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Domain-specific epistemological beliefs' expression in initial teacher education: A systematic review

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Abstract

This systematic review examines how preservice teachers' (PSTs) domain-specific epistemological beliefs (EB) are studied and understood within initial teacher education (ITE) with attention to theoretical, contextual, and methodological aspects. Findings from 24 empirical studies published up to 2024 were synthesized. The review analyzed theoretical frameworks, research designs, and tools commonly used to explore PSTs' EB across specific domains. Cross-study evaluations are challenging due to the ambiguity created by the lack of justification for framework selection, although the variety of theoretical lenses enhances the field. Similarly, methodological preferences such as the dominance of quantitative and cross-sectional studies using closed questionnaires offer generalizable insights but limit the depth of understanding regarding EB development. Nevertheless, specific contexts of ITE were identified as catalysts for developing EB, and some EB were seen as key predictors of student-centered teaching practices. The field shows theoretical and methodological fragmentation but offers insights into how ITE might influence EB. Bridging current gaps is crucial for a deeper understanding of PSTs' conceptions of knowledge and learning. Recommendations include adopting longitudinal designs, clarifying theoretical foundations, and involving broader ITE stakeholders such as mentors and policymakers whose beliefs also shape teacher education.

Keywords: Domain-specific, Epistemological beliefs, Initial teacher education, Preservice teachers, Professional learning, Review.

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Contribution of this paper to the literature
This review synthesizes domain-specific epistemological beliefs of preservice teachers, highlighting overlooked theoretical justifications and underexplored contexts. It is the first review to critically analyze methodological patterns and propose new directions by integrating the perspectives of broader stakeholders, offering a more comprehensive understanding of epistemological beliefs in teacher education.

1. Introduction

Epistemological beliefs (EB) are people's presumptions and perceptions on the nature of knowledge and the process of acquiring it (Hofer & Bendixen, 2012). These beliefs relate to the definition of knowledge and how knowledge is constructed, evaluated, and developed (Hofer, 2001). EB plays a relevant role in educational sciences, specifically in shaping teachers' and students' interpretation and justification of knowledge and the overall learning process (Gholami & Husu, 2010).

The theories that conceptualize EB are rooted in constructs brought forth by seminal authors in the field of education. Perry's (1970) developmental perspective on EB served as the foundation for subsequent research and framework development in the field, specifically, developmental models of epistemology. These models describe how individuals' understanding of knowledge evolves. Kuhn, Cheney, and Weinstock (2000) propose four stages: realist, absolutist, multiplist, and evaluativist highlighting the shift from objective to subjective knowledge coordination. Similarly, King and Kitchener (1994) outline three stages of reflective thinking, focusing on how individuals handle ill-structured problems.

A system of beliefs approach encompasses Schommer-Aikins's epistemological belief system within a multidimensional view (Schommer-Aikins, 2004). It presents epistemology as a collection of independent beliefs about knowledge and learning. These beliefs develop asynchronously and do not necessarily form a coherent system though mature beliefs support higher-order thinking. Buehl and Alexander (2001) argue that EB evolve from general to domain-specific knowledge and are influenced by academic experience and expertise based on the beliefs about the academic knowledge model.

Accordingly, personal epistemology models focus on how individuals construct knowledge and justify their beliefs. Hofer and Pintrich (1997) highlight the developmental nature of personal epistemology emphasizing its dependence on context and discipline. Meanwhile, the epistemological resources model (Hammer & Elby, 2002) sees knowledge as a set of flexible cognitive resources activated depending on the learning environment.

Overall, these models collectively illustrate the complexity of epistemological development showing how beliefs evolve in response to different experiences and contexts.

EB dimensions are commonly classified within a spectrum ranging from absolute to evolving, simple to advanced or naïve to sophisticated understandings. Less developed positions tend to perceive truth as fixed and unquestionable whereas more refined perspectives recognize knowledge as dynamic and context-dependent. (Schommer-Aikins, 2004). Such classifications provide a framework for understanding EB, its progression, and how individuals construct and refine their views on knowledge.

Another characteristic of EB is domain-specific (Buehl & Alexander, 2005; Muis, Bendixen, & Haerle, 2006). There has been a growing interest in this matter in the last decades (Sinatra & Kardash, 2004) showing that domain-specific norms and practices shape beliefs about the nature of knowledge and learning processes within subject areas (Hofer, 2001; Limon, 2006).

Nevertheless, research in this field is disputed and ambiguous due to various theoretical frameworks and methodologies (Limon, 2006). The existing works on the conceptual characteristics of EB focus more on critical opinions about inconsistencies in the research than on the already developed research systematization (Bråten, 2010; Limon, 2006). In the rare cases where analyses of the existing literature were conducted, these are centered on a single domain (Schiefer, Edelsbrunner, Bernholt, Kampa, & Nehring, 2022) despite providing relevant information, they do not present a sufficiently broad overview of the topic nor a sufficiently deep view on characteristics such as the theoretical frameworks or the methodological designs.

An essential perspective in which the literature still requires further impulse and development is that of preservice teachers (PSTs) (Brownlee, Purdie, & Boulton-Lewis, 2001). Initial teacher education (ITE) is a formative stage where PSTs interpret and engage with information. However, EB often inhibited ITE's value leading to teacher education programs that do not significantly impact PSTs' views on knowledge and knowing (Pajares, 1992).

As PSTs learn about pedagogy and curriculum, they are more likely to reflect on their beliefs and be more open to changing them (Selley, 2013). Hence, PSTs represent an optimal population for EB research as the ITE context enables researchers to observe the reconfigurations and their relationship with the development of their teaching understandings (Muis et al., 2006). Despite the relevant connection between EB and ITE, it is challenging to situate the multifaceted impact associated with them while also considering how these beliefs are uniquely tethered to the specific domains within the preparatory journey of PSTs.

1.1. Significance

This review delves into the granularity of a) theoretical frameworks – there are several, and they respond to different things, calling for a systematization of what has prevailed in theoretical mapping and its possible relationship with other factors. b) Domain specificity: the domains act as a context through which PSTs come to understand what counts as legitimate knowledge and the pathways to its acquisition. c) Methodological designs to understand how EB is being analyzed and what might be missing for a better understanding of the phenomenon. and d) EBs' relationship with ITE - what differences there are throughout the teacher education process and what influence curricula can have on this development. Such an analysis will offer insights and implications of the literature, contributing to a comprehensive understanding of the relevance of EB for both PSTs and ITE.

1.2. Research Questions

This systematic review aims to scrutinize what is known about PSTs EB in ITE and organize scientific data that is accessible within this context. The research questions that guided the review of these studies were as follows: (Q1) What is the theoretical framework used? (Q2) What domain (subject) is explored in the research? (Q3) Which methodological designs were used to access EB? (Q4) What EB do PSTs have during ITE? (Q5) What is the interplay between EB and ITE?

2. Methodology

The protocol used in this systematic review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. This study was approved by the Research Ethics Committee of the first author's institution and followed the guidelines stated in the Declaration of Helsinki.

2.1. Eligibility Criteria

Following the Preferred Reporting Items for Systematic Reviews (Page et al., 2021) guidelines, eligibility criteria followed the PICOS approach: Participants-PSTs of any subject; interventions-related to PSTs EB; comparisons-EB at any given moment or throughout an initial teacher training program; outcomes- in reference to the EB theoretical framework, PSTs domain of study, EB development and methodological preferences; study design with a qualitative approach (including exploratory, emergent design, hybrid case study, self-study, case study, action research and visual methods), quantitative research and mixed-method research. Studies had to be empirical articles collecting primary data as we are interested in (a) epistemological beliefs, (b) PSTs, (c) published in peer-reviewed international journals, (d) available in full-text, and (e) written in English, Portuguese, or Spanish. systematic reviews, conceptual articles and studies with experienced teachers were not included. No restrictions were applied to publication year, participants' age or gender.

2.2. Information Sources

Searches were performed on February 5th, 2025 in the following online databases: EBSCO, ERIC, Web of Science and SCOPUS. In addition to all the database papers published until the search date, external researchers (experts) were consulted to suggest articles that could integrate the systematic review.

2.3. Search Strategy

Boolean operators (AND /OR) were used and the title, abstract, or keywords were required to include ("epistemological beliefs", "personal epistemology", "epistemic beliefs" and "epistemic cognition") and ("preservice teacher", "student teacher", "teacher education", "apprentice teacher" and "practice teacher"). Additionally, each study's title, abstract, and reference list were manually searched to identify eligible studies not captured by the electronic searches.

An additional search was conducted by reviewing the reference lists of the included studies. Two researchers independently conducted the selection process to reduce the risk of potential bias. Both researchers possess knowledge of this research methodology and EB. Any disagreements were resolved through mutual agreement.

2.4. Study Selection

The initial search of the databases was exported to reference manager software (EndNoteX9). Automated removal of duplicates was performed using EndNoteX9 but further manual removal of duplicates was required. Two researchers individually and independently evaluated the titles and abstracts of retrieved articles to assess their eligibility to be included in this article. The study abstracts that did not provide enough information according to the stabilized eligibility criteria were retrieved for full-text evaluation. In the second phase, articles were excluded if, based on the full text. a) There was no information on domain specificity. b) EB was not reported by domain. c) EB was not reported. d) Not focused on PSTs and d) domain-specific EB were reported but in a different subject to the one for which the PSTs were being prepared. In case of disagreement between the two authors, the differences were discussed until consensus was achieved.

The initial research returned 1175 results (EBSCO: 426; ERIC:342; Web of Science: 163; SCOPUS: 244). After removing duplicates and according to inclusion criteria, 100 articles were listed as eligible for full-text screening. 78 articles were excluded for one or more reasons. Full-text screening of eligible articles revealed 22 papers identified for inclusion in the qualitative synthesis. Additionally, two more papers suggested by field experts were found to fulfil the eligibility criteria. A total of 24 papers were included in this systematic review. The PRISMA flow chart of the study protocol is presented in Figure 1. It illustrates the various stages of the search process and the procedures employed for the study selection.

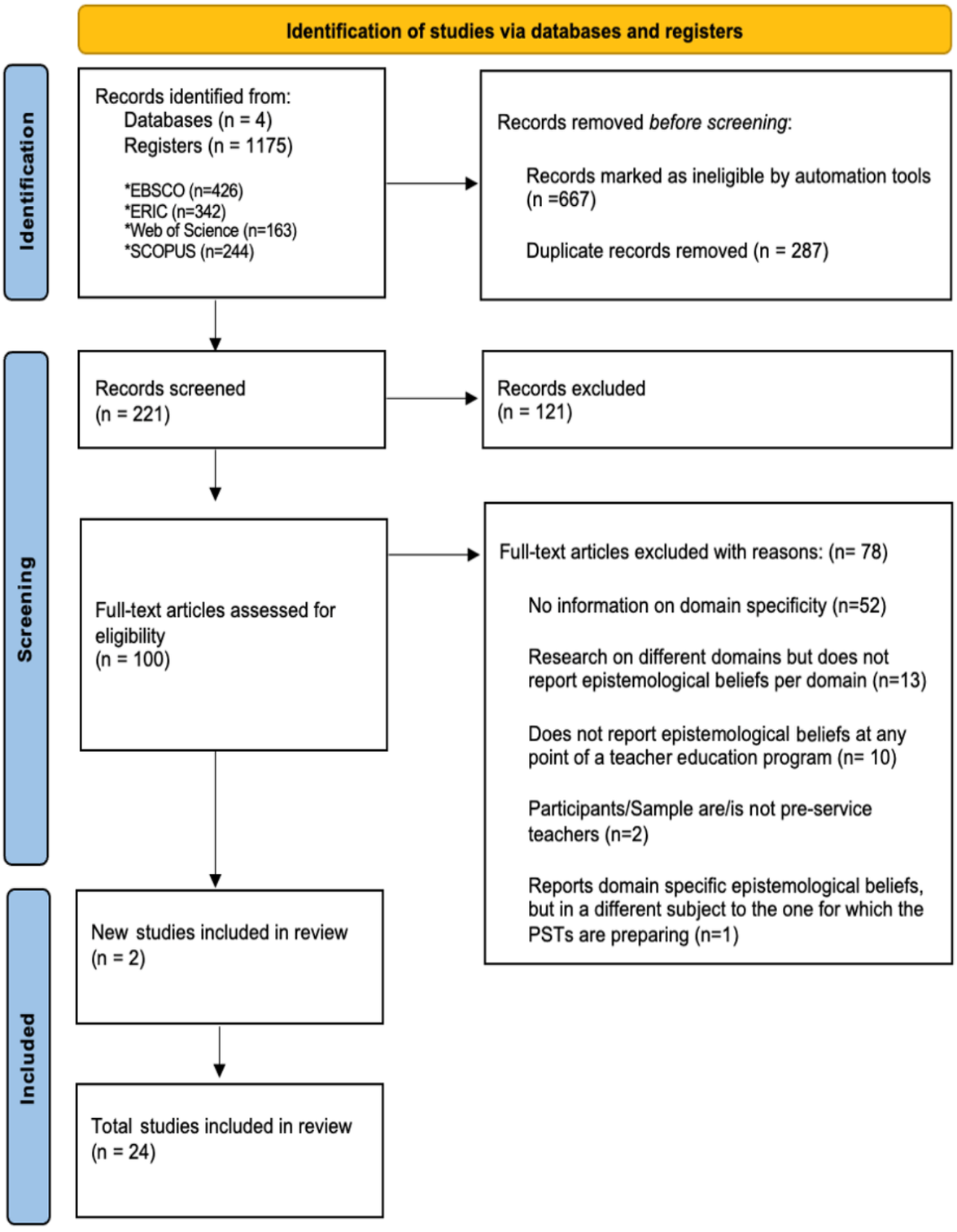

Figure 1. Study flowchart.

2.5. Quality Check and Rigor

The protocol for this systematic review was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on September 30th, 2022 Inplasy Protocol 3919. Moreover, the recommendations of the PRISMA statement were followed to improve the clarity, transparency, and quality of the systematic review.

The methodological quality of the studies was assessed using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018) which allows the evaluation of qualitative, quantitative, and mixed-methods studies. All studies included were assessed through MMAT version 2018. The category chosen to assess each paper was defined by its methodology. 21 papers appeared to meet the criteria of the assessment tool, and three papers only met some of the criteria but MAAT discouraged their exclusion (see Table 1).

Table 1. MAAT results: A critical assessment of methodological quality.

Studies that meet all MAAT criteria			
Qualitative studies	**Quantitative non-randomized studies**	**Quantitative descriptive studies**	**Mixed- methods studies**
Guilfoyle, McCormack, and Erduran (2020) Guilfoyle, McCormack, and Erduran (2024) Kang (2008) Löfström and Pursiainen (2015)	Deniz (2011)	Atici (2023) Bayraktar (2019) Bejerano et al. (2023) Güven, Sülün, and Çam (2014) Kirmizi and Irgatoglu (2021) Saricoban and Kirmizi (2021) Sojat (2020) Yenice (2015)	Dinç and Üztemur (2017) Ozturk and Yilmaz-Tuzun (2017) Topcu (2013)
Studies that meet most MAAT criteria			
Qualitative studies	*Quantitative randomized controlled trials*	*Quantitative descriptive studies*	
Markic and Eilks (2012)	Gill, Ashton, and Algina (2004)	Choi and Kwon (2012) Kızkapan, Nacaroğlu, and Kırmızıgül (2024) Zorlu (2017)	
Studies that meet some MAAT criteria			
Mixed- methods studies			
Cady and Rearden (2007) Huang-Yao and Shu-Ping (2010) Markic and Eilks (2012)			

3. Findings

3.1. Overview of Studies' Features

Tables 2, 3, and Appendix A provide an alphabetical overview of the study characteristics included in the qualitative synthesis. Table 2 identifies each study's theoretical and demographic characteristics. Table 3 provides an overview of the key topics in each study. Additionally, Appendix A presents each study's aim, methodological design, and outcomes alphabetically to provide an organized overview.

Although there is no minimum time interval in this research, the oldest article is from 2004, and 15 papers are from the last ten years (2014-2024). These studies are geographically dispersed covering three continents with a greater incidence in Turkey (n=11).

Most articles (n=11) are grounded in Schommer's (1990) theoretical framework. There are also several references to Hofer and Pintrich (1997) and Perry (1970). Some articles include frameworks by Chinn and Malhotra (2011) and Markic and Eilks (2008) but the diversity seems limited overall. Additionally, one article has no defined theoretical framework.

Table 2. Theoretical, geographical and demographical characteristics. Country relates to where the ITE takes place. The theoretical framework relates to the theoretical lenses used to characterize EB. Domain is the subject/discipline of the ITE (e.g., science means an ITE preparing natural science teachers). Standings mean the ITE year PSTs were attending.

Author	**Country**	**Framework**	**Domain**	**Standings**
Atici (2023)	Turkey	Schommer (1990)	Physical education	3rd and 4th
Bayraktar (2019)	Turkey	Schommer (1990)	Science	3rd
Bejerano et al. (2023)	ND - Asia	Celik, Muukkonen, and Dogan (2021)	Science	Not defined
Cady and Rearden (2007)	USA	Perry (1970)	Mathematics; Science	Final year
Choi and Kwon (2012)	Korea	Schommer (1990)	Mathematics	All
Deniz (2011)	USA	Hofer and Pintrich (1997)	Science	All
Dinç and Üztemur (2017)	Turkey	Schommer (1990)	Social studies	All
Gill et al. (2004)	USA	Not Defined	Mathematics	1st
Guilfoyle et al. (2020)	Ireland	Chinn and Malhotra (2011)	Science	Final year
Guilfoyle et al. (2024)	Ireland	Chinn and Malhotra (2011)	Science	Final year
Güven et al. (2014)	Turkey	Schommer (1990)	Science	2nd
Huang-Yao and Shu-Ping (2010)	Taiwan	Schommer (1990)	Science	Not defined
Kang (2008)	USA	Perry (1970)	Science	Not defined
Kirmizi and Irgatoglu (2021)	Turkey	Schommer (1990)	English	All
Kızkapan et al. (2024)	Turkey	Hofer and Pintrich (1997)	Science	2nd t, 3rd and 4th
Löfström and Pursiainen (2015)	Finland	Hofer and Pintrich (1997)	Mathematics	Not defined
Markic and Eilks (2012)	Germany	Markic and Eilks (2008)	Physics; Chemistry; Biology; Science	1st
Markic and Eilks (2013)	Germany	Markic and Eilks (2008)	Chemistry	1st, 3rd and 5th
Ozturk and Yilmaz-Tuzun (2017)	Turkey	Schommer (1990)	Science	All
Saricoban and Kirmizi (2021)	Turkey	Schommer (1990)	English	All
Sojat (2020)	Croatia	Markic and Eilks (2008)	Chemistry	1st year
Topcu (2013)	Turkey	Hofer and Pintrich (1997)	Physics; Chemistry; Biology	Final year
Yenice (2015)	Turkey	Schommer (1990)	Science	All
Zorlu (2017)	Turkey	Schommer (1990)	Science	2nd and 4th

In the compilation of selected articles, 4081 PSTs actively engaged as participants in the respective studies. The participants consisted of PSTs in different stages of their university degrees – grade level. It is important to note that ITE has different durations. For example, in Turkey, the ITE programs studied in these papers have a duration of 4 years. In Germany, the program lasts 5 years. This means that the category all covers different durations of ITE. The same applies to the final year category since it does not represent the same number of ITE years in all cases.

The studies analyzed reported different findings and provided an overview of each study's presentation (see Table 3). The synthesized findings from the reviewed studies are presented in the subsequent sections.

Table 3. Overview of the themes per study.

Authors	EB description	Grade level differences	Short-term courses/ Interventions	EB and teaching approach
Atici (2023)		x		
Bayraktar (2019)	x			
Bejerano et al. (2023)				x
Cady and Rearden (2007)			x	
Choi and Kwon (2012)		x		x
Deniz (2011)			x	
Dinç and Üztemur (2017)	x	x		x
Gill et al. (2004)			x	
Guilfoyle et al. (2020)	x			
Guilfoyle et al. (2024)			x	
Güven et al. (2014)			x	
Huang-Yao and Shu-Ping (2010)			x	x
Kang (2008)			x	x
Kirmizi and Irgatoglu (2021)		x		x
Kızkapan et al. (2024)	x			
Löfström and Pursiainen (2015)	x			
Markic and Eilks (2012)	x			x
Markic and Eilks (2013)	x	x		
Ozturk and Yilmaz-Tuzun (2017)				x
Saricoban and Kirmizi (2021)				x
Sojat (2020)	x			x
Topcu (2013)	x			
Yenice (2015)	x	x		
Zorlu (2017)				x

3.2. Research Design Approaches

Most studies (13 out of 24) employed quantitative methods, utilizing statistical analyses and numerical data. Various survey instruments were employed to collect data, including the epistemological belief questionnaire (Schommer, 1990)—n=5; the epistemological belief survey (Chan, 2004)—n =3; and the discipline- focused epistemological beliefs questionnaire (Hofer, 2000)—n=3. Two other studies relied on country-specific questionnaires, one of which was influenced by the work of Hofer and Pintrich (1997)

Additionally, five studies utilized a qualitative methodology. These studies have delved into the subjective experiences and individual reasoning underpinning PSTs epistemologies through in-depth interviews, reflective writing analysis, and participant observation.

The other six studies adopted a mixed-method approach. These varied methodological procedures, each with their respective affordances and limitations, play a critical role in deciphering the complexity of EB and often lay the groundwork for developing targeted educational interventions in ITE. These varied research designs provide a holistic view of the complexity of EB contributing to the development of educational interventions within ITE.

3.3. Characterizing Domain-Specific EB in ITE

The PSTs' EB varies across different subject domains, reflecting domain-specific orientations. Studies (n=10) on this research characterized the PSTs' EB in various domains, each with specificities.

In science education, research shows a range of EB among PSTs. Bayraktar (2019) found that science PSTs displayed more sophisticated beliefs in dimensions related to knowledge change, reasoning, and construction but less developed beliefs in terms of authority and the source of knowledge. Similarly, Yenice (2015) highlighted that science PSTs tended to hold sophisticated beliefs, emphasizing effort over innate ability and rejecting the notion of absolute truth. The relationship between EB and understanding of scientific disciplines was further examined by Kızkapan et al. (2024) who found that PSTs with more sophisticated EB also held more developed views on the nature of science. However, challenges in epistemological development were identified by Guilfoyle et al. (2020) who noted that PSTs often held "non-availing" EB that hindered their engagement with educational research. Moreover, perceptions of the epistemic similarities and differences between science and education studies impacted their evaluation of educational theories.

In social studies, Dinç and Üztemur (2017) found that PSTs exhibited relatively sophisticated EB across most dimensions. However, their beliefs about the structure of knowledge were only moderately sophisticated. Additionally, they perceived social studies as a subject closely connected to real life and regarded it as relatively easy to teach at the middle school level.

Mathematics PSTs demonstrated distinct domain-specific EB. According to Löfström and Pursiainen (2015) they tended to adopt a formalistic and performance-oriented approach to mathematics relying heavily on memorization and authoritative sources. Their primary focus was obtaining correct answers rather than engaging in deeper problem-solving and reasoning. In contrast, their views on pedagogy were more relativistic emphasizing subjective interpretations and intuition over theoretical foundations. This contrast between their EB in mathematics and pedagogy presented challenges in effectively integrating the two domains for teaching.

For physics, chemistry, and biology PSTs, research highlights disciplinary differences in EB. Topcu (2013) found that PSTs viewed knowledge in biology as more tentative and open to multiple interpretations. In contrast, knowledge in physics and chemistry was perceived as more certain, simple, and reliant on external authority. A

similar pattern was observed by Markic and Eilks (2012) who reported that EB among PSTs ranged from objectivist, fact-based views to more constructivist orientations. Notably, physics PSTs tended to hold the most traditional beliefs, while biology PSTs demonstrated more modern perspectives on teaching and learning.

Studies focusing specifically on chemistry PSTs revealed contrasting trends. Markic and Eilks (2013) found that constructivist EB sees learning as an active and self-directed process. However, Sojat (2020) reported a predominantly traditional, teacher-centered approach among Croatian chemistry PSTs, with over 90% adhering to this perspective and only a small fraction adopting constructivist-oriented beliefs.

These findings illustrate the complexity of PSTs EB across disciplines. While some progress toward more sophisticated understandings of knowledge and learning, others retain traditional perspectives that may impact their teaching approaches.

3.4. Exploring the Link between ITE Grade Level and EB

Yenice (2015) found no significant differences in EB across grade levels, suggesting that EB remains stable throughout teacher education.

In contrast, Markic and Eilks (2013); Dinç and Üztemur (2017) and Atici (2023) observed a developmental trend in which higher-grade PSTs demonstrated more sophisticated, complex, and dynamic EB, aligning with a shift towards constructivist perspectives. Markic and Eilks (2013) noted that PSTs move from teacher-centered to student-centered beliefs. Dinç and Üztemur (2017) found increased sophistication in the certainty of knowledge dimension. Atici (2023) indicated that fourth-year students had more developed beliefs than third-year students regarding learning by ability.

On the other hand, Choi and Kwon (2012) and Kirmizi and Irgatoglu (2021) presented the opposite perspective reporting a regressive trend where higher-grade PSTs held more objectivist, fixed, and authority-dependent beliefs. Choi and Kwon (2012) linked this shift to the test-driven Korean education system, while Kirmizi and Irgatoglu (2021) suggested that cultural factors contributed to first-year PSTs having more sophisticated beliefs than their senior counterparts. Thus, while some studies support an expected progression toward more complex EB, others highlight cultural and systemic influences that may hinder or even reverse this development.

3.5. Impact of Short-Term Courses and Interventions on EB Development

Kang (2008) and Güven et al. (2014) explored how practical experiences influence PSTs' EB. They found that field experiences provided opportunities for EB development with PSTs' teaching goals aligning with their beliefs, though contextual factors sometimes led them to revert to traditional methods. Similarly, hands-on science lab activities and reflective diaries (Güven et al., 2014) promoted EB development in all dimensions except "certain knowledge," showing a positive interaction between reflective diary scores and EB growth.

Similarly, Guilfoyle et al. (2024) also found that research experiences in ITE can contribute to the development of PSTs' EB although the extent and nature of this development might vary. Conducting research in science helps PSTs develop a more nuanced understanding of the tentative and interpretative nature of scientific knowledge, while research in education studies allows them to gain a more complex understanding of researcher subjectivity and the limitations of educational research.

Further exploring reflection interventions, Deniz (2011) and Gill et al. (2004) focused on self-reflection as a mechanism for EB development. Deniz (2011) conceptual change intervention encouraged PSTs to discuss, access, and reflect on cognitive processes, significantly improving their EB across all dimensions. Thinking dispositions such as openness to alternative views were key in post-intervention outcomes. Similarly, the intervention used augmented activation and refutational text (Gill et al., 2004) to challenge and activate PSTs' existing beliefs, identifying effortful cognitive processing as essential for EB change, particularly in mathematics.

Huang-Yao and Shu-Ping (2010) and Cady and Rearden (2007) examined how collaborative experiences shape PSTs' EB. A web-based knowledge forum fostered collaborative discourse and constructivist beliefs (Huang-Yao & Shu-Ping, 2010). PSTs decreased their beliefs about the authority of experts and the certainty of knowledge and significantly reduced their beliefs about the traditional, teacher-centered conception of teaching. Similarly, Cady and Rearden's methods course, which emphasized student-centered approaches, helped PSTs develop more sophisticated EB, even though contradictions remained in their teaching practices—math PSTs leaned toward student-centered lessons despite holding teacher-as-authority beliefs, while science PSTs viewed their subject as interactive but still used teacher-centered methods.

3.6. Understanding the Connection between EB and Teaching Approaches

EB is deeply connected with PSTs' pedagogical choices, particularly in teaching approaches and instructional options. The findings across multiple studies (n=11) suggest that PSTs' views on the nature of knowledge and knowing significantly shape how they conceptualize teaching and learning, ultimately influencing their instructional decisions.

Bejerano et al. (2023) identified that PSTs' epistemological worldviews—realist, conceptualist, and relativist are directly linked to their teaching approaches. Realist teachers favor information transmission, conceptualist teachers encourage student participation, and relativist teachers promote student autonomy. Furthermore, PSTs' beliefs about the certainty of knowledge are positively associated with their outcome expectations for students, while their beliefs about the simplicity of knowledge negatively correlate with their epistemological worldviews. Additionally, PSTs assume that student-centered teaching approaches will only be effective if their students also hold simplistic views about knowledge.

In the Croatian context, Sojat (2020) found that most chemistry PSTs maintain traditional, teacher-centered EB, reflected in their transmission-based instructional approaches. Similarly, Saricoban and Kirmizi (2021) observed that PSTs who believe in knowledge certainty, source, and learning ability tend to prefer transmission-based, teacher-centered instruction. However, these EB explain only 14% of the variance in instructional preferences, indicating the presence of other influential factors.

Ozturk and Yilmaz-Tuzun (2017) highlighted that PSTs with more sophisticated EB, acknowledging knowledge's tentative and complex nature are more likely to engage in effective reasoning and decision-making

regarding socioscientific issues. Conversely, those with less sophisticated beliefs such as viewing knowledge as certain or easily acquired, struggle with the complexity of these issues and rely on intuitive reasoning. Kang (2008) reinforced this pattern showing that PSTs who perceive knowledge as evolving aim to cultivate students' scientific thinking and inquiry skills. In contrast, those who perceive knowledge as fixed emphasize transmitting factual knowledge. Similarly, Markic and Eilks (2012) noted that constructivist views of knowledge, recognizing its tentative and socially constructed nature align with student-centered teaching, whereas knowledge as a fixed set of facts corresponds to transmission-based instruction.

Kirmizi and Irgatoglu (2021) found that learning requires effort is positively correlated with student-focused teaching approaches whereas other dimensions, such as innate ability, authority, and certainty of knowledge did not significantly impact teaching approaches. Zorlu (2017) expanded this discussion by highlighting that EB's views on the nature of science influence their instructional approaches. Those with a positivist view tend to adopt traditional methods, while those embracing a constructivist perspective employ more student-centered techniques.

Huang-Yao and Shu-Ping (2010) emphasized that EB are closely tied to pedagogical beliefs. They propose that engaging PSTs in constructivist-oriented knowledge-building practices can shape their epistemological and pedagogical beliefs, ultimately impacting their classroom performance. Similarly, Dinç and Üztemur (2017) proved that teachers with sophisticated EB who recognize knowledge as complex and contextual are more likely to adopt student-centered and inquiry-based teaching methods. In contrast, teachers with naïve beliefs rely more on rote memorization and lecture-based strategies.

Lastly, Choi and Kwon (2012) explored the relationship between EB and their instructional approaches, demonstrating that their perspectives on mathematical knowledge and learning shape their teaching practices. This influences students' beliefs and academic performance underscoring the need for teachers to guide PSTs toward developing more constructive and adaptive teaching approaches.

These findings collectively affirm that EB is a foundational framework for shaping PSTs' teaching approaches. The extent to which PSTs view knowledge as fixed or evolving, simple or complex, and certain or uncertain has profound implications for their instructional strategies, reinforcing the need for teacher education programs to foster sophisticated epistemological perspectives to support more effective teaching practices.

4. Discussion

This systematic review aimed to understand how PSTs EB is being studied and what is known about them during ITE. Accordingly, it raised divergent questions about the theoretical and methodological approaches and highlighted relevant themes for PSTs, such as enhancers of more sophisticated EB.

The temporal spectrum shows increased interest in studying PSTs' EB over the past ten years. The reformulations of ITE in various countries may justify this increase by seeking to understand EB in professional development contexts (Deniz, 2011; Sojat, 2020).

There is a wide variety of frameworks. In most cases, there is no justification for the choice of why the framework is the best for the work being done. This raises questions about the importance of tailoring the theoretical framework to the work's objectives. Since there is a variety of an EB framework, the pertinent selection of theoretical lenses is a key point that can bring even more clarity and scientific dimension to research results.

As the theoretical lenses for understanding EB differ among studies, the classification of dimensions cannot be discussed across the results. The myriads of theoretical frameworks employed across studies suggest a healthy diversity, but perhaps this fragmentation could benefit from greater convergence. According to Fives and Buehl (2008), only some empirical studies have explored teachers' EB using a clear and justified theoretical framework. This ambiguity may be responsible for the difficulty in understanding EB and its relevance to teacher training. However, present and previous studies' theoretical frameworks and methodological choices encompass the potential of more comprehensive approaches to EB in ITE and offer hope for the future of EB studies.

Methodologically, cross-sectional works, quantitative methodology and data collection through closed questionnaires with large samples were notable characteristics. The diversity of EB questionnaires, ease of application, and the ability to generate generalizable results justify this preference. The predominance of quantitative methodologies (13 out of 24 studies) using structured instruments such as the epistemological belief questionnaire (Schommer, 1990) and the epistemological belief survey (Chan, 2004) raises concerns about the depth of understanding these methods provide. While numerical insights are valuable, they may lack the nuance captured by qualitative and mixed-method approaches which offer a more holistic perspective on PSTs' belief evolution. EB are personal, profound and complex conceptions and trying to define them through a purely descriptive lens can be reductive. Just like with theoretical frameworks, research designs also need to align with the objectives of the work being developed. Without this coherence, the results may be difficult to interpret and inform ITE. Similarly, the rapid pace of change within educational contexts suggests that longitudinal perspectives on the evolution of EB may yield critical insights into teachers' professional development (Kang, 2008).

The findings revealed notable domain-specific variations in PSTs' EB, emphasizing the influence of disciplinary orientations. Studies indicated that science PSTs tend to develop sophisticated beliefs regarding knowledge construction and change while mathematics PSTs often exhibit more rigid, performance-driven views relying on memorization and authority. Similarly, social studies PSTs demonstrate relatively sophisticated perspectives but may struggle to recognize knowledge structure complexity. These differences highlight the necessity for discipline-specific approaches when addressing EB in ITE. Recognizing these variations is essential for designing teacher education programs that support the development of more refined EB, ultimately influencing instructional practices and student learning outcomes.

Essential conclusions were reached regarding the behavior of EB at different grade levels. PSTs at higher grade levels would present more sophisticated EB but there were two contexts where this did not happen. The justifications are related to the solid Confucian influence in the Korean ITE (Choi & Kwon, 2012) and the adaptation to a new reform in the Turkish ITE. Conversely, other studies suggest a positive developmental trajectory, indicating that PSTs in the later years of their programs tend to embrace more constructivist views, moving away from teacher-centered epistemologies. This duality suggests that external cultural and systemic

factors may play a significant role in shaping EB, necessitating a closer examination of how institutional contexts influence epistemological growth.

Beliefs are permeable and dynamic structures that act upon new knowledge and question their meaning (Zheng, 2009). Interventions such as field experiences (Kang, 2008), research participation (Guilfoyle et al., 2024) and reflection-based strategies (Deniz, 2011) have shown promising results in fostering more sophisticated EB. Studies highlight that guided reflection and engagement in inquiry-based learning can effectively challenge naïve beliefs and promote epistemic growth. This underscores the active role that ITE curriculums should play in helping PSTs discover new teaching methods and the importance of developing the ability to work and reflect within their professional settings.

These results agree with general research on EB indicating that introducing entrepreneurial activities for PSTs can help them reflect on their beliefs and practices, observe different teaching approaches, share experiences, and embrace an evolutionary approach leading to the collaborative development of beliefs and practices (Ertmer & Ottenbreit-Leftwich, 2010; Goksu & Demir, 2021). EB is sensitive to and influenced by the learning context (Muis et al., 2006) and that sophisticated EB can be fostered directly through deliberated reflection and discussion of their referential and structural facets (Brownlee, 2004).

A key point in this analysis was understanding the suggested relationship between EB and teaching approaches and the implication that EB can predict the pedagogical choices of PSTs. For instance, PSTs' beliefs about the certainty and simplicity of knowledge significantly shape their instructional strategies, with more naïve beliefs leading to rigid, fact-based teaching approaches (Saricoban & Kirmizi, 2021; Sojat, 2020). Moreover, studies indicate that PSTs holding realist epistemological worldviews often favor direct instruction and information transmission, whereas those with constructivist perspectives tend to engage in student-centered, inquiry-driven practices (Bejerano et al., 2023). This relationship has been evidenced in other contexts beyond this review where people who believe that knowledge is evolutionary resort to more strategic thinking and interpret inconclusive content more accurately (Kardash & Howell, 2000).

Assuming this relationship exists, interest in developing more sophisticated EB should be enhanced for more democratic and engaging teaching pedagogies. This context should understand EB investigation as an opportunity to adapt and recreate ITE since these beliefs influence instructional preference and the acceptance of more student-centered approaches (Bahcivan, 2014).

4.1. Limitations and Implications for Future Research

Despite the thorough review, there are certain limitations to this study. Acknowledging these limitations can lead to a better understanding and maintain the review's integrity. As this review has extensively discussed, the diversity of methodological designs and theoretical frameworks creates ambiguity, contributing to the difficulty of generalizing results. Moreover, the variety of sociocultural characteristics, educational policies, and ITE standards is not just a limitation but a reminder to consider the context of each investigation to interpret these findings accurately.

Nevertheless, this paper synthesizes research on the EB of PSTs in various domains and highlights gaps for future research. First, clarifying the theoretical lenses that guide the work developed about EB is decisive. While various theoretical frameworks should be explored, explaining the theories behind the interpretation is important to clarify the analysis and results.

Second, it is crucial to reconsider which research methods contribute to a better understanding of ITE contexts. Therefore, future research needs to have a comprehensive understanding. Less descriptive and more intervention studies are needed to perceive the implications of ITE reconfiguring future teachers' EB. This can be achieved through case studies, action research, ethnographies, and longitudinal approaches. These efforts will help fill the gaps in our knowledge and improve the practicality of research findings, ultimately fostering the development of adaptable and thoughtful PSTs in the ever-changing field of ITE.

Considering the above recommendations, analyzing ITE curriculums and short-term courses might reveal the potential for educational interventions to facilitate the progression towards EB development. This literature synthesis enriches our understanding of how EB develops and paves the way for identifying practices that foster rich, informed and adaptive teaching practices.

Finally, while this literature research has primarily focused on PSTs, teacher and school tutors are also relevant to ITE. Therefore, collaborative research with these agents can deepen and refine the understanding of the development of EB.

5. Conclusion

The findings suggest that teacher education programs should include good practices and short-term courses focused on developing more sophisticated EB. The relationship between more sophisticated EB and student-centered approaches were grasped which is pertinent for further comprehension of the current panorama of teaching demands. Future research must adopt longitudinal designs underpinned by robust theoretical frameworks to address the research gaps and the factors driving EB development.

Understanding the nature of EB is paramount as it provides valuable insights into the intricacies of how PSTs perceive and acquire knowledge. It is possible to equip ITEs with the necessary tools to impact EB reconfiguration and make informed decisions to support their professional growth by gaining a deeper understanding of how PSTs conceptualize knowledge and learning (Erbas, 2013). The gaps in our current understanding uncover new dimensions of epistemology that will enrich our collective knowledge and advance the field of education.

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Appendix

Appendix A. Summary of data extraction from selected studies.

Author	Main objective	Main findings
Atici (2023)	Examine the relationship between physical education PSTs' EB and academic self-efficacy	Physical education PSTs had high EB but low academic self-efficacy. There was a low negative relationship between grade level, EB, and academic self-efficacy.
Bayraktar (2019)	Explore PSTs scientific EB and attitudes toward science	PSTs had relatively developed EB; here were no significant differences between gender. It is suggested that the developed EB might result from ITE, but there is still room for improvement.
Bejerano et al. (2023)	Identify the EB held by science PSTs.	PSTs' EB, worldviews, and self-efficacy beliefs are interconnected, with self-efficacy and outcome expectancy being significant predictors of their EB about the "Innate ability" factor. PSTs hold relatively simplistic bEB about "Certain Knowledge" and "Simple knowledge", which are associated with their confidence in using student-centered teaching approaches.
Cady and Rearden (2007)	Identify PSTs EB and compare them between the two domains, within a course on SCA.	75% of PSTs had dualist views and expected the teacher to hold all content knowledge. Overall, PSTs have more traditional beliefs in mathematics that in sciences. EB are informed by previews experiences.
Choi and Kwon (2012)	Explore Korean PSTs EB about mathematics	Math PSTs held simple EB and objective and non-constructivist views towards mathematics. It is suggested that EB are influenced by cultural values.
Deniz (2011)	Examine PSTs EB in science and the factors that mediate those changes, within an intervention.	Conceptual change intervention was effective in improving PSTs EB views about science in all four dimensions; Thinking dispositions are related to EB development – higher thinking dispositions are associated with more sophisticated EB.
Dinç and Üztemur (2017)	Define PSTs EB about social studies	PSTs generally hold sophisticated EB about social studies. 4th year PSTs and female PSTs have more sophisticated EB than 1st year and males. Sophisticated EB are associated with democratic approaches preference.
Gill et al. (2004)	Investigate a instructional intervention to account for changes in PSTs EB.	The intervention, particularly refutational texts, provided EB development; Systematic processing does not mediate the relation between instruction and EB change.
Guilfoyle et al. (2020)	Consider PSTs EB on the acceptance or rejection of "Education studies" from their initial teacher education.	EB salient features of PSTs' evaluation about Education Studies; PSTs recognize potential value of Education Studies for their practice, but something hinders further engagement.
Guilfoyle et al. (2024)	Explore how student research projects can promote the development of PSTs' EB.	Research experiences in ITE can contribute to the development of PSTs' EB though the extent and nature of the development varies. Additionally, research in science can lead PSTs to develop a more nuanced understanding of the tentative and interpretative nature of scientific knowledge.
Güven et al. (2014)	Examine how PSTs learning experiences	EB dimensions improved except for certain knowledge

Author	Main objective	Main findings
	and reflective diaries affect their EB.	(Already sophisticated in the beginning); Reflective diaries may help PSTs to reconstruct their views and beliefs.
Huang-Yao and Shu-Ping (2010)	Investigate changes in PSTs EB within a collaborative knowledge building approach.	Engaging students in knowledge-building is helpful in shifting their pedagogical beliefs and EB to become more constructivist-oriented.
Kang (2008)	Identify possible connections among teaching goals, EB, and teaching actions during ITE.	PSTs EB and teaching goals influence their instructional choices. Some PSTs enacted more sophisticated EB than the ones they expressed, which means ITE provided opportunities for them to develop and translate EB into practice.
Kirmizi and Irgatoglu (2021)	Investigate the relationship between PSTs EB and their approaches to teaching.	PSTs with more sophisticated EB are more likely to adopt SCA. Effort (EB dimension) predicts PSTs teaching approaches.
Kızkapan et al. (2024)	Examine the relationship between PSTs' understanding of the nature of science, EB, and pseudoscientific beliefs.	PSTs with more sophisticated EB also have more sophisticated views on the nature of science. There is no significant correlation between PSTs' EB, pseudoscientific beliefs, and nature of science views.
Löfström and Pursiainen (2015)	Understand PSTs EB and if EB might be a problem in pedagogical development.	PSTs relied on authority, as a justification for mathematical knowledge. PSTs viewed pedagogical knowledge as unrelated to practice; Engaging in research projects can help PSTs understandings on pedagogical knowledge.
Markic and Eilks (2012)	Describe PSTs EB within their respective teaching domain.	Physics and chemistry PSTs hold traditional beliefs; Biology and Science PSTs hold more modern beliefs; Making EB explicit and fostering self-reflection in ITE could help PSTs to adopt SCA.
Markic and Eilks (2013)	Investigate PSTs EB in different stages of ITE	PSTs hold traditional beliefs about teaching and learning in the beginning of ITE; PSTs appear to have the most modern teaching beliefs midway through ITE. Senior PSTs tended toward more modern beliefs but not as strong and midway PSTs.
Ozturk and Yilmaz-Tuzun (2017)	Investigate the relationship between PSTs EB and informal reasoning	PSTs were found to possess no highly sophisticated EB; PSTs who have higher scores on innate ability, certain knowledge, and quick learning may have lower scores on their total argument construction.
Saricoban and Kirmizi (2021)	Observe potential correlations between PSTs EB, perceived engagement levels, and instructional preferences.	Effort dimension influenced instructional preferences; Teacher engagement has more connection with instructional preferences, than EB. PSTs favored constructivist instructional preferences.
Sojat (2020)	Investigate the initial PSTs EB.	90% of PSTs hold traditional EB , viewing learning as direct transmission of knowledge. It is suggested that PSTs EB are influenced by their experiences as students.
Topcu (2013)	Assess PSTs domain- specific EB.	EB about certainty of knowledge is less sophisticated in Physics; PSTs viewed authority and expertise as the source of knowledge more in physics and chemistry than in biology. The differences might be attributed to the inherent characteristics of each discipline.
Yenice (2015)	Identify the relationship between PSTs EB and their metacognitive perceptions about the nature of science.	PSTs had sophisticated EB about the nature of science and the process of knowledge construction; Gender had a significant effect, justified by epistemic maturity. Grade level had no significance, justified by the holistic development during ITE.
Zorlu (2017)	Investigate the relationship between PSTs EB about the nature of science and their science learning self-efficacy perceptions	95% of PSTs hold EB closer to the traditional understanding of science; Science Learning Self-Efficacy predicts and explain 23% of the EB scores.

Regarding the content table, the first column provides the "Author(s)", which presents the author(s) of the study and the publication year. The second column, "Main Objective" highlights the main research question of the study. The third column, "Main findings", provides the results overview.