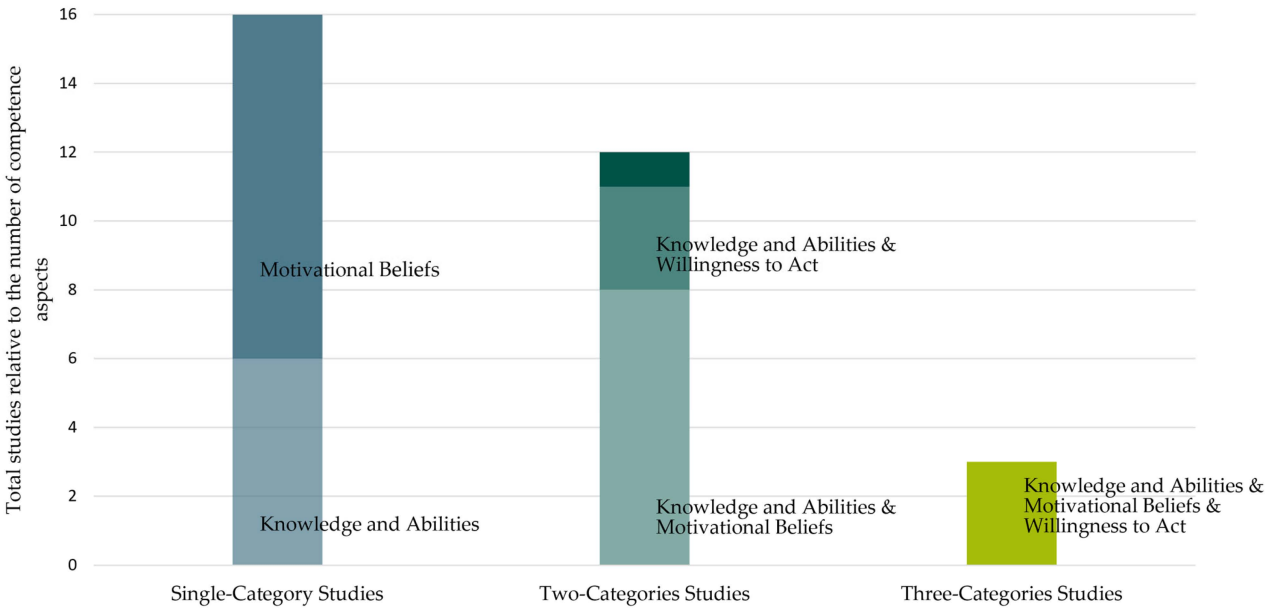


Figure 7. Presentation of the number of different competence aspects examined in the studies.

4. Discussion

To critically reflect on the findings of this review, it is essential to reconnect with the overarching research focus. This study examines the methodological and contextual characteristics of research on ESD-related competences among pre-service teachers, as well as the aspects of professional action competence that have been investigated in empirical studies. The results provide insights into key developments in this research field. The analysis of the temporal and geographical distribution of studies illustrates how research on ESD-related competences has evolved over time and in different regions. Furthermore, the methodological characteristics of the selected studies highlight dominant research designs and approaches. In addition, the examination of competence aspects covered in empirical studies reveals which dimensions of professional action competence have been addressed and how they relate to the broader discourse on ESD in teacher education.

4.1. Temporal and Geographical Distribution of the Studies

One result concerns the development of research into ESD over time. The review shows that over the last ten years, the number of empirical studies on ESD-related competences among pre-service teachers has noticeably increased, aligning with the growing political and scientific interest in sustainability education. This trend reflects the influence of global initiatives aimed at promoting ESD. The UN Decade of ESD (2005–2014) [85], the UNESCO Global Action Program on ESD (2015–2019) [89], and the current UNESCO ESD 2030 [90] program have raised awareness of sustainability education and may have contributed to the increasing academic discourse on the subject. However, this does not necessarily imply a direct causal relationship, as other factors, such as national research priorities and academic funding structures, may also influence the extent of research activity.

In this context, it is also useful to examine the geographical distribution of studies. Differences between countries could suggest that some nations have integrated UNESCO's ESD agenda more systematically into their education policies than others. While European countries and Australia, for example, implemented corresponding education policy measures in the early 2010s (e.g., [91–93]), other regions show a time lag or lower levels of engagement with ESD (e.g., [94]). However, the degree of political commitment to ESD does not always correlate with research output. For instance, although Central Asia has actively

engaged in educational policymaking, ESD has not been widely implemented in practice. Factors such as a predominant focus on environmental education rather than holistic ESD, lack of coordination between education and environmental ministries, and language barriers—since many key ESD documents are only available in English [95]—may have hindered systematic implementation. These structural challenges could partially explain why, despite political initiatives, there are still few empirical studies on ESD implementation in those regions.

China has also made significant progress, particularly through integration into national education strategies and model schools. Nevertheless, regional disparities persist, and there is no uniform curricular framework. The focus remains strongly on ecological aspects, while comprehensive integration into all subjects is still lacking [96]. It is notable that this review did not identify any empirical studies from China. Possible reasons for this may include language barriers and the limited indexing of Chinese research in major English-language databases. Chinese science and technology publications are often available only through national platforms and journal aggregators not covered by traditional Western indexing tools [97].

In East Asia, research interest in ESD has been growing, particularly in Japan, Malaysia, South Korea, and Indonesia, while countries such as Cambodia, Laos, and Myanmar remain underrepresented [98]. This review identified one study from Indonesia and one from South Korea [60,75]. Research in this region appears to be shifting from environmental education toward a broader ESD perspective, with ecological aspects continuing to dominate [98]. This suggests that, while ESD is increasingly incorporated into education policies, this does not necessarily correspond to a proportional increase in empirical research. Possible reasons for this discrepancy could include variations in academic priorities, availability of research funding, or structural differences in national education systems.

A particularly striking finding is the limited number of studies from the USA and Canada, despite both countries being recognized for their strong research output [99]. This raises the question of whether ESD is genuinely less researched in these contexts or whether structural factors are responsible for the lower number of studies identified in this review. One possible explanation is the decentralized nature of the education systems in both countries. Unlike many European nations, which have explicitly embedded sustainability into national education policies, the USA and Canada delegate education policy decisions to individual states and provinces [100,101]. In Canada, for example, education policy priorities vary significantly across provinces, making it challenging to systematically integrate ESD into teacher education. A 2012 report by the Council of Ministers of Education, Canada (CMEC) highlighted the absence of a coherent strategy for embedding ESD into teacher training [102]. A follow-up study from 2014 confirmed that, despite numerous initiatives, a national framework remains lacking, resulting in some provinces (e.g., Manitoba, Ontario) making more progress than others [103]. However, the limited number of studies identified in this review does not necessarily indicate a lack of engagement with ESD; it may also reflect variations in research priorities, institutional support, or the visibility of research outputs in international databases.

Further, no studies from the Global South were identified in this review. While this could indicate that ESD has not been systematically integrated into education systems in these regions, other explanations are also possible. Challenges such as limited scientific capacity, insufficient funding, fragmented education policies, and a focus on environmental education rather than a comprehensive ESD strategy may hinder large-scale implementation [104,105].

A general limitation of this review relates to potential publication bias. The visibility of studies is often influenced by language, indexing practices, and the preference for pub-

lishing significant or theoretically well-embedded results. Research from certain disciplines, countries, or with null findings may be underrepresented in the included databases. As such, the patterns observed in this review may not fully reflect the actual breadth of existing research on ESD-related competences in teacher education [106].

4.2. Methodological Characteristics of the Selected Studies

The review shows clear methodological patterns (see Table 4). Most studies use cross-sectional designs (n = 18) and rely heavily on self-assessment questionnaires (e.g., [59,76,78]). While this methodology provides valuable insights, it also has limitations, particularly in relation to social desirability effects and the difficulty of mapping the dynamic development of competences [86].

Although 12 mixed-methods studies were identified, they show a wide methodological diversity with different foci. Some of these studies combine qualitative and quantitative methods in a way that provides deeper insights into the perception and development of ESD competences (e.g., [19]). However, others only use mixed-methods approaches in a complementary way, for example by using qualitative data to interpret questionnaire results (e.g., [4]). The relatively small number of such studies indicates that there is still a lack of comprehensive triangulating research approaches that systematically link both the subjective perspectives of trainee teachers and objective competence measurements. Greater consideration of mixed-methods designs could help to better capture the complexity of competence development in teacher education and overcome the limitations of one-sided methodological approaches.

Another key finding is the comparatively strong dominance of intervention-based studies, with many studies using pre- and post-tests to evaluate the effectiveness of ESD training programs (see Section 3.3). This is in line with the general research tradition in teacher education which uses intervention studies as a means of measuring professional development [86]. However, many of these interventions focus on short-term effects, which leaves the question of the sustainability of such training programs unanswered.

It is also striking that no intervention-independent longitudinal studies were identified. Such studies could provide valuable insights into the long-term skills development of pre-service teachers by tracking their development over several training phases. One possible explanation for the dominance of cross-sectional and quantitative designs to date lies in research economic considerations: cross-sectional surveys can be carried out comparatively quickly, are cost-efficient and provide timely results. Longitudinal studies, on the other hand, require greater organizational and financial effort as well as a long-term research infrastructure, which makes their implementation more difficult [107].

This methodological focus reflects the fact that previous research often offers snapshots, but only provides a limited picture of the long-term development of ESD competences. At the very least, intervention designs with pre-post surveys enable the assessment of competence development as well as the evaluation of the quality and effectiveness of ESD interventions in higher education teaching. However, this review did not specifically look for studies that link other influencing factors such as students' previous experience, institutional framework conditions or lecturers' teaching skills to the development of ESD skills. Findings in this area would be particularly interesting, as they could allow a differentiated analysis of the specific conditions that are conducive to competence development [108]. The focus on the isolated assessment of competences without explicit consideration of contextual influencing factors could indicate that the complexity of competence development has not yet been sufficiently addressed. This contradicts the theoretical models that emphasize the interaction of various factors.

The analysis of the samples in the examined studies shows that most studies do not provide detailed information on the training phase of the participating pre-service teachers. However, in the studies that do explicitly provide this information, a heterogeneous picture emerges. No clear patterns can be identified, as some studies explicitly examine Bachelor's students (e.g., [48]), others Master's students (e.g., [77]) or a mixture of both (e.g., [72], see Section 3.4). This makes it difficult to compare the results, as it remains unclear at what stage of professionalization the participants are and to what extent this influences the ESD-related competences measured. Another problem is the lack of differentiation with regard to the studied subjects. While some studies explicitly examine natural science subjects such as biology, chemistry or physics, many other studies do not specify whether the participants come from a broad range of subjects or whether specific subject areas were taken into account (see Section 3.4). According to Vukelić [11], since ESD and the associated competences are understood as a holistic and interdisciplinary concept, the exclusive survey of ESD competences in certain subject areas could never be fully comprehensive in terms of ESD. At the same time, this is understandable insofar as ESD in school practice is often located in supporting subjects such as geography [109,110]. However, the concentration of studies on certain subjects could mean that the potential of interdisciplinary ESD teaching is insufficiently captured and certain dimensions of ESD competence remain underrepresented in research. It is notable that most studies do not systematically record long-term skill development. This raises the question of the extent to which the skills development measured in these studies actually remains stable in the long term. If students were re-examined at a later date, it would be possible to check whether the skills they have acquired have been sustainably integrated into their professional self-image. Research to date has provided hardly any findings in this regard. This underlines the need for longitudinal studies that analyze the development of ESD competences across different phases of education and could thus provide valuable insights into the sustainability of ESD interventions.

The analysis showed that the distribution of studies among pre-service teachers for primary education (n = 11), secondary education (n = 9) and both types of school (n = 7) is relatively balanced. The difference does not appear to be significant and does not indicate a considerable unequal distribution. A look at the studies on primary education shows that the examined subjects are not explicitly named in most cases (e.g., [57,67]). In the few studies that do provide information, the focus is on general studies in primary schools in Germany (e.g., [76]). This confirms the importance of subject teaching as a central supporting subject for ESD at the primary level (see [109]). At the secondary school level, on the other hand, natural science disciplines (e.g., biology, chemistry) appear to dominate (e.g., [63,66]). A possible explanation for this could be that many researchers conducting these studies may themselves have a background in the natural sciences or science education disciplines. If this were the case, their academic background and methodological expertise might have led them to focus on these subject areas, which could explain the higher representation of studies on pre-service science teachers. However, this was not systematically examined in this review and remains a hypothesis. In addition, this pattern may not only reflect the disciplinary backgrounds of the researchers but also the fact that ESD is often implemented in educational practice within specific subject areas that are inherently aligned with sustainability-related content, such as science or geography. These so-called "ESD-affine" subjects offer natural entry points for addressing ecological, social, and economic issues, and are thus more frequently used as vehicles for ESD implementation in schools [40]. This could indicate that ESD has so far been considered in subject-specific contexts, whereas interdisciplinary or general education approaches are less frequently investigated. This raises the question of whether the current distribution of research topics

truly reflects the relevance of ESD across all subjects or whether it is influenced by the disciplinary backgrounds of the researchers conducting the studies—an aspect that would require further investigation. This also shows that existing research does not fully meet the requirements of holistic ESD, as a stronger interdisciplinary perspective would be necessary for a more comprehensive anchoring.

However, it should be noted that this finding could be distorted by the selection of samples in the analyzed studies. It appears that many of the studies specifically selected students from the typical ESD subjects, which means that pre-service teachers from other disciplines are less likely to be included. This could mean that there is not only a lack of interdisciplinary approaches in teacher training, but also a lack of studies that explicitly examine students outside of the traditional teacher training subjects. Future research should therefore specifically include pre-service teachers from a broader range of subjects in order to better understand the dissemination and development of ESD skills in different subject cultures.

4.3. Competence Aspects

The analysis reveals that research on ESD competences of pre-service teachers has not yet given equal attention to all competency dimensions. While cognitive and motivational-affective aspects are relatively frequently examined, the explicit assessment of willingness to act remains significantly less common (see Section 3.5). This contradicts Vukelić's theoretical competence model [11] which conceptualizes ESD as an action-oriented educational approach and emphasizes that knowledge and attitudes alone are insufficient to foster sustainable action.

Notably, some studies explicitly investigate self-efficacy as part of the motivational competence dimensions (n = 8). According to Vukelić, self-efficacy plays a central role in implementing ESD, as teachers must not only possess knowledge but also develop confidence in their ability to successfully teach sustainability-related content [11]. Nevertheless, the number of studies addressing this aspect remains limited. Self-efficacy is often examined in conjunction with other motivational factors (e.g., [48]) but is rarely considered in isolation (e.g., [74]). A notable exception is Vukelić's own study [80], in which she simultaneously examined self-efficacy and willingness to act. This aligns with her theoretical model, which explicitly emphasizes the interdependence of these two aspects. While her findings provide valuable insights, they also highlight a gap in the broader research landscape: No other study identified in this review has investigated these two dimensions together, suggesting that the relationship between self-efficacy and willingness to act in the context of ESD remains underexplored. This suggests that while the topic receives some attention in research, a systematic and comprehensive analysis of its interactions with other competence dimensions is still lacking.

At the same time, the results highlight that analyzing individual competency dimensions in isolation fails to reflect the holistic nature of ESD competence models. Since ESD competences emerge from the interplay of cognitive, motivational, and action-related aspects, future studies should systematically examine these dimensions in relation to one another. For instance, considering self-efficacy without linking it to other components of professional competence may overlook crucial factors influencing the actual implementation of ESD in classrooms. This represents a clear research gap that could be addressed through more integrative study designs.

Another methodological issue is that the data collection instruments used in the studies were not analyzed in detail in this review, and in some cases, they were not available for inspection. This makes it difficult to assess their validity in measuring ESD competences. The diversity of measurement instruments indicates that no standardized approach for com-

petency assessment has yet been established, a challenge also noted in the broader literature on competency measurement in teacher education [111,112]. Furthermore, ensuring the validity of competency assessments remains a critical issue in educational research. Jenssen, Blömeke and Dunekacke [113] emphasize that systematic validation procedures, such as expert evaluations and content validation, are necessary to establish reliable measurement instruments. Similarly, Schaper [114] argues that a lack of transparency in validation processes can lead to uncertainties regarding whether competency assessments truly capture the intended constructs or merely reflect isolated aspects such as knowledge or attitudes. Different theoretical models suggest varying measurement approaches, making it difficult to compare professional action competences in a standardized manner. Furthermore, it remains unclear whether the instruments effectively measure the intended competency dimensions or merely capture isolated aspects such as knowledge or attitudes [111–114].

Seifert et al. [115] emphasize that professional competence cannot be adequately assessed through a single instrument but instead requires a multimodal approach. More recent studies confirm this view: Aparicio-Herguedas and Navarro-Asencio [116], in their systematic review, highlight the wide range of assessment methods available, yet note the absence of a unified standard for measuring competences in teacher education. They stress that self-assessments dominate research, whereas experimental studies examining causal relationships remain scarce. Additionally, Brookhart [117] argues that assessing teaching competences is highly context-dependent and that purely quantitative methods often fail to capture the complexity of competency development.

These general findings align with the results of the present review. The studies included in this analysis also show a strong reliance on self-assessment instruments for evaluating ESD-related competences. However, it is often unclear to what extent these instruments accurately capture the intended competency dimensions. Furthermore, there is a lack of triangulated data collection methods that systematically link cognitive, motivational-affective, and action-related aspects. While some studies employ more comprehensive data collection approaches, there remains a general absence of standardized procedures enabling cross-study comparisons (see Section 3.5). This confirms the challenges of competency measurement in teacher education and underscores the need for further methodological development in this research area. In particular, the dominance of self-assessments presents a methodological limitation, as these are not always reliable indicators of actual competency levels [116]. The lack of standardization in measurement instruments further complicates study comparisons and may result in differing levels of emphasis on competency dimensions, depending on the underlying conceptualization of ESD. A targeted examination of validation studies on competency assessment in teacher education could contribute to the development of more consistent and methodologically sound survey instruments.

These methodological challenges highlight the necessity for future research to focus on developing coherent and validated instruments that systematically capture all relevant ESD competency dimensions. Moreover, it would be beneficial to promote studies that explicitly investigate the practical application of ESD in order to better understand its significance in school practice.

In a global context, it is evident that the measurement and assessment of ESD competences are shaped not only by content-related factors but also by educational policy and institutional frameworks. The increasing emphasis on competency models in teacher education reflects a broader trend toward competency-based education (CBE). In her review of the evolution of CBE, Burnette [118] notes that education systems worldwide are progressively adopting competency-oriented approaches, driven by political demands for educational quality, economic necessities, and institutional funding programs. Particularly in higher education, CBE is seen as a promising strategy to equip students with practical

skills and enhance adaptability to evolving labor market demands [118]. Strengthening competency orientation could also play a key role in advancing ESD-related teacher education, particularly in terms of its systematic integration into existing educational structures.

In highly regulated education systems, such as those in France and South Korea, where teacher education is centrally governed [99], embedding ESD as an integral component of teacher education may be more feasible. However, the lack of studies from France in this review, and the presence of only one study from South Korea suggest that while ESD may be embedded in education policy in such systems, it does not necessarily translate into extensive empirical research. Possible explanations include the integration of ESD into general teacher training, reduced visibility as an independent research field, or the publication of relevant studies in non-English-language journals, leading to their exclusion from this review. In countries with highly standardized education systems, where competency-based education is increasingly emphasized, a differentiated analysis of competency dimensions could be essential to ensure the sustainable integration of ESD into teacher education. The rising prominence of competency models in teacher education underscores the need to consider ESD not merely as an additional component but as an integral part of professional action competence. This shift is also reflected in the broader international educational landscape, where competency-oriented educational frameworks continue to gain importance.

The unequal emphasis on different competency dimensions in existing research also poses challenges to the implementation of ESD in school practice. If knowledge and attitudes are prioritized while willingness to act and implementation skills receive less attention, there is a risk that ESD remains theoretical rather than practical. This is particularly concerning because sustainable development cannot be achieved through knowledge transfer alone but requires the ability and commitment to facilitate transformative educational processes [11]. Therefore, future studies should increasingly explore how pre-service teachers are not only made aware of ESD but also actively equipped to integrate it into their daily teaching practice.

5. Conclusions

This review set out to examine the methodological and contextual characteristics of empirical research on ESD-related competences among pre-service teachers, as well as the dimensions of professional action competence that have been investigated so far. The findings reveal that current research is shaped by several limitations. These include a geographical imbalance in study locations, a dominance of cross-sectional designs and self-assessment methods, and a narrow focus on cognitive and motivational dimensions of competence. As a result, the long-term development of ESD competences and their practical implementation in teacher education remain underexplored. Furthermore, only limited attention seems to be given to the interaction of influencing factors such as prior experience, institutional frameworks or subject-specific differences in the studies included in this review. Based on these findings, future research should strive for more methodological diversity and transparency in the assessment of ESD competences. This includes the careful development and selection of assessment tools that are appropriate for capturing the multidimensional nature of competence development. Furthermore, a broader inclusion of subject disciplines and a systematic examination of interrelations between competence dimensions, particularly those related to action, would be beneficial. Longitudinal and mixed-methods designs could offer valuable perspectives in this regard.

Implications for teacher education could be drawn on several levels. First, ESD might be more consistently embedded across a wider range of subjects, rather than being concentrated in traditionally sustainability-related disciplines such as geography or biology.

Second, teacher training programs could move beyond imparting knowledge and attitudes by placing greater emphasis on fostering willingness to act and practical implementation skills. Third, future educators might benefit from developing a reflective and interdisciplinary professional identity that enables them to navigate the complexity of sustainability challenges in everyday teaching practice.

The results of this review may serve as a foundation for further empirical and practical developments in ESD-related teacher education.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17093856/s1. Supplementary Documents: The PRISMA-ScR checklist.

Author Contributions: Conceptualization, research design, methodology, data collection, validation, data analysis, visualization, writing—original draft, S.V.; supervision and conceptualization, M.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The study protocol is openly available on the Open Science Framework (OSF) at https://osf.io/ga4ny/files/osfstorage/67cf1c6f7869cfe617bb330c (accessed on 17 March 2025).

Acknowledgments: We want to thank Sven Hanses (S.H.) and Linnéa van Dreuten (L.v.D.) for their supporting work during the data analysis and preparation (coding and visualization).

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ESD	Education for Sustainable Development
SD	Sustainable Development
EE	Environmental Education
EfS	Education for Sustainability
TESD	Teacher Education for Sustainable Development
SDG	Sustainable Development Goal
CK	Content Knowledge
PCK	Pedagogical Content Knowledge
NAM	Norm Activation Model
EVT	Expectancy-Value Theory
TPB	Theory of Planned Behavior
CBE	Competency-based Education
fsQCA	fuzzy-set Qualitative Comparative Analysis
CMEC	Council of Ministers of Education, Canada
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNECE	United Nations Economic Commission for Europe
PRISMA-ScR	Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews
OSF	Open Science Framework

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