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Systematic Review

Systematised Review of Know-How in Teacher Training: Science–Technology–Society Teaching in the Primary School Classroom

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Abstract

Scientific literacy is a key element in today's society, shaping everyday life and fostering informed decision-making and critical thinking. However, the traditional transmission of science, among other factors, has fostered a simplistic and negative view of this field of knowledge, leading to a detachment of the population from it. In this context, teachers need to assume a transformative role. To this end, it must be recognised that didactic change cannot be limited to cognitive aspects, given the relevance of attitudes as a key component of professional knowledge and as a driver of a consolidated shift. Concern about this reality leads us to describe the structure and content of scientific knowledge related to the study of Primary Education teachers' attitudes towards the teaching of the Nature of Science and Technology. A mixed-methodological design was employed, comprising a documentary-bibliometric study with a science-mapping approach and documentary analysis. The results showed that studies often focus on the cognitive component of attitudes, mainly on beliefs about knowledge or self-efficacy. However, studies on affective or conative components remain scarce, and none have been found that comprehensively address all three components of attitudes, despite their potential to provide a deeper understanding of their role in educational change. The need to address teachers' attitudes holistically is highlighted to better understand the evaluative and motivational factors that guide teaching practices. Likewise, the importance of moving towards studies based on educational interventions that promote the development of science as useful for life is emphasised.

Keywords: attitudes; bibliometric analysis; critical thinking; nature of science and technology; scientific production; teacher training

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1. Introduction

Science (and technology) play a crucial role in contemporary society. As Vázquez-Alonso and Manassero-Mas (2007) point out, in both the public and private spheres, it is necessary to act on socio-scientific issues, since the world itself is the product of technoscientific research. In this regard, scientific literacy emerges as an essential element not only for the integral development of individuals but also for their active participation as critical and responsible members of a global citizenship (Castellví & González-Monfort, 2020; Pastor-

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García et al., 2019), as contemporary challenges (such as climate change, sustainability, social equity, or technological justice) transcend borders and require a shared understanding.

For this reason, scientific and technological literacy has become a fundamental pillar of Global Citizenship Education (GCE) (Fueyo et al., 2015; Thompson, 2016), being directly linked to the Sustainable Development Goals and, more specifically, to Education for Sustainable Development (ESD). Through it, it is possible to foster Critical Thinking (CT), creativity, communication, and collaboration (Tenreiro-Vieira & Vieira, 2021), 21st-century competences necessary to imagine and build a more just and sustainable world (Almerich et al., 2020). In this way, science can be understood as a social and cultural phenomenon that, when integrated into educational processes from an early age, provides students with tools to understand natural phenomena, reflect on the interactions between society and nature, and question the inequalities that affect local and global life (Sheridan et al., 2017).

However, propedeutic education still predominates (Vázquez-Alonso & Manassero-Mas, 2007). The model of science that has been and continues to be transmitted through educational institutions remains limited and detached from this transformative perspective. Traditional curricula and teaching methods focus on the transmission and reception of concepts, theories, methods, and applications (Muñoz-García, 2014), which has led multiple generations to acquire a negative and simplistic view of science, perceiving it as inaccessible or disconnected from everyday life. This conception not only distances students from scientific learning but also hinders their critical and active participation in socio-scientific issues and, by extension, in the challenges of global citizenship (Pérez-Foguet & Lazzarini, 2019; Yemini et al., 2019). Consequently, the complexity of scientific knowledge generates a demarcation that is not only cognitive but also social (Bindé, 2005).

In light of this situation, a change in educational processes is needed—one that promotes scientific literacy suitable for all people. This should be understood not merely as the acquisition of content, but also as an interactive and participatory educational process that fosters critical awareness, civic engagement, and the construction of alternatives in favour of social justice and sustainable development.

1.1. The Nature of Science and Technology to Address the Simplistic and Negative Vision

To overcome the aforementioned errors arising from traditional teaching, a new meta-knowledge about science emerges from interdisciplinary reflections by scientists and educators from different perspectives: the Nature of Science (NOS) (Acevedo et al., 2016). This concept emphasises that science goes beyond content; it is related to historical, philosophical, and sociological circumstances.

However, as Vázquez-Alonso and Manassero-Mas (2017) state, the field of NOS is controversial due to the lack of agreement on the taxonomies that define it; it is neither static nor universal but complex, multifaceted, and changing. Several authors have proposed taxonomies or consensus frameworks on what should be considered in the teaching of NOS.

These include the taxonomies proposed by Lederman et al. (2002) and Matthews (2012); McComas (2002); Osborne et al. (2003); Irzik and Nola (2011, 2014); and Erduran and Dagher (2014), as well as the Science–Technology–Society (STS) Tradition updated by Manassero and Vázquez (2019). These taxonomies not only include epistemological content, but also favour the development of informed conceptions of NOS, that is, conceptions closer to real science (Abd-El-Khalick, 2013).

Although all these frameworks offer important perspectives that should be taken into account, the research presented here shows a greater affinity with the STS Tradition, as it addresses epistemological, external and internal sociological, and definitional aspects of science and technology.

The introduction of NOS will allow us to develop sound scientific literacy that goes beyond what science is to reflect on science and its role in society (Muñoz-García, 2014). This approach enables a deeper understanding of knowledge, strengthens social interactions, and reinforces scientific values by incorporating social, historical, and environmental dimensions. It also promotes working with science from the immediate environment, stimulating vocations and fostering the acquisition of a more humanistic scientific-technological culture.

Meta-knowledge, therefore, prevents the construction of a decontextualised view of science that renders STS relationships invisible and hinders the impact of CT, inherent to scientific practice, on the understanding and appreciation of social problems (Solbes & Vilches, 1997). Moreover, reciprocally, CT fosters a deeper and more meaningful understanding of NOS and helps to overcome cognitive difficulties by stimulating the ability to question, argue, and analyse scientific knowledge in its multiple dimensions (Vázquez-Alonso & Manassero-Mas, 2018; Vieira et al., 2010). In other words, this perspective in science education also allows us to explore the development of critical capacity for understanding and resolving socio-scientific problems (Torres & Solbes, 2016).

Thus, science teaching based on an understanding of NOS contributes not only to the education of scientifically literate citizens but also to that of critical citizens capable of making informed and responsible decisions in the face of contemporary socio-scientific challenges (Solbes, 2019). Although this content is a relevant indicator of innovation in science teaching, its inclusion in classrooms is still rarely observed. Studies show that explicit and reflective teaching does not necessarily guarantee that teachers will implement it in their classrooms (Abd-El-Khalick, 2013).

1.2. The Union of Reason and Emotion to Promote the Didactic Change

The situation outlined above highlights the importance of defining which aspects of teacher education are necessary for teachers to assume a transformative role in teaching. In this regard, teacher education should be grounded in a process that fosters didactic change (Mellado, 2003).

It should be borne in mind that reflection on teaching is not solely a cognitive process but also requires emotional commitment. It involves both the head and the heart, as it challenges teachers' emotional and cognitive competences at both a personal and a professional level (Avraamidou, 2014; Day, 1999; Wenger, 1998). From this perspective, didactic change is conceived as a continuous process of evolution in ways of thinking, feeling, and acting.

These ideas make it clear that didactic change entails not only professional but also personal transformation. It is therefore an experience of identity (Wenger, 1998), which reveals the need for teacher learning and development to go beyond knowledge and skills alone (Avraamidou, 2014; Rivera-Maulucci, 2013). In line with this approach, the present study, as discussed later, focuses on teachers' attitudes, that is, the knowing-how-to-be dimension of teaching.

From a theoretical perspective, it is necessary to clarify the concept of attitude as a construct, given its deep embedding in everyday language and its multiple definitions. Morales (2000), based on Katz's (1960) definitions, argues that attitude is a learned, not innate, and stable predisposition. However, it can change, either favourably or unfavourably, in response to an object (individuals, groups, ideas, situations, etc.). This definition allows us to state that attitudes can be positive or negative; that is, they are evaluative predispositions with a motivational component involving affectivity and a tendency to act (Sarabia, 1992). Moreover, their learned nature makes them a fundamental factor to consider in education, due to their influence on behaviour and learning.

In addition to the diversity of definitions, numerous models examine the structure of attitudes. Within the tridimensional model, we can identify a clear parallel with the structure of competences and, therefore, with educational objectives (Hogg & Vaughan, 1995; Martín-Baro, 1983). These three components are: the cognitive component, expressed through beliefs and opinions (favourable or unfavourable); the affective component, which refers to the feelings and emotions of acceptance or rejection, liking or disliking that are activated in response to a stimulus; and the conative–behavioural component, which refers to predispositions and statements of intention toward the object of the attitude.

In the field of Science Education, the literature proposes various taxonomies to organise and facilitate its study. Gardner (1975) distinguishes between attitudes towards science, of an affective and evaluative nature, and scientific attitudes, linked to cognitive and rational thinking. Nevertheless, the objects of attitude in this field should go beyond learning science itself. Hodson (1988) highlights the role of the school in fostering a balanced attitude towards science teaching, which is incorporated into his classification—an aspect that constitutes the central focus of the present study.

1.3. Purpose of the Study

Based on the foregoing considerations, it is deemed appropriate to investigate how the scientific literature has addressed the study of attitudes. This decision is grounded in several reasons. First, didactic change is a complex process and remains a relatively under-researched area (De Pro et al., 2022). Second, existing evidence indicates that processes of change are more likely to be consolidated when they integrate attitudes and values (Sanmartí, 2001), thus positioning attitudinal change as a key component of didactic change. Finally, the current body of literature lacks systematic reviews that enable an integrated understanding of how this field of research has been configured, its main approaches, and which attitudinal dimensions remain underrepresented. This situation highlights the need for studies that provide a comprehensive and structured overview of the scientific knowledge produced to date.

Therefore, we intend to describe the structure, content, and relationship of scientific knowledge on the attitudes of trainee and practising Primary School teachers towards the teaching of the NOS. In this way, we aim to answer the following questions:

(1) How is the scientific literature on the attitudes of primary school teachers towards teaching the nature of science and technology structured and organised?
(2) What aspects related to attitudes are predominantly addressed in the literature, and what problems are detected?
(3) What research gaps and future directions emerge from the existing body of knowledge in this field?

All of these are conducted to promote future research that will make new contributions to the body of knowledge to support educational improvement.

2. Method

The systematised review corresponds to a theoretical investigation (Montero & León, 2007). A documentary-bibliometric study is carried out, based on hermeneutics (Hoyos, 2010) and scientometrics (Spinak, 1998). The design of both phases, which can be identified with the explanatory sequential strategy (Hernández-Sampieri & Mendoza, 2018), is carried out from a descriptive and evaluative perspective.

To favour transparency, rigour, clarity and replication of the process followed to carry out the systematised literature review, a combination of the SALSA Framework method recommended by Codina (2018) and developed by Grant and Booth (2008) is used, in which four interrelated phases are contemplated (search, evaluation, analysis and synthesis), with the scientific mapping technique with the support of the VOSviewer software (version 1.6.19). This software allows the generation of graphical representations to speed up and facilitate the analysis and understanding of bibliometric networks (Van Eck & Waltman, 2010).

Bibliometric analysis was employed to provide a macro-level overview of the intellectual structure and thematic evolution of research on teachers' attitudes. This approach complements documentary analysis by enabling the identification of dominant themes, emerging lines of inquiry, and underexplored areas, thereby directly supporting the study's research questions. The process followed (Figure 1) aims, first, to obtain an overview of the thematic lines in the field of study through scientific mapping and, second, to acquire detailed, in-depth knowledge of the existing literature on the object of study.

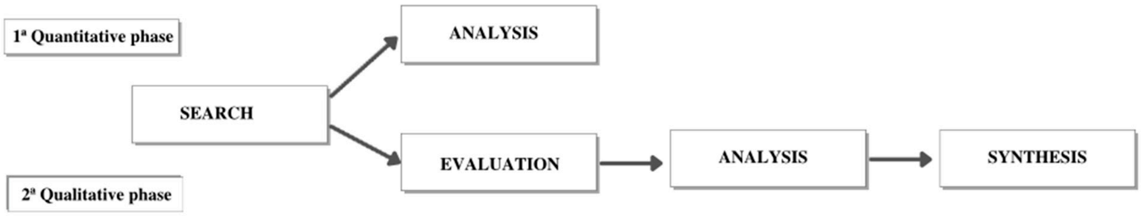

Figure 1. Phases of the investigation.

The phases of the qualitative pathway are complemented by five of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria (Page et al., 2021). The search phase includes the description of the research sources and the presentation of the strategy carried out. The evaluation phase is made visible through the specification of the study selection process. The analysis phase presents the characteristics of the studies selected after the evaluation. Finally, the synthesis phase is described, including the procedure used to achieve this end.

2.1. Sample

Given the nature of the object of study, the unit of analysis corresponds to the documents to be evaluated. Therefore, the search phase is carried out to identify evidence to support the systematised review. Since the quality of such a search affects the entire review, a simple process consisting of faceting, deriving, and combining is applied (Codina, 2018). From the central theme (the attitudes of practising and trainee Primary Education teachers towards teaching NOS), the necessary keywords were derived in English and Spanish to represent the various dimensions of the study (Figure 2).

The keywords were combined using Boolean Operators (OR for synonyms and AND for facets) and parameters, following inclusion and exclusion criteria (indicated later), resulting in the search equations (Figure 2). Several trial-and-error equations with different levels of specificity were used to assess the quality of the results.

The designed search equations are introduced in the Scopus and Web of Science (WOS) databases as a general subgroup and Dialnet and Teseo as a specific subgroup, to generate an optimal group. The databases were selected based on accessibility, subject coverage and the quality and reliability of the publications.

Evidence Collection and Evaluation Procedure

In addition to the search phase, the evaluation phase is conducted to make the review more dynamic. The evaluation of the documents is carried out by establishing different inclusion and exclusion criteria (Figure 3) to systematise and speed up the selection of documents that will form part of the reference bank, which will go on to the documentary analysis and synthesis phase.

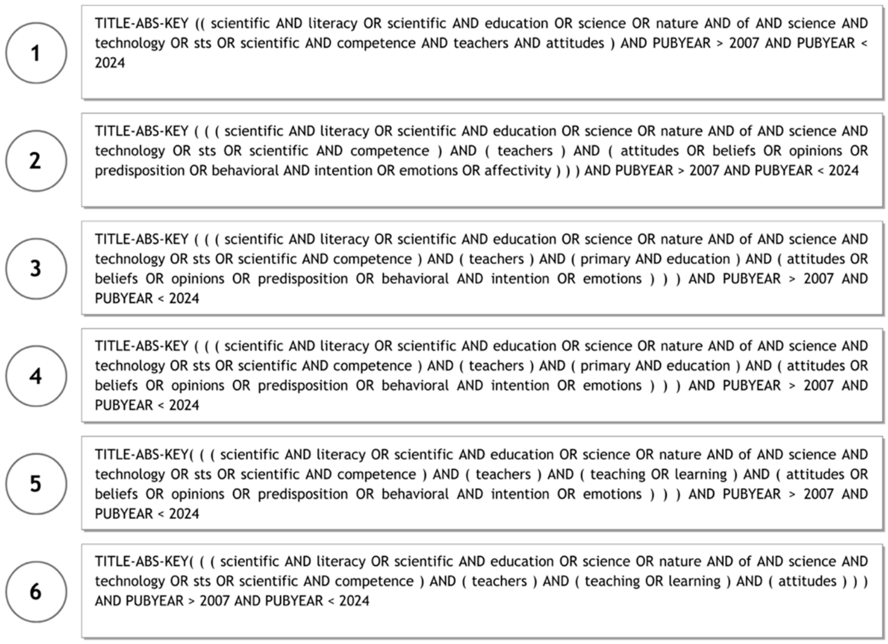

Figure 2. Search equations.

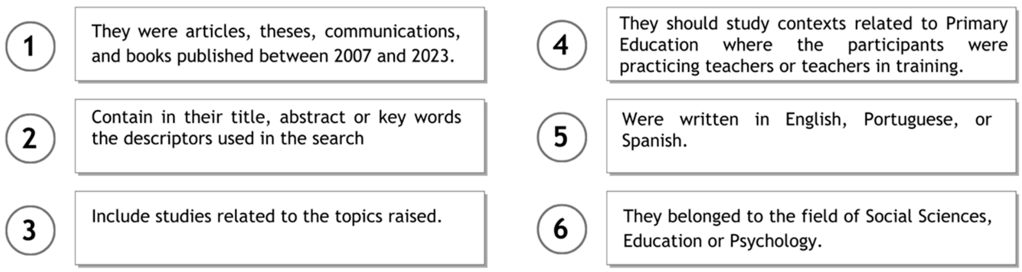

Figure 3. Assessment criteria.

The inclusion and exclusion criteria were defined to ensure coherence with the research questions and the exploratory nature of the study. Documents were included if they addressed primary school teachers' attitudes towards teaching the Nature of Science and Technology, whether explicitly or implicitly, and met minimum standards of scientific quality. Exclusion after the initial search phase was primarily due to thematic misalignment, insufficient focus on attitudes, or irrelevance to teacher education.

These criteria were applied as follows: reading the title and abstract, a superficial reading, and, finally, a complete reading, after considering whether the document was of interest. Figure 4 shows a flowchart summarising the strategy used.

2.2. Data Analysis Procedure

Once the documents were collected, the analysis was conducted using VOSviewer. A word cooccurrence analysis was carried out through a network map to identify, in general terms, the lines of research and topics related to the object of study. In the analysis carried out to generate this map, a binary count was performed on the total number of documents detected in the initial search. A total of 25,216 words were identified; however, only those that appeared at least 10 times were included in the analysis. A total of 272 words met the threshold. This resulted in a selection of 163 words (60% of the most relevant terms). These words were further filtered to eliminate duplicates using a Thesaurus. Redundant content and content that was not data-ink were also eliminated. This reduced the number of words analysed to 62. To facilitate the visualisation of the conformed map, the maximum number of edges was limited to 400.

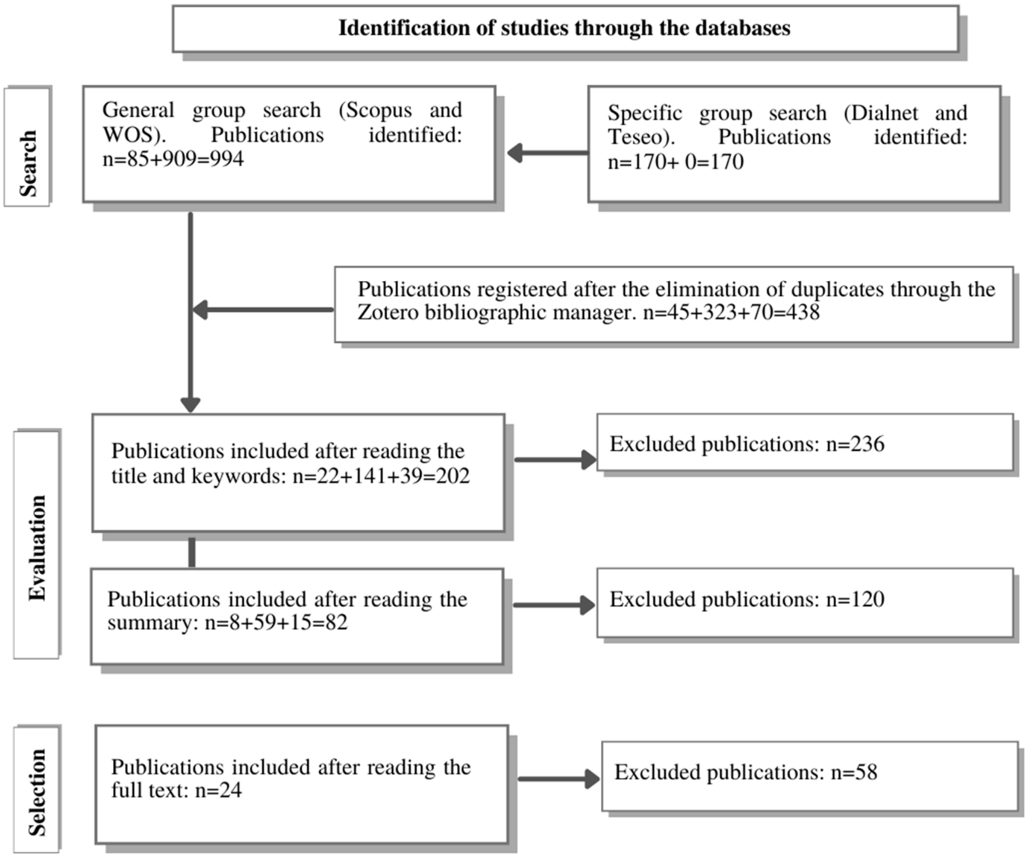

Figure 4. PRISMA flow chart.

Secondly, to describe the selected writings included in the document bank, an annotated bibliography was prepared (Table 1) that included relevant elements to be distinguished within a unit of analysis (Hoyos, 2010). On this, a process of synthesis and interpretation (Hart, 2008): description of the main approaches and key concepts, the main debates and problems, and the gaps and opportunities for research offered by this field of study.

Table 1. Commented bibliography.

Author and Year	Country	Paradigm	Design	Collection Technique	Attitude Component and Object
(Aragón-Núñez et al., 2021)	Spain	Quantitative.	Descriptive, correlational and predictive	Questionnaire (Likert scale)	Cognitive component (pedagogical and scientific beliefs towards the image of science, its learning and its teaching)
(Callejas-Restrepo & Vázquez Alonso, 2009)	Colombia	Quantitative.	Descriptive, comparative and predictive	Multiple choice questionnaire (COCTS).	Cognitive component (Views towards STS issues)
(Delgado Iglesias, 2015)	Spain	Quantitative.	Descriptive	Questionnaire (Likert scale)	Cognitive component (opinion on science and scientific knowledge)
(Mateos Núñez & Martínez Borreguero, 2021)	Spain	Quantitative	Descriptive and inferencial	Questionnaire	Cognitive component (beliefs about one's own competence and beliefs about the usefulness of science for students) Affective component (emotions towards the areas of knowledge and science education)
(Clerici, 2008)	Italy	Quantitative.	Descriptive, correlational and comparative	Knowledge level tests and a self-report questionnaire.	Cognitive component (self-efficacy to teach) Affective component (affections towards disciplines)
(Murphy & Smith, 2012)	Irleland	Quantitative.	Descriptive	Questionnaire (Likert scale and open questions)	Cognitive component (beliefs towards the discipline and its teaching capabilities). Affective component (liking)
(Barnes et al., 2015)	Oklahoma (USA)	Quantitative.	Correlational and factorial	Form Q	Cognitive and conative component (beliefs about the nature of science and intention to teach it)
(Aguirregabiria & Garcia-Olalla, 2022)	Spain	Quantitative.	Descriptive	Questionnaire (Likert scale, dichotomous questions and open questions).	Cognitive component (beliefs about the usefulness of science, perception of the importance of science in the curriculum, perception of their ability). Affective component (liking for science topics)
(Cadena-Nogales et al., 2022)	Spain	Quantitative.	Descriptive, correlational and comparative	Questionnaire	Cognitive component (opinions/beliefs about unjustified epistemic knowledge).
(Fernández-Carro et al., 2023)	Spain	Quantitative.	Descriptive and explorative	Survey.	Cognitive component (beliefs in pseudoscience and superstition)
(Fuertes-Prieto et al., 2020)	Spain	Quantitative.	Descriptive and comparative	Survey and questionnaire	Cognitive component (beliefs in pseudoscience and superstition)

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Table 1. *Cont.*

Author and Year	Country	Paradigm	Design	Collection Technique	Attitude Component and Object
(Esteban et al., 2019)	Spain	Quantitative.	Descriptive and correlational	Questionnaire	Affective component (negative and positive emotions experienced in an STS learning experience)
(Kartal et al., 2019)	Turkey	Quantitative.	Descriptive and comparative	Questionnaire (Likert scale)	Cognitive component (self-efficacy beliefs in NDC teaching). Cognitive component (beliefs about the NDC curriculum, about teachers and the learning environment, about lessons and about how science is learned).
(Kaya et al., 2009)	Turkey	Mixt	Descriptive and comparative	Questionnaire (Likert scale) and interview	Cognitive component (perceived importance of STS issues). Affective component (interest in STS issues and the science teacher's interest in STS topics).
(Kim & Tan, 2011)	Korea	Qualitative	Interpretative	Reflective writing and group discussions.	Cognitive component (views and beliefs about science education)
(Malandrakis, 2018)	Greece	Mixt	Comparative	Interview and questionnaire (Likert scale and factor ranking)	Cognitive component (efficacy beliefs and confidence)
(Mansour, 2013)	Egypt	Qualitative	Comparative case study.	Semi-structured interview, classroom observations, and lesson plans.	Cognitive component (beliefs about science education)
(Martínez-Borreguero et al., 2022)	Spain	Quantitative.	Comparative	Likert scale (emotional variables and self-efficacy). Multiple-choice questionnaire and open-ended questions (knowledge).	Cognitive component (self-efficacy beliefs). Affective component (emotions towards STEM areas)
(Ozturk-Akar & Dogan, 2013)	Turkey	Quantitative.	Descriptive and inferential	Multiple choice questionnaire (VOSTS).	Cognitive component (Views towards STS issues)
(Tosun & Ozturk, 2020)	Turkey	Quantitative.	Correlational and comparative	Survey.	Cognitive component (beliefs about competence in science teaching—self-efficacy)

Table 1. *Cont.*

Author and Year	Country	Paradigm	Design	Collection Technique	Attitude Component and Object
(Vazquez-Alonso et al., 2013)	Spain	Quantitative.	Descriptive, comparative and predictive	Multiple choice questionnaire (COCTS)	Cognitive component (Views towards STS issues)
(Walag et al., 2022)	Philippines	Quantitative.	Explorative and correlational	Questionnaire	Cognitive component (self-efficacy beliefs)
(Ward et al., 2020)	New Zeland	Qualitative	Case studies	Interview	Cognitive component (self-efficacy beliefs)
(Yalvac et al., 2007)	Turkey	Quantitative.	Descriptive	Multiple choice questionnaire (VOSTS)	Cognitive component (Views towards STS issues)

3. Results

The results of the two phases carried out are presented below.

3.1. Results of the Bibliometric Analysis

In analysing the data and formulating the results, the study focused on examining which topics are significantly addressed in the documents detected in the search (Figure 5).

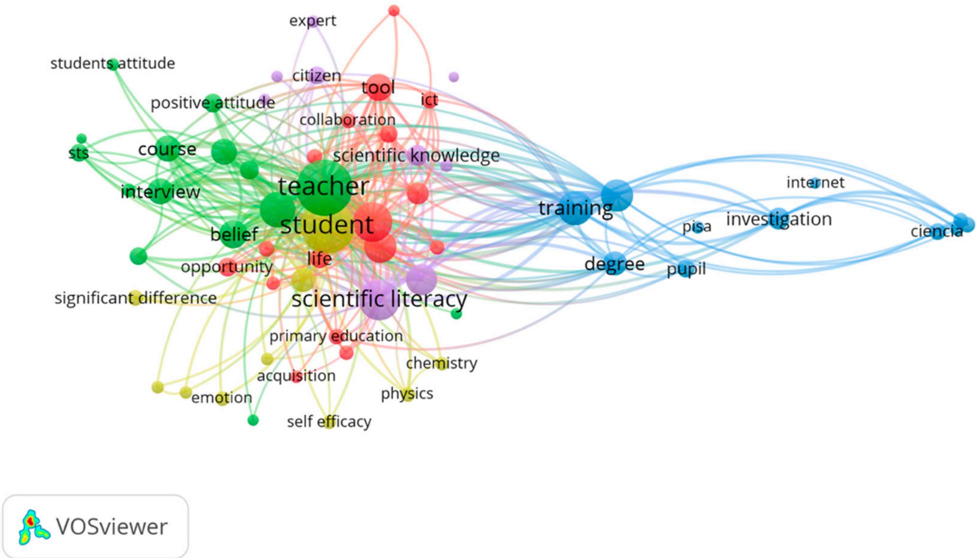

Figure 5. Network visualisation. Note. Cooccurrence analysis of terms in title and abstract (Mín. Strength = 0, Máx. Lines = 400).

Looking at the map generated, we can identify five clusters. A more detailed visualisation shows that the first cluster (red in Figure 5) is mostly centred on the term "knowledge" and includes items such as school, scientific competence, assessment, ICT, opportunity, digital competence, and teacher training, among others. Therefore, we can infer that there is a predominant trend in research investigating how ICT can facilitate and promote scientific competence and, therefore, the need to assess teachers to take advantage of digital competence opportunities.

The second cluster identified (green in Figure 5) is mainly grouped around the term "teacher" and is made up of 15 nodes, of which socio-scientific issues, arguing, beliefs, positive attitude, STS, trainee teachers, and course, among others, stand out. This composition allows us to infer that there is an interest in promoting education on socio-scientific issues to make visible the relationship between STS, to foster the ability to argue as an essential manifestation of CT, and to enhance students' capacity for reflection, evidence-based analysis, and informed decision-making. In addition, to promote beliefs towards science to avoid a simplistic and dogmatic vision and to favour positive attitudes that promote interest, participation, and learning, among others. These ideas could form the basis of research aimed at the intervention and evaluation of the promotion or evolution of teachers' knowledge, skills, and attitudes towards science, as well as the detection of aspects to be improved in training.

In the case of the third cluster (blue in Figure 5), made up of eleven nodes, with the term "training" being the most frequent and, therefore, the term to which the terms are most closely linked, suggest that there is a concern or interest in teachers and their training, given that they play a central and transcendental role in the teaching of experimental sciences. In this sense, the presence of terms such as grade, educator, research, science, technology, society, PISA, and student, among others, allows us to deduce that the research aims to investigate the preparation of future teachers through approaches that relate science, technology, and society to approach this field of knowledge in a contextualised and real way and to foster a deep understanding of science. On the other hand, the presence of the terms student and PISA suggests that the research aims to explore how educators' training relates to student performance and which aspects can be improved using PISA tests.

The fourth cluster (yellow in Figure 5) comprises nodes formed by the following terms: chemistry, physics, control group, experimental group, self-efficacy, interest, emotion, and "student", which is the most frequent term. These terms suggest a trend in research focusing on interventions with future chemistry and physics teachers to corroborate possible differences in outcomes depending on the use of different teaching and learning methodologies. In addition, the terms emotion, interest, and self-efficacy suggest an interest in understanding the role of the attitudinal component in the acquisition and implementation of competencies.

The fifth and last cluster (purple in Figure 5) has a smaller composition than the other groupings and lower occurrence levels. The terms that compose it are as follows: citizenship, critical thinking, future, science education, enquiry, and history, among others. These terms are grouped around "scientific literacy", indicating that a line of research is beginning to emerge that aims to respond to the complex current and future challenges. This line stems from the current contextual situation, where CT emerges as a key 21st-century competence, essential within scientific literacy not only to enhance the understanding of science but also to contribute to the formation of a critical and responsible global citizenship, capable of actively participating in the construction of more sustainable, just, and democratic societies.

From this perspective, science education takes on a central role as a vehicle for developing these competencies in educational practice. Promoting learning experiences grounded in inquiry, historical analysis of science, and reflection on its social implications is essential to advancing towards a more comprehensive and transformative scientific literacy.

Furthermore, the presence of the term critical thinking suggests a growing interest in educational processes that develop higher-order skills, equipping citizens to adapt to and transform a changing world. The aim is no longer to memorise scientific content but to construct meaning.

It is worth noting that the number of publications has been increasing over time (Figure 6). The growth in published literature reflects a gradual increase in interest and attention paid to science education since 2015.

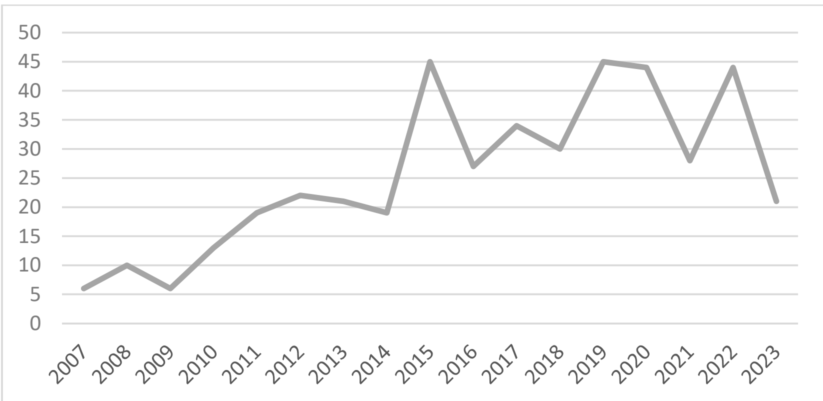

Figure 6. Publication per year.

3.2. Results of the Documentary Analysis

3.2.1. Approaches and Key Concepts

Research in experimental science education is a consolidated and growing field worldwide, despite the difficult challenges it has faced to achieve "research normality" (De Pro & Rodríguez, 2011). In the annotated bibliography (Table 1), studies conducted in countries such as Italy, Turkey, Spain, Ireland, Egypt, the United States, and Colombia can be consulted. The number of documents published has increased in the last five years. However, we can affirm that the number of publications on the specific topic we wish to investigate is not abundant.

In the search and evaluation process, we have observed that the line of research can be broken down into two main, interrelated areas. Firstly, diagnostic studies are carried out to understand and evaluate various aspects of the teaching profession. Secondly, intervention-based studies are conducted to improve specific aspects of the teaching profession. In these areas, where academic journal articles and conference papers (published as book chapters) predominate, we have identified certain patterns and approaches.

On the one hand, if we look at the ontological, epistemological and methodological assumption, we can observe that studies of a quantitative nature are predominantly carried out, in which questionnaires or surveys are used to carry out statistical analyses that make it possible to describe, correlate, compare or predict the behaviour of the variable under study to carry out its diagnosis or evaluation. Qualitative studies are rare; however, they offer highly relevant insights into the variables under study, as case studies are used as a research method. Mixed studies are even less frequent.

On the other hand, recurring themes are identified in the selected studies. We can classify the evidence into five themes. Firstly, we frequently find studies that analyse the beliefs or opinions of practising and trainee teachers regarding STS issues. This research reveals that views are often inadequate or naïve (Barnes et al., 2015; Ozturk-Akar & Dogan, 2013; Yalvac et al., 2007). However, interventions by Kartal et al. (2019) and Kaya et al. (2009) reflect that views can be modified and evolve through appropriate educational processes. The study by Vazquez-Alonso et al. (2013) also found that practising teachers achieve higher scores than trainee teachers.

Secondly, there are numerous studies that assess self-efficacy beliefs about one's ability to teach science. The study by Walag et al. (2022) with practising teachers reveals that knowledge determines self-efficacy beliefs. This finding provides a broader understanding of the results reported in the studies by Kartal et al. (2019), Malandrakis (2018), Martínez-Borreguero et al. (2022) and Murphy and Smith (2012). All of them reveal improvements in trainee teachers' self-efficacy beliefs for teaching science after participating in training courses. Murphy and Smith (2012) also report that the initial results are alarming due to their low level (negative character). This is also highlighted in the study carried out by Clerici (2008). In this line, Ward et al. (2020) conducted a case study reporting that self-efficacy develops over time through various influences (e.g., classroom experiences, emotional states). Tosun and Ozturk (2020) also report that perceived competence is related to various aspects such as gender, workload, and collaboration.

Thirdly, and less frequently, we also find studies that focus on teachers' beliefs about science teaching. The results reveal a collective unconscious with a tendency towards traditional teaching. The initial results of the intervention carried out by Aragón-Núñez et al. (2021) show traditional positions in trainee teachers, and the qualitative study by Mansour (2013) reflects an inconsistency. Teachers manifest constructivist beliefs; however, their praxis is predominantly traditional. From this perspective, Kim and Tan's (2011) contributions on teachers' various contradictions about their beliefs about science teaching are interesting.

Fourthly, there are studies focusing on the affective component. Aguirregabiria and Garcia-Olalla (2022), Clerici (2008), Kaya et al. (2009), Mateos Núñez and Martínez Borreguero (2021), Martínez-Borreguero et al. (2022), and Murphy and Smith (2012) investigate affect, liking or interest in scientific subjects or areas, revealing a predominance of negative affect or a tendency to move away from this area. Interventions in the last three studies show that training can transform these effects. Esteban et al. (2019), for their part, focus on emotions towards learning, revealing their influence on performance.

In fifth place, very close to the present time, we find an emerging interest in the study of beliefs and opinions about pseudosciences and superstitions, which reflect the widespread acceptance of these issues among teachers in training. Specifically, Fernández-Carro et al. (2023) report that the beliefs of this group do not differ from those of their generational group despite their role as trainers; Fuertes-Prieto et al. (2020) state that these beliefs are independent of interest in science and technology, and Cadena-Nogales et al. (2022) reveal a significant influence derived from gender and academic level. In addition, cognitive style is a predictor (it is necessary to reinforce the rational style).

It is worth noting, as can be seen in the analysis of the studies selected as evidence, that there is a variety of research that analyses these variables through intervention proposals. In other words, there are not merely diagnostic studies. The field of study is moving towards the joint construction of theory and practice to promote real changes in the educational context, grounded in knowledge of the opportunities and weaknesses inherent in reality.

In short, the literature offers strong points. However, regarding the evaluation of the attitudinal dimension (in the affective-emotional system) of trainee and practising Primary Education teachers, the literature is scarce. As indicated below, some problems and gaps need to be filled due to the relevance of scientific and technological literacy in everyday life. Further studies in these fields are necessary to promote real changes in education.

3.2.2. Discussions and Problems

The role of science and technology in today's society makes science education a key field of study, as science and technology literacy influences people's lives. Therefore, it is necessary to understand the challenges or problems that need to be addressed.

Through the construction of the Theoretical Framework, problems such as the simplistic and negative view of science by the population or debates about what science to teach and how to teach it were reflected. The detailed analysis of the documents also allows us to discover a series of other problems and debates in the field studied. The results obtained in the different selected studies reveal that teachers (practising or in training) have erroneous beliefs about the NOS, they do not feel competent or confident enough to teach science (self-efficacy beliefs), their beliefs about science teaching differ from their practice, they experience negative emotions towards science, and they accept pseudo-scientific issues.

All these problems are obstacles to the teaching role in generating innovative proposals in the classroom that promote critical scientific and technological literacy, one that not only enhances understanding of scientific knowledge but also fosters a reflective and responsible perspective on its role in society and everyday life. In this sense, various authors conclude that it is necessary to review and transform training plans due to their influence on the personal and professional dimensions of future teachers and, therefore, on schoolchildren (Callejas-Restrepo & Vázquez Alonso, 2009; Clerici, 2008; Delgado Iglesias, 2015). The studies propose concrete actions to begin this path of transformation of educational processes. Several studies conclude that it is necessary to consider students' particularities, including their needs, previous conceptions, and experiences, among others (Aguirregabiria & Garcia-Olalla, 2022; Vazquez-Alonso et al., 2013), to achieve successful teaching and learning processes. Therefore, it is essential to move from the traditional to the constructivist position (Aragón-Núñez et al., 2021; Barnes et al., 2015), in which, following the ideas of Mansour (2013) and Ozturk-Akar and Dogan (2013), teachers reflect on their own construction of the world and of teaching. This aspect is fundamental if we also take into account the non-scientific beliefs detected by several authors (Cadena-Nogales et al., 2022; Fernández-Carro et al., 2023; Fuertes-Prieto et al., 2020). Malandrakis (2018) adds the need to promote training that includes real classroom practice.

All these issues reveal the need to address teachers' thinking. Learning is a product of thinking. Therefore, revealing their initial thinking, how it is constructed, and how it evolves will enable the development of educational processes adapted to their needs, ideas, and previous experiences. In this context, it becomes especially relevant to conceive education as a process that goes beyond the mere transmission of knowledge, fostering the construction of understanding through reflection and critical thinking (Núñez-López et al., 2017).

A paradigmatic shift is therefore required—one that regards teachers as researchers of their own practice, capable of analysing, questioning, and transforming their professional activity. This implies considering critical thinking not only as a transversal skill but also as a curricular content that demands teachers capable of designing educational proposals aimed at its development.

Consequently, effective teacher education becomes essential to enable educators to master this competence to ensure that they can teach it, moving towards the conception of the teacher as a reflective professional, one capable of understanding the complexity and uncertainty of our times, and of accompanying, guiding, and stimulating the integral development and learning of their students (Pérez, 2010; Rivas & Saiz, 2020).

In short, it is necessary to continue to make progress in this area. This progress should be based on the problems detected to promote the construction of responses connected to educational reality.

3.2.3. Research Gaps and Opportunities

The analysis of key approaches and concepts, debates and problems allows us to gain insight into what is being researched and what conclusions are being reached. This information is key to identifying potential research opportunities that help alleviate obstacles to achieving scientific and technological literacy for life, enabling citizens to understand and transform the current reality.

Firstly, several studies have focused on assessing what trainees and practising teachers know and what they are like. As mentioned above, these studies have led to reflection on the need to reorient training. In other words, research must continue to find answers to the question of how to improve what teachers know and are. Therefore, an analysis of initial and in-service training curricula is required to build a teaching body capable of reflecting on educational praxis and promoting renewal.

Secondly, there is only one study (Mansour, 2013) that aims to evaluate and understand in depth how teachers proceed. It is therefore necessary to analyse the educational strategies employed to detect weaknesses and discover opportunities. These processes must take place in cooperation between universities and schools and must be directed towards the construction of teaching materials that facilitate and enhance the proper teaching of science.

Finally, we can detect another absence in the literature. The evidence collected shows that there is a predominant focus on the cognitive component of attitudes, on beliefs and opinions. This may be due to the components contemplated in the CDC-NDC Hexagonal Model of Acevedo-Díaz and García-Carmona (2016). Various dimensions of attitudes (self-efficacy beliefs, opinions on STS issues, etc.) are studied. However, the attitude is not considered holistically, with its three components being directed towards broader attitudinal factors or objects.

In short, research in this field is a key tool in the current socio-educational context. Science and technology shape our reality; therefore, it is necessary to move towards a citizenry capable of understanding their environment and acting actively and critically within it.

4. Discussion and Conclusions

The systematised review has focused on gathering and analysing evidence to identify ways to advance the construction of the body of knowledge related to the Didactics of Experimental Sciences to promote educational improvement. This area of knowledge is booming because, amid advances in science and technology, several problems arising from citizens' lack of scientific and technological literacy are being identified. Therefore, it is necessary to study these problems.

The application of bibliometric and documentary analysis has enabled us to obtain, first, a general view of the area and, second, a specific view of the object of study. Therefore, the analysis has allowed us to organise the evidence collected during the quantitative and qualitative phases. The bibliometric analysis of the documents retrieved from the search reveals that, from 2015 onwards, there has been greater interest in advancing ideas for educational changes to equip citizens with scientific and technological literacy appropriate to their needs. We can therefore conclude that academic production is evolving. New areas of interest are appearing, such as CT, the role of ICT and the media, the influence of attitudes, etc.

Regarding the documentary analysis, the presentation of the data has allowed us to identify a research perspective in the area based on intervention, which promotes real change arising from the evaluation or diagnosis of a given situation. However, regarding knowing how to be, the focus is on the cognitive component of attitudes. Most studies assess teachers' self-efficacy. Nevertheless, self-efficacy constitutes only one dimension of teachers' attitudinal framework. Therefore, this focus is limited to the cognitive component of attitudes, neglecting other affective and conative aspects that also influence teachers' positions toward science teaching.

This issue becomes more relevant if we consider the Theory of Planned Behaviour (Ajzen & Fishbein, 1980). Attitude constitutes a determining factor in the formation of intentions and behaviours. A favourable attitude can strengthen intention even when self-efficacy is low, whereas a negative attitude can weaken it despite a high perception of competence. Therefore, addressing attitudes allows for a better understanding of the evaluative and motivational factors that guide teaching action.

Moreover, when behaviour has not yet been carried out, attitude is a more accessible and stable indicator than self-efficacy, whose validity may be limited without prior experience. In this sense, the study of attitudes towards science education offers a more comprehensive perspective for analysing the processes of teaching and learning in science and for gaining a deeper understanding of their role in didactic change.

Although studies focusing explicitly on this subject remain relatively scarce, the initial search yielded a substantial number of publications. In recent years, scientific production in this field—along with related areas—has experienced significant growth, posing methodological challenges in data management and analytical depth. For this reason, the review was conducted using four major international databases and within a delimited time span to ensure a manageable, methodologically rigorous analysis, particularly given the combined use of bibliometric mapping and documentary synthesis. While this temporal delimitation may have limited the inclusion of very recent publications, the results nonetheless capture the main trends and structural developments of a rapidly expanding field.

It should also be noted that the country of origin was not considered as an inclusion or exclusion criterion in the document selection process. The predominance of studies from certain countries is therefore likely attributable to differences in research traditions, publication practices, language use, or the degree of journal indexing in the databases consulted. Consequently, this geographical distribution should not be interpreted as a methodological bias, but rather as a reflection of the current visibility of research in international academic databases.

We believe that these limitations are partially mitigated by the research design adopted. The use of a mixed analytical approach has enabled a detailed examination of both the structure and content of scientific knowledge in this area, as well as an understanding of how these elements are interconnected. This approach has facilitated the identification of dominant perspectives, methodological and conceptual obstacles, and emerging avenues for future research. Expanding the range of databases and extending the temporal scope, therefore, represent valuable directions for future studies, which could further enrich and refine the insights presented here.

Despite these limitations, the study presents significant implications related to didactic change in the field of the Didactics of Experimental Sciences. On the one hand, it highlights the need for and direction of such change to advance towards the education of a scientifically and technologically literate citizenry capable of adapting to and transforming lifestyles derived from technoscientific advances.

This scientific literacy must be accompanied by a critical literacy that enables not only the understanding of science and technology but also the capacity to act, question, and transform reality. Within this framework, and considering the problems identified, Critical Thinking (CT) emerges as a key tool for the education of individuals capable of facing the complexity of the modern world, making informed decisions, and participating responsibly in the construction of more just and sustainable societies (Almerich et al., 2020; Tenreiro-Vieira & Vieira, 2000).

On the other hand, the study reveals that, to achieve this didactic change, it is essential to consider the dimension of knowing how to be. The emotional brain exerts a decisive influence on learning and behaviour and is also an essential factor in personal and professional well-being and autonomy. Consequently, teacher education must conceive of teachers holistically, promoting a classroom culture that addresses all dimensions of the person. This formative experience will be reflected not only in teachers' professional development but also in their future educational practice.

In line with these implications and as a forward-looking projection directly derived from the results, a study has been proposed to address some of the identified educational problems and improve science teaching processes, to bridge the traditional gap between educational research and the real issues encountered in classrooms. Specifically, this future line of research (García-Marigómez, 2025) focuses on developing a theoretical model to guide the planning of science teaching from a perspective aligned with the challenges of twenty-first-century science and technology, while attending to the areas necessary for its comprehensive implementation. This model is based on a holistic conception of the teacher, explicitly incorporating a component centred on teachers' attitudes, to structure a gradual didactic change model (Mellado, 2003).

Therefore, the scientific discipline must advance towards an understanding of teaching thinking from a comprehensive and integrated perspective.

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Abbreviations

The following abbreviations are used in this manuscript:

STS	Science–Technology–Society
CT	Critical Thinking
NOS	Nature of Science
GCE	Global Citizenship Education
ESD	Education for Sustainable Development
WOS	Web of Science

References

Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education*, *22*, 2087–2107. [CrossRef]

Acevedo, J. A., García-Carmona, A., & Aragón-Méndez, M. M. (2016). Un caso de historia de la Ciencia para aprender naturaleza de la ciencia: Semmelweis y la fiebre puerperal. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *13*(2), 408–422. [CrossRef]

Acevedo-Díaz, J. A., & García-Carmona, A. (2016). "Algo antiguo, algo nuevo, algo prestado". Tendencias sobre la naturaleza de la ciencia en la educación científica. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *13*(1), 3–19. [CrossRef]

Aguirregabiria, F., & Garcia-Olalla, A. (2022). Primary school teacher in training and the natural sciences: Previous experience, self-perception and training needs. *Góndola*, *17*(2), 268–285. [CrossRef]

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Prentice Hall.

Almerich, G., Suárez-Rodríguez, J., Díaz-García, I., & Orellana, N. (2020). Estructura de las competencias del siglo XXI en alumnado del ámbito educativo. *Factores Personales Influyentes. Educación XX1*, *23*(1), 45–74. [CrossRef]

Aragón-Núñez, L., Jiménez Tenorio, N., Vicente Martorell, J. J., & Eugenio, M. (2021). ¿Progresan las concepciones sobre la ciencia de futuros maestros/as tras la implementación de propuestas constructivistas para la alfabetización científica? *Góndola, Enseñanza y Aprendizaje de las Ciencias*, *16*(1), 78–95. [CrossRef]

Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education*, *50*(2), 145–179. [CrossRef]

Barnes, C., Angle, J., & Montgomery, D. (2015). Teachers describe epistemologies of science instruction through Q methodology. *School Science and Mathematics*, *115*(3), 141–150. [CrossRef]

Bindé, J. (2005). *Hacia las sociedades del conocimiento: Informe mundial de la UNESCO*. UNESCO. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000141908 (accessed on 1 January 2021).

Cadena-Nogales, P., Solaz-Portoles, J., Echegoyen-Sanz, Y., & Sanjose-Lopez, V. (2022). Level of acceptance of epistemically unwarranted beliefs in pre-service primary school teachers: Influence of cognitive style, academic level and gender. *Journal of Baltic Science Education*, *21*(3), 398–407. [CrossRef]

Callejas-Restrepo, M. M., & Vázquez Alonso, Á. (2009). Actitudes respecto a los temas CTS de profesores colombianos en formación y en ejercicio. *Enseñanza de las Ciencias: Revista de Investigación y Experiencias Didácticas*, 2428–2433. Available online: https://raco.cat/index.php/Ensenanza/article/view/294322 (accessed on 5 January 2026).

Castellví, J., & González-Monfort, N. (2020). Educação para uma cidadania crítica na Espanha: Mudanças e continuidades. *Revista Espaço do Curriculo*, *13*(2), 166–175. [CrossRef]

Clerici, R. (2008). Knowledge and attitudes of future schoolteachers in the scientific-mathematical sphere: Some evidences for Italy. *Educational Studies*, *34*(4), 277–287. [CrossRef]

Codina, L. (2018). *Revisiones bibliográficas sistematizadas: Procedimientos generales y Framework para ciencias humanas y sociales*. Universitat Pompeu Fabra.

Day, C. (1999). Teachers as inquirer. In *Developing teachers, the challenges of lifelong learning* (pp. 22–47). Falmer Press.

Delgado Iglesias, J. (2015). Evaluación inicial del aprendizaje de contenidos científicos en los maestros en formación. In *VII encuentro internacional de aprendizaje significativo; V encuentro iberoamericano sobre investigación en enseñanza de las ciencias* [Recurso electrónico] (pp. 1023–1030). M. C. Caballero Sahelices, J. Á. Meneses Villagrá, & M. A. Moreira (coords.). Universidad de Burgos, Servicio de Publicaciones e Imagen Institucional. Available online: https://dialnet.unirioja.es/servlet/extart?codigo=6873299 (accessed on 10 February 2021).

De Pro, A., de Pro, C., & Cantó, J. (2022). Cinco problemas en la formación de maestros y maestras para enseñar ciencias en Educación Primaria. *Revista Interuniversitaria de Formación del Profesorado*, *97*(36.1), 185–202. [CrossRef]

De Pro, A., & Rodríguez, J. (2011). La investigación en la didáctica de las ciencias experimentales. *Educatio Siglo XXI*, *29*(1), 129–148.

Erduran, S., & Dagher, R. F. (2014). *Reconceptualizing the nature of science for science education*. Springer.

Esteban, R., Marcos-Merino, J., De Jesus, J., & Pixel. (2019, March 21–22). *Training pre-service teachers to connect biology teaching to daily life: Role of positive emotions*. 8th New Perspectives in Science Education, Florence, Italy.

Fernández-Carro, R., Vilchez, J., Vilchez-Gonzalez, J., & Ezquerra, A. (2023). Multivariate analysis of beliefs in pseudoscience and superstitions among pre-service teachers in Spain. *Science & Education*, *32*, 909–925. [CrossRef]

Fuertes-Prieto, M., Andrés-Sánchez, S., Corrochano-Fernández, D., Urones-Jambrina, C., Delgado-Martin, M., Herrero-Teijon, P., & Ruiz, C. (2020). Pre-service teachers' false beliefs in superstitions and pseudosciences in relation to science and technology. *Science & Education*, *29*(5), 1235–1254. [CrossRef]

Fueyo, A., Hevia, I., & García, S. (2015). *Haciendo educación para el desarrollo: Guía didáctica*. Universidad de Oviedo.

García-Marigómez, C. (2025). *Nuevos desafíos de la educación científica en la era digital: El papel de las actitudes de los docentes de Educación Primaria en el cambio didáctico hacia una alfabetización mediática en ciencias con una perspectiva crítica* [Ph.D. thesis, Universidad de Valladolid].

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education*, *2*, 1–41. [CrossRef]

Grant, M. J., & Booth, A. (2008). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, *26*(2), 91–108. [CrossRef] [PubMed]

Hart, C. (2008). *Doing a literature review: Releasing the social science research imagination*. Sage.

Hernández-Sampieri, R., & Mendoza, C. P. (2018). *Metodología de la investigación. Las rutas cuantitativa, cualitativa y mixta*. McGraw Hill Education.

Hodson, D. (1988). Toward a philosophically more valid science curriculum. *Science Education*, *72*, 19–40. [CrossRef]

Hogg, M. A., & Vaughan, G. M. (1995). *Psicología social*. Editorial Médica Panamericana.

Hoyos, C. (2010). *Un modelo para investigación documental*. Señal Editoria.

Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science. *Science & Education*, *20*(7–8), 591–607. [CrossRef]

Irzik, G., & Nola, R. (2014). New directions for nature of science research. In M. Matthews (Ed.), *International handbook of research in history, philosophy and science teaching* (pp. 999–1021). Springer.

Kartal, E., Dogan, N., Irez, S., Cakmakci, G., & Yalaki, Y. (2019). Teachers' beliefs about learning and teaching nature of science: Professional development program. *EGitim Ve Bilim-Education and Science*, *44*(198), 291–307. [CrossRef]

Kaya, O., Yager, R., & Dogan, A. (2009). Changes in attitudes towards science-technology-society of pre-service science teachers. *Research in Science Education*, *39*(2), 257–279. [CrossRef]

Kim, M., & Tan, A. (2011). Rethinking difficulties of teaching inquiry-based practical work: Stories from elementary pre-service teachers. *International Journal of Science Education*, *33*(4), 465–486. [CrossRef]

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Towards valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497–521. [CrossRef]

Malandrakis, G. (2018). Influencing Greek pre-service teachers' efficacy beliefs and self-confidence to implement the new "Studies for the Environment' curricula. *Enviromental Educational Education Research*, *24*(4), 537–563. [CrossRef]

Manassero, M. A., & Vázquez, A. (2019). Conceptualización y taxonomía para estructurar los conocimientos acerca de la ciencia [Conceptualization and taxonomy to structure the knowledge about science]. *Revista Eureka Sobre Enseñanza Y Divulgación De Las Ciencias*, *16*(3), 3104–3117. [CrossRef]

Mansour, N. (2013). Consistencies and inconsistencies between science teachers' beliefs and practices. *International Journal of Science Education*, *35*(7), 1230–1275. [CrossRef]

Martín-Baro, I. (1983). *Acción e ideología. Psicología social desde Centroamérica* [Action and ideology. Social psychology from Central America]. UCA Editores.

Martínez-Borreguero, G., Naranjo-Correa, F., & Mateos-Nunez, M. (2022). Cognitive and emotional development of stem skills in primary school teacher training through practical work. *Education Sciences*, *12*(7), 470. [CrossRef]

Mateos Núñez, M., & Martínez Borreguero, M. G. (Dir. tes.). (2021). *Diseño y validación de metodologías didácticas aplicadas en el aula de educación primaria para mejorar el dominio cognitivo y emocional en la enseñanza/aprendizaje de competencias stem*. Available online: https://dialnet.unirioja.es/servlet/exttes?codigo=302259 (accessed on 12 March 2021).

Matthews, M. (2012). Changing the focus: From nature of science (NOS) to features of science (FOS). In M. S. Khine (Ed.), *Advances in nature of science research* (pp. 3–26). Springer.

McComas, W. F. (2002). *The nature of science in science education, rationales and strategies*. Kluwer Academic Publishers.

Mellado, V. (2003). Cambio didáctico del profesorado de ciencias experimentales y filosofía de la ciencia. *Enseñanza de las Ciencias*, *21*(3), 343–358.

Montero, I., & León, O. (2007). A guide for naming research studies in Psychology. *Internacional Journal of Clinical and Health Psychology*, *7*(3), 857–862.

Morales, P. (2000). *Medición de actitudes en psicología y educación*. Universidad Pontificia de Comillas.

Muñoz-García, G. A. (2014). Comprensión sobre la naturaleza de la ciencia en la enseñanza de las ciencias desde el enfoque ciencia, tecnología y sociedad (CTS). *Revista Trilogía*, *6*(11), 61–76. [CrossRef]

Murphy, C., & Smith, G. (2012). The impact of a curriculum course on pre-service primary teachers' science content knowledge and attitudes towards teaching science. *Irish Educational Studies*, *31*(1), 77–95. [CrossRef]

Núñez-López, S., Ávila-Palet, J.-E., & Olivares-Olivares, S.-L. (2017). El desarrollo del pensamiento crítico en estudiantes universitarios por medio del Aprendizaje Basado en Problemas. *Revista Iberoamericana de Educación Superior*, *8*(23), 85–103. [CrossRef]

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What 'ideas-aboutscience' should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, *40*(7), 692–720. [CrossRef]

Ozturk-Akar, E., & Dogan, D. (2013). Turkish pre-service teachers' views of science-technology-society: Influence of a history of science course. *Journal of Baltic Science Education*, *12*(6), 793–802. [CrossRef]

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDoland, S., . . . Thomas, J. (2021). Declaración PRISMA 2020: Una guía actualizada para la publicación de revisiones sistemáticas. *Revista Española de Cardiología*, *74*(9), 790–799. [CrossRef]

Pastor-García, I., López-Toro, A., & Moral-Toranzo, F. (2019). Assessment approach of development education and global citizenship education. *Revista Iberoamericana de Estudios de Desarrollo*, *8*(1), 244–269. [CrossRef]

Pérez, Á. I. (2010). Nuevas exigencias y escenarios para la profesión docente en la era de la información y de la incertidumbre. *Revista Interuniversitaria de Formación del Profesorado*, *24*(2), 17–36.

Pérez-Foguet, A., & Lazzarini, B. (2019). Continuing professional education in engineering faculties: Transversal integration of sustainable human development in basic engineering sciences courses. *Journal of Cleaner Production*, *218*, 772–781. [CrossRef]

Rivas, S. F., & Saiz, C. (2020). Programa de desarrollo de pensamiento crítico en la Universidad de Salamanca. In *Pensamento Crítico em Universidades Iberoamericanas* (pp. 31–78). S. F. Rivas, C. Saiz, & R. M. Vieira (Orgs.). Brazil Publishing.

Rivera-Maulucci, M. S. (2013). Emotions and positional identity in becoming a social justice science teacher: Nicole's story. *Journal of Research in Science Teaching*, *50*, 453–478. [CrossRef]

Sanmartí, N. (2001). Enseñar a enseñar ciencias en secundaria: Un reto muy completo. *Revista Interuniversitaria de Formación del Profesorado*, *40*, 31–48.

Sarabia, B. (1992). El aprendizaje y la enseñanza de las actitudes. In C. Coll, J. I. Pozo, B. Sarabia, & E. Valls (Eds.), *Los contenidos de la reforma. Enseñanza y aprendizaje de conceptos, procedimientos y actitudes* (pp. 133–198). Aula XXI y Satillana.

Sheridan, V., Landy, D., & Stout, V. (2017). The return of the "Black Babies": How development education affects schoolchildren's attitudes to the majority world—The Trócaire 2012 Lenten campaign. *Race Ethnicity and Education*, *22*, 858–874. [CrossRef]

Solbes, J. (2019). Cuestiones socio-científicas y pensamiento crítico: Una propuesta para cuestionar las pseudociencias. *Tecné, Episteme y Didaxis: TED*, *46*, 81–99. [CrossRef]

Solbes, J., & Vilches, A. (1997). STS interactions and the teaching of physics and chemistry. *Science Education*, *81*(4), 377–386. [CrossRef]

Spinak, E. (1998). Indicadores cienciométricos. *Ciência da informação*, *27*(2), 144–148. [CrossRef]

Tenreiro-Vieira, C., & Vieira, R. M. (2000). *Promover o pensamento crítico dos alunos. Propostas concretas para a Sala de Aula*. Porto Editora.

Tenreiro-Vieira, C., & Vieira, R. M. (2021). Promover o pensamento crítico e criativo no ensino das ciências: Propostas didáticas e seus contributos em alunos portugueses. *IENCI*, *26*(1), 70–84. [CrossRef]

Thompson, K. (2016). Developing education v. education for development. *ANNALS, AAPSS*, *424*, 16–28. [CrossRef]

Torres, N. Y., & Solbes, J. (2016). Contribuciones de una intervención didáctica usando cuestiones sociocientíficas para desarrollar el pensamiento crítico. *Enseñanza de las Ciencias*, *34*(2), 43–65. [CrossRef]

Tosun, C., & Ozturk, S. (2020). Science teachers and pre-service science teachers' science teaching competence belief scores in the resource room in terms of certain variables. *Teachers and Teaching*, *26*(5–6), 365–394. [CrossRef]

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. [CrossRef] [PubMed]

Vazquez-Alonso, A., Garcia-Carmona, A., Manassero-Mas, M. A., & Bennassar-Roig, A. (2013). Science teachers' thinking about the nature of science: A new methodological approach to its assessment. *Research in Science Education*, *43*(2), 781–808. [CrossRef]

Vázquez-Alonso, A., & Manassero-Mas, M. A. (2007). En defensa de las actitudes y emociones en la educación científica (I): Evidencias y argumentos generales. *Revista Eureka*, *4*(2), 247–271. [CrossRef]

Vázquez-Alonso, A., & Manassero-Mas, M. A. (2017). Una conceptualización de la Naturaleza de la Ciencia y la Tecnología para reducir la brecha entre investigación y enseñanza de las ciencias. *Enseñanza de las Ciencias*, 3851–3858. Available online: https://raco.cat/index.php/Ensenanza/article/view/337518 (accessed on 5 January 2026).

Vázquez-Alonso, A., & Manassero-Mas, M. A. (2018). Más allá de la comprensión científica: Educación científica para desarrollar el pensamiento. *Revista Electrónica de Enseñanza de las Ciencias*, *17*(2), 309–336.

Vieira, R., Tenreiro-Vieira, C., & Martins, I. (2010). Pensamiento crítico y literacia científica. *Alambique: Didáctica de las Ciencias Experimentales*, *65*, 96–103.

Walag, A., Fajardo, M., Bacarrisas, P., & Guimary, F. (2022). A canonical correlation analysis of filipino science teachers' scientific literacy and science teaching efficacy. *International Journal of Instruction*, *15*(3), 249–266. [CrossRef]

Ward, G., Dixon, H., & Withy, H. (2020). Primary science teachers' self-efficacy and outcome expectancy: A case study. *Australian Journal of Teacher Education*, *45*(9), 79–91. [CrossRef]

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Yalvac, B., Tekkaya, C., Cakiroglu, J., & Kahyaoglu, E. (2007). Turkish pre-service science teachers' ciews on science-technology-society issues. *International Journal of Science Education*, *29*(3), 331–348. [CrossRef]

Yemini, M., Tibbitts, F., & Goren, H. (2019). Trends and caveats: Review of literature on global citizenship education in teacher training. *Teaching and Teacher Education*, *77*(1), 77–89. [CrossRef]

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