DO TEACHERS' BELIEFS TURN TO PRACTICE? COUNTRYSIDE SECONDARY SCHOOL SCIENCE TEACHERS' TEACHING BELIEFS, SCIENTIFIC EPISTEMOLOGICAL BELIEFS, AND APPROACHES TO TEACHING

Reymund Derilo

Associate Professor III, Nueva Vizcaya State University, Philippines

✉ rcderilo@nvsu.edu.ph

ABSTRACT

This study employed a convergent parallel mixed-method design to examine the teaching beliefs of secondary school teachers and determine the relationship between their scientific epistemological beliefs and pedagogical approaches. Semi-structured interviews were utilized to explore teachers' teaching beliefs, while quantitative analysis involved a descriptive-correlational approach, employing two adapted questionnaires: Scientific Epistemological Belief Questionnaire (SEBQ) and Approaches to Teaching (ATI). Analysis of interview responses reveals that most teachers prioritize creating a student-involved classroom environment, typically teacher-initiated learning, rather than allowing student-led initiatives. They generally view themselves as facilitators of learning, base their teaching decisions on the curriculum, and believe that students demonstrate understanding by reiterating what has been taught. Quantitative analysis indicated that science teachers in the province largely demonstrate traditional beliefs regarding the origins and characteristics of scientific knowledge while predominantly employing transitional teaching approaches in their practice. Furthermore, the study found a correlation between teachers' SEBs and adopting learner-focused teaching approaches. Integration and meta inference of qualitative and quantitative findings bear significant implications for science education, suggesting avenues for enhancing, restructuring, and reforming teachers' teaching and epistemological beliefs. Hence, efforts should focus on fostering teachers' deeper understanding of the nature of science.

KEYWORDS

Approaches to teaching, nature of science, teaching beliefs, scientific epistemological beliefs

HOW TO CITE

Derilo R. (2025) 'Do Teachers' Beliefs Turn to Practice? Countryside Secondary School Science Teachers' Teaching Beliefs, Scientific Epistemological Beliefs, and Approaches to Teaching', *Journal on Efficiency and Responsibility in Education and Science*, vol. 18, no. 2, pp. 64–77. http://dx.doi.org/10.7160/eriesj.2025.180201

Article history
Received
February 13, 2024
Received in revised form
November 22, 2024
Accepted
January 27, 2025
Available on-line
June 30, 2025

Highlights

- *Teachers' interview responses reveal diverse instructional beliefs, characterized by a notable prevalence of instructive and transitional belief orientations.*
- *The majority of the science teachers exhibit fairly traditional scientific epistemological beliefs.*
- *Significant and moderate correlations exist between teachers' approaches to teaching and their scientific epistemological beliefs.*
- *Integration and metainference of qualitative and quantitative findings revealed areas of convergence and divergence, offering significant implications for science education and basic education policy reviews.*

INTRODUCTION

The prime objective of teaching at any education level is to bring about a significant and fundamental transformation in the learner (Tebabal and Kahssay, 2011). To enhance knowledge transfer, teachers should use suitable teaching approaches, methods, and strategies that align with specific goals and desired outcomes. Educational researchers have long been intrigued by questions regarding how teachers select

their teaching methods and strategies. Additionally, unresolved aspects include the factors influencing these choices and decisions and why some teachers favor teacher-focused rather than student-focused approaches.

Beliefs are critical when understanding a teacher's practice (Luft and Roehrig, 2007). What a teacher does in the classroom is representative of his beliefs (Wallace and Kang, 2004). Teachers' action-oriented approach to science learning is needed; this requires recognizing that students can and should be encouraged to learn science in their everyday lives as there are numerous contexts outside the classroom wherein students can learn about science (Bencze et al., 2009). Learning would take place with the appropriate teachers' attitudes, emotions, and views of the nature of science, coupled with effective pedagogical content knowledge (Van Driel et al., 2007).

Teachers' beliefs have been found to have a positive correlation with practice. There is a positive correlation between teachers' beliefs and teachers' instruction and learning of science, what is introduced to as "nested" epistemological views (Tsai, 2002). While there is instability about where these beliefs stem from, Tsai's finding gives an essential example of how epistemological views about teaching and learning can and do influence classroom practice. Several research findings likewise give data about how empirical science perspectives rise above societies and may be identified with teachers' classroom experience (Donnelly, 1999; Gustafson and Rowell, 1995; Koballa et al., 1990; Tsai, 2002). If these perspectives on teaching and learning play a significant role in shaping practices, they should grab the attention of the science education community. How teachers' views and beliefs translate into action becomes extremely crucial, especially when considering how learners develop their belief systems through instruction. Teachers who align with a more constructivist perspective on learning are likely to consider how learners understand concepts (Hashweh, 1996).

Teachers' choice of teaching methods and strategies is influenced by various factors, with a significant impact on their epistemic beliefs (EBs) (Keys and Bryan, 2001). Scientific epistemological beliefs (SEBs) specifically pertain to beliefs about the source and nature of scientific knowledge (Hofer and Pintrich, 1997). SEBs can be classified as traditional or contemporary, reflecting views on the exactness and changeability of scientific knowledge (Bråten and Strømsø, 2005). SEBs shape each element of the teaching process and guide teachers in their decisions and choices (Putnam and Borko, 1997). Studying teachers' epistemological beliefs is crucial for understanding their conceptualization of work, teaching practices, and decisions in the classroom (Olafson and Shraw, 2010). Mansour (2009) emphasizes the powerful influence of teachers' beliefs over their insight in shaping how they deliver knowledge. When teachers hold static or dynamic conceptions of science, their objectives align with either performance or mastery goals (Chen and Pajares, 2010). Individual conceptions about knowledge and how individuals come to understand concepts are crucial elements in providing valuable insights into the mental processes of each individual (Hidayatullah and Csíkos, 2023).

As we navigate through the changing landscapes of educational philosophies such as constructivism and post-positivism, it becomes crucial to reassess the importance of SEBs in science education (Chen et al., 2014; Guilfoyle et al., 2020; Guo et al., 2022; Vieira et al., 2017; Yucel, 2018). Constructivism, emphasizing active student participation and knowledge construction, aligns with the study's exploration of how teachers' epistemological beliefs (SEBs) influence their instructional strategies. This philosophy posits that learners build upon their prior knowledge, and similarly, teachers' beliefs about science and its teaching evolve through experience. In contrast, post-positivism offers a more nuanced perspective on knowledge as tentative and subject to change, which mirrors the present study's examination of how teachers' beliefs about the nature of scientific knowledge influence their teaching approaches. These philosophical perspectives directly inform the research questions and methodology, guiding the investigation of the relationship between teachers' SEBs and their instructional choices and how these beliefs shape educational practices in science classrooms. Delving into teachers' teaching beliefs and epistemic beliefs offers valuable insights into how they shape their teaching approaches and strategies in the science classroom. Luft and Roehrig (2007) noted that making these beliefs "visible" is key to understanding and eliciting teachers' perspectives.

A review of existing literature on SEBs and teaching approaches reveals several notable research gaps. This study aims to address these gaps, particularly in understanding how educational policies, especially in rural Philippine contexts, influence the implementation of reform-based teaching practices despite teachers' positive beliefs about such methods. While the connection between teachers' epistemological beliefs (EBs) and teaching practices is well-established, there is limited exploration of how local policies, resources, and contextual factors shape these beliefs. Additionally, the study examines the barriers preventing teachers from aligning their beliefs with classroom practices, particularly in environments constrained by policy. Furthermore, the research highlights the lack of studies on how teachers' beliefs about the nature of science (NOS) influence their teaching approaches. Moreover, the scarcity of mixed-methods research designs to explore these complex issues represents a significant gap, as such approaches offer a more holistic understanding of the relationships between beliefs, teaching strategies, and educational outcomes in rural settings.

This study aims to uncover the beliefs of secondary school teachers in rural areas regarding their scientific epistemological development. By analyzing teachers' interview and survey responses, the study seeks to enhance understanding of the current challenges in basic science education within the locality. Specifically, the study intends to (1) explore the nature and development of teachers' teaching beliefs and scientific epistemological beliefs (SEBs) and examine how these beliefs influence their teaching practices; (2) assess the relationship between teachers' beliefs about the nature of science (NOS) and their teaching approaches; and (3) integrate qualitative and quantitative findings to provide a more comprehensive understanding of the interplay between teachers' beliefs, teaching strategies, and educational outcomes in rural science education. Through these objectives, the study

aims to contribute to the ongoing dialogue on improving science education in rural areas, focusing on the role of teachers' epistemological beliefs and teaching approaches.

METHODS

Design and Sample

In this research, a convergent parallel mixed-method design was employed. For the qualitative part of the study, a semi-structured interview was employed to determine the teachers' teaching beliefs using the interview guide developed by Luft and Roehrig (2007). This guide included 7 questions designed to elicit the teaching beliefs of each teacher, analyze their thoughts, and understand their beliefs. Once the responses were collected, they were inductively analyzed through the Content Analysis method (CA) to comprehend how certain perspectives were manifested within each teacher. Patton (1990) refers to this as an orientational methodology. For the quantitative aspect of the study, a descriptive-correlational design was used to determine secondary school science teachers' scientific epistemological beliefs and teaching approaches, as well as the possible association between these variables. The teachers were asked to complete two survey questionnaires: the Scientific Epistemological Belief Questionnaire (SEBQ) and Approaches to Teaching (ATI).

A letter to the Schools Division Superintendent (SDS) of the Department of Education - Nueva Vizcaya was sent for approval to conduct this study. Thereafter, an endorsement letter was provided and forwarded to the administrators of the secondary schools in the province. The sample of 54 secondary school science teachers who participated in the study was drawn from a diverse set of schools within the province, which provides a representative cross-section of the broader population of science educators. The selection process began with the endorsement of school administrators, who introduced the researcher to the science teachers within their institutions. All 54 teachers voluntarily agreed to participate, completing the survey questionnaires, and 18 also took part in brief interviews once data saturation was reached. This step ensures a balance of both quantitative and qualitative data. The sample offers insights into the perspectives and practices of science teachers in the province, including various educational backgrounds, specializations, and levels and years of experience. The specific focus on these teachers reflects the broader trends within secondary school science education, particularly in rural and provincial settings. By studying this sample, which mirrors larger schools in the region, the research can draw conclusions about the dynamics of science teaching in similar rural and underserved areas. This approach not only provides a micro-perspective on science education but also offers implications for educational policies and practices on a more macro level, enhancing the relevance and generalizability of the findings to other schools in similar contexts.

Instruments

Teachers Belief Interview (TBI). Luft's and Roehrig's (2007) TBI was used to document teachers' teaching beliefs. The tool consists of seven questions depicting epistemological beliefs in teaching and learning development. There are five belief categories: traditional, instructive, transitional, responsive, and reform-based. The tool has a Cronbach alpha coefficient for the internal consistency of 0.70. Teachers' beliefs were categorized into five, namely, traditional, instructive, transitional, responsive, and reform-based. Traditional beliefs focus on the transmission of information or reliance on established sources. Teachers adhering to these beliefs see their role as delivering information to students. On the other hand, instructive beliefs center around creating experiences that are teacher-focused or decided by the teacher. Teachers with instructive beliefs aim to provide students with hands-on experiences in laboratory science, which emphasizes a student-focused approach to minimize disruptions. On the contrary, Transitional beliefs occupy the middle ground between traditional and contemporary beliefs in teaching and learning science. These beliefs emphasize teacher-student relationships, subjective decisions, and emotional responses. Teachers with transitional beliefs feel responsible for guiding students in developing understanding and process skills, modifying their teaching to align with students' preferences to build rapport. In contrast, responsive beliefs revolve around collaboration, feedback, and knowledge development, with teachers setting up classrooms for students to take charge of their learning. Lastly, reform-based beliefs, the most modern among contemporary teaching beliefs, focus on mediating student knowledge and fostering interaction. In this approach, teachers provide experiences that help students comprehend their knowledge and make sense of science.

Scientific Epistemological Belief Questionnaire (SEBQ). The SEBQ used in this study was adapted from Baliton's (2005) master's thesis at the University of the Philippines – Diliman, with permission obtained via email from the original author. This survey instrument evaluates teachers' beliefs about various aspects of scientific knowledge, including scientific theory, the scientific method, scientific law, and the role and image of scientists. It employs a 4-1 Likert scale, allowing participants to express their level of agreement with statements about the nature of science. Notably, Baliton had previously applied the SEBQ to a sample similar to the target population of this study, further validating its relevance and applicability. Additionally, the instrument underwent pilot testing with a sample similar to the study's target group, though distinct from the final sample, to ensure its suitability and reliability. The SEBQ demonstrated strong reliability, with a Cronbach's Alpha value of 0.8583, which indicates excellent internal consistency. For analysis, the instrument classifies beliefs into four categories: traditional (M = 1.00–1.74), fairly traditional (M = 1.75–2.49), fairly contemporary (M = 2.50–3.24), and contemporary (M = 3.25–4.00). By adapting and validating the SEBQ for this study, its relevance and suitability for investigating science teachers' epistemological beliefs in rural Philippine schools are firmly established.

Approaches to Teaching (ATI). The tool was adapted from Trigwell and Prosser (2004). The ATI was intended to measure a teacher's approach to teaching about another construct, such as student learning outcomes, enthusiasm, or organization. There are two 11-item subscales within the ATI. The first is the information transfer/teacher-focused scale (ITTF), and

the second subscale is the conceptual change/student-focused scale (CCSF). There are no established normal values for the inventory as it is intended to be used in a relational way and may depend on context. Classification of teachers' approaches to teaching was determined based on their score range on the ATI. However, as a scoring guide, the following was used: for CCSF items, scoring was as follows: always true = 5; sometimes true = 4; true half the time = 3; frequently true = 2; and never true = 1. On the other hand, items representing ITTF approaches were scored in reverse. Cronbach's alpha values were 0.75 (CCSF approach) and 0.73 (ITTF approach). Scores were interpreted as follows: 22.0–39.6: knowledge transmission; 39.7–57.2: knowledge acquisition; 57.3–74.8: transitional stage; 74.9–92.4: conceptual development; and 92.5–110.0: conceptual change.

Analysis and Integration of Qualitative and Quantitative Results

This study followed the integration process through data transformation outlined by Fetters et al. (2013). The approach involves two main steps. First, qualitative data were converted into quantitative data through content analysis (Table 1), enabling the identification of teachers' beliefs in numerical form. Second, the transformed data were integrated and analyzed alongside the original, non-transformed data (discussion section). This integration facilitated a comprehensive discussion, combining insights from both qualitative and quantitative perspectives to provide a more robust understanding of the research findings. Moreover, integration by narrative was employed in analyzing teachers' teaching beliefs, approaches, and epistemological beliefs. Specifically, a weaving approach was used, where qualitative and quantitative findings were presented together on a concept-by-concept basis. This method allowed for a cohesive and interconnected discussion of the findings, highlighting the interplay between qualitative insights and quantitative evidence within each thematic framework.

RESULTS

Capturing Teachers' Teaching Beliefs

The TBI is intended to determine teachers' beliefs about the teaching and learning process inside a science classroom. To ensure the integrity of the collected data, teachers' responses were carefully categorized using the categorization guide by Luft and Roehrig (2007).

TBI Questions	Teachers' Classification (%)				
	Traditional	Instructive	Transitional	Responsive	Reform based
Q1. How do you maximize student learning in your classroom?	27.8	5.6	38.9	11.1	16.7
Q2. How do you describe your role as a teacher?	5.6	5.6	16.7	0	72.2
Q3. How do you know when your students understand?	0	61.1	22.2	11.1	5.6
Q4. How do you decide what to teach and what not to teach in the school setting?	66.7	16.7	16.7	0	0
Q5. How do you decide when to move on to the next topic in your class?	0	83.3	11.1	5.6	0
Q6. How do your students learn science best?	0	0	50.0	44.4	5.6
Q7. How do you know when learning is occurring in your classroom?	0	16.7	27.8	44.4	11.1

Table 1: Teachers' Beliefs Categorization Based on Their Responses to the Interview

Table 1 presents a classification of teachers' responses to the seven Teaching Beliefs Interview (TBI) questions. Regarding maximizing student learning (Q1), the data show that most teachers' beliefs are categorized under the transitional belief (38.9%). This means that most teachers focus on creating a classroom environment that involves the students but whose initiative starts with the teacher and not with the students themselves. Regarding the teacher's role description (Q2), 72.2% believe they are facilitators of learning and mediators of students' prior and pre-existing knowledge. On the other hand, the majority (61.1%) of the teachers have instructive beliefs about when a student has gained comprehension (Q3), which suggests that the majority believe in the notion that students have understood the lesson if they can already reiterate or demonstrate what has been presented in class. When deciding what to teach (Q4), most teachers (66.7%) possess teacher-focused, traditional beliefs, which suggests that the adopted curriculum guides most teachers in deciding what to teach and what not to teach.

Deciding when to move on to the next topic (Q5), most teachers predominantly fall into the instructive category (83.3%). This suggests that their decision when to move on to the next topic is teacher-directed and is based on a basic understanding of facts and concepts. Regarding how students learn science best (Q6), more than half of the respondents (50.0%) possess transitional beliefs, suggesting that most teachers believe that students learn science concepts best by doing or by involving the learners in various hands-on activities. Similarly, many of the respondents (44.4%) believe in a more contemporary belief displaying responsive beliefs on how a student best learns science concepts, implying that many teachers also believe that students learn science best by encouraging and challenging them to create their own understanding based on their observations.

Finally, in assessing when learning is occurring (Q7), most teachers (44.4%) hold contemporary, responsive beliefs, believing that it is when students start interacting with their peers or their teacher or when the students start defending their own ideas through evidence and examples that learning has already taken place in the classroom.

The following sections comprehensively present the results of the analysis from teachers' responses to the 7 questions. Sample responses were presented as examples.

How do you maximize student learning in your science classroom?

Some teachers who demonstrate traditional beliefs focus on structured environments where teachers manage time to enhance student learning. Teacher E stated, "*To maximize student learning in the classroom, time management is needed.*" On the other hand, teachers with instructive beliefs involve closely monitoring students' behaviors and engagement, with teachers like Teacher R emphasizing discipline, saying, "*I will not ignore misconduct in the class that will disturb other students. I believe that learning takes place in a disciplined class.*" These beliefs guide teachers in maintaining order to foster effective learning.

Most of the teachers interviewed demonstrate transitional beliefs. These beliefs revolve around shaping a classroom atmosphere that actively engages students. These are further subdivided into two categories: cognitive and affective. Cognitive beliefs may seem aligned with contemporary views; however, they are classified as transitional because the initiative originates from the teacher rather than the students. This distinction is evident in the perspectives of Teachers H and U, who advocate for providing hands-on activities and diverse experiences to guide students in constructing their ideas. Teacher H said, "*To maximize student learning in my classroom, I must provide various hands-on activities and first-hand experiences that will teach the students to construct their ideas.*" Teacher U emphasizes the importance of offering varied activities and strategies to address the diverse learning needs and challenges of students: "*I believe that by giving different sets of activities and strategies to cater to most of the learners' learning (needs and difficulties), I can maximize learning (in my classroom).*" On the other hand, affective beliefs center on teachers' emotional dispositions in expressing feelings accompanying ideas and actions. Teacher J held such beliefs when she said, "*I think I can maximize learning by fostering strong relationships with my students, both inside and outside the classroom*."

Some teachers' responses also reflect responsive beliefs. These beliefs are student-centered, focusing on creating classroom environments that encourage interaction and collaboration. Teacher D, for example, believes that "*group work discussions, brainstorming, Socratic method of teaching, silent reading, and analysis of extra reading materials*" enhance learning. At the same time, Teacher P emphasizes that "*interactions in all classroom activities promote better learning*." Some teachers, however, have shown reform-based beliefs that emphasize individualized learning, allowing students to choose their learning methods. Teacher N reflects this by stating, "*by giving differentiated instructions*," believing that students learn best when their interests and strengths are considered. This approach aligns with differentiated instruction, recognizing students' diverse learning styles.

How do you describe your role as a science teacher?

Some teachers demonstrate traditional beliefs, prioritizing structure and information in the classroom and viewing their role as knowledge providers. Teacher C, for example, describes teaching as a "*very tedious task, such as managing the class*," but adds, "*I find it enjoyable*," reflecting this approach's labor-intensive yet fulfilling nature. Other teachers exhibit instructive beliefs, focusing on providing experiences and managing classroom behavior. Teacher N, for instance, believes teachers should extend their roles beyond just education, stating that they must also act as mentors, disciplinarians, and even spiritual guides. Some teachers display transitional beliefs, emphasizing the importance of building strong connections with students and fostering a deep understanding of the subject. Teachers like D and O view their role as multifaceted, with Teacher D saying, "*Being a teacher means opening young minds to the wonders and realities of the world*," and Teacher O considering teaching a role of "*model, challenger, leader, counselor, mother, sister, and friend.*"

However, none of the teachers in this study demonstrated responsive beliefs that focus on collaboration between teachers and students and empowering students to take control of their learning. This suggests a gap in fostering collaborative, student-led learning environments.

It was found that most of the teachers demonstrate reform-based beliefs about their roles as science teachers. With this belief, the teacher's role primarily mediates between students' existing knowledge and the subject matter. Teachers view themselves as guides, assisting students in making sense of their surroundings in alignment with established knowledge. Two illustrative responses come from Teachers G and H. Teacher G said, "*My role is to facilitate learning and inspire students to make them enjoy the learning process, to discover new things through science.*" Likewise, Teacher H emphasizes "*the teacher's role as a facilitator of learning, to guide students to construct their understanding while correcting any misconceptions they may have.*"

How do you know when your students understand?

Traditional beliefs are embodied by teachers who believe that students have grasped a lesson when they can repeat information communicated by the teacher. According to these teachers, hearing this information from the students at least three times is crucial for confirmation. Notably, none of this study's respondents demonstrated such traditional beliefs. This absence of alignment with the mentioned beliefs among the interviewed teachers suggests a divergence from the notion that repetition and varied presentation formats are key indicators of lesson comprehension.

Most of the teachers, however, have demonstrated instructive beliefs. These are evident among teachers who gauge students' understanding based on their ability to articulate or demonstrate the content presented in class. These educators posit that true comprehension is demonstrated when students perform well on practical examinations, accurately reproduce answers on written tests, and articulate concepts using their own words. Teacher F's response clearly illustrates instructive beliefs: "*I know my students learn when they get high scores*

and can answer questions even if you paraphrase." Notably, Teacher F places significant emphasis on assessments, utilizing both formative and summative evaluations as key indicators of students' comprehensive understanding. This trend is similarly observed in Teacher I's response, where, in addition to assessments, he said, "*They learn when they have the ability to answer questions, even when rephrased, and it is considered a sign of students having fully grasped the lesson.*"

Some teachers demonstrate transitional beliefs, assessing understanding through students' ability to explain or respond in ways that connect with the lesson. This can be cognitive, like Teacher D using quizzes and oral reviews, or affective, based on students' facial expressions. Teacher D says, "*I just know*" when students understand. Teachers Q and R also emphasize cognitive and affective indicators, noting positive behavior and relevant questions as signs of comprehension.

Responsive beliefs are reflected in teachers who value students' ability to apply knowledge in discussions or real-life situations. Teacher H believes understanding is shown when students can "*apply or integrate or relate topics with other lessons*," while Teacher N values when students "*ask situations related to the topic.*"

Reform-based beliefs focus on applying knowledge in new contexts. Teacher G exemplifies this by stating, "*It is when they know to apply the theories learned through practical situations in life.*"

How do you decide what to teach and what not to teach in the school setting?

About one-third of the teachers interviewed demonstrate traditional beliefs shaped by strict adherence to the prescribed curriculum and external factors such as time constraints. These teachers prioritize covering all topics outlined in the curriculum. For instance, Teacher B states, "*I follow the CG (curriculum guide), TG (teacher's guide), and LM (learners' manual)… all the topics should be discussed.*" Teacher C adds, "*Competencies are non-negotiable; it should be taught*," while Teacher N emphasizes, "*The Department of Education already prepared curriculum guides, and I am teaching based on the competencies specified in the curriculum.*"

Other teachers exhibit instructive beliefs, where personal preferences, the relevance of content, and the availability of materials influence their teaching choices. Teacher K explains, "*When materials needed are not available locally and when the topic duplicates what has been taught in the previous grade*," indicating that the availability of resources and prior coverage guide her decisions. Teacher Q shares a similar view: "*Teaching should be based on what the students need and what is applicable in their community.*"

Transitional beliefs are evident in teachers who adjust their teaching based on student feedback and abilities. Teacher G states, "*Through initial assessment of students' knowledge about the topic, the resources provided by the school are used,*" indicating that students' understanding shapes instructional decisions. Teacher O ensures that "*at least 75% of the students have understood the lesson before proceeding to the next lesson,*" focusing on student comprehension before moving on.

Responsive beliefs are held by teachers who base their decisions on student feedback, interests, and misconceptions, believing that active engagement enhances learning. On the other hand, reform-based beliefs focus on a student-centered approach guided by research and educational standards to ensure content is appropriate and aligns with specified standards. Unfortunately, these beliefs were not reflected in the teachers' responses.

How do you decide when to move on to the next topic in your class?

Instructive beliefs, where teachers base decisions on students' grasp of concepts, are common among 83% of the respondents. Teachers like Teacher I, who move on when "*students could pass the summative test and could greatly tell what they have understood,*" reflect this belief. Similarly, Teacher V decides to proceed when "*students have already understood the topic*" and can demonstrate their knowledge through assessments. These teacher-directed decisions emphasize assessing student understanding before advancing.

In contrast, the responses did not reflect traditional beliefs, where decisions are driven by curriculum and time constraints. Transitional beliefs, seen in teachers like Teacher N, who waits for students to "*explain the topics through class recitation*," show reliance on student feedback. Responsive beliefs, exemplified by Teacher D, involve adjusting the pace based on student progress. At the same time, no teachers in the study demonstrated reform-based beliefs, which would involve ongoing evaluations to gauge readiness for new topics.

How do your students learn science best?

Half of the teachers interviewed in this study exhibited transitional beliefs, where teachers emphasized hands-on activities for effective learning. For instance, Teacher L believes students learn best "*when they perform laboratory experiments, demonstrations, and simulations*." Similarly, Teacher R stresses that students learn best by "*doing the activities and experiments by themselves*." Additionally, approximately 45% of the respondents held responsive beliefs, focusing on student engagement and interpretation of phenomena. Teacher D highlights this approach: "*My students learn science best through observation and dialogue*." At the same time, Teacher H believes learning is most effective when students engage in "*enjoyable activities where they share and present their results, outputs, thoughts, and ideas*."

No teachers in the study demonstrated traditional or instructive beliefs, where learning is teacher-centered or mimicking. One teacher, Teacher N, reflected reform-based beliefs, advocating for student-driven learning through diverse materials and activities, though this was not widely shared among respondents.

How do you know when learning is occurring in your science classroom?

Around 45% of the teachers in this study demonstrated responsive beliefs, where learning is perceived as occurring when students actively engage with peers or the teacher on the topic. Teacher H exemplifies this, stating that learning occurs "*when there is active participation between the teacher and my students and/or among the students themselves*."

Similarly, Teacher V believes learning occurs when "*students are engaged actively in the teaching and learning process*." None of the teachers exhibited traditional beliefs, where learning is gauged by observing student behavior, such as attention or order. Some teachers, like Teacher C and Teacher W, held instructive beliefs, asserting that learning is evident when students can follow instructions and demonstrate mastery. Teacher C noted that "*learning has occurred when the students have mastered the lesson through their scores*." Teachers with transitional beliefs, such as Teacher B, perceive learning based on student reactions, stating, "*Learning occurs in class when students start to react.*" Teacher I combines cognitive and affective aspects, saying, "*Academic noise, maximum participation in class, high assessment results, enthusiasm, and interest signals that learning is taking place.*" Lastly, reform-based beliefs, held by teachers like Teacher D and Teacher G, emphasize learning when students ask questions and show curiosity.

Secondary School Teachers' Scientific Epistemological Beliefs (SEBs)

The teachers' SEBs were determined to identify the prevailing beliefs of the teachers about the nature of science (NOS). Table 2 shows the classification of teachers based on their beliefs, which are manifested in their responses in the SEBQ.

SEB Classifications	*N*	Percentage
Traditional	5	9.26
Fairly Traditional	32	59.26
Fairly Contemporary	11	20.37
Contemporary	6	11.11
Total	54	100.00

Table 2: Teacher Classification Based on Their Scientific Epistemological Beliefs

Table 2 shows that most teachers are classified as fairly traditional (59.26%), meaning that more than half of the respondents still disagree with the constructivists' belief in scientific epistemologies. In contrast, a combined portion of teachers (fairly contemporary and contemporary) embrace more modern and evolving scientific knowledge perspectives and somehow accept science's dynamic and revolutionary nature. The distribution highlights the variability in teachers' epistemological beliefs within the sample, emphasizing the need for tailored approaches to pedagogy and professional development initiatives to consider and address this diversity to enhance science education practices. The question of why most teachers possess fairly traditional scientific epistemological beliefs still needs to be answered and understood.

Profile Variables	*N*	Mean SEB	SD	SEB
Age				
20 to 30 years old	16	2.45	.078	Fairly Traditional
31 to 40 years old	12	2.49	.085	Fairly Traditional
41 to 50 years old	17	2.44	.128	Fairly Traditional
51 years and above	9	2.54	.065	Fairly Contemporary
Number of Years Teaching Science				
1 to 5 years	16	2.38	.103	Fairly Traditional
6 to 10 years	11	2.44	.035	Fairly Traditional
11 to 15 years	12	2.49	.092	Fairly Traditional
16 to 20 years	8	2.47	.158	Fairly Traditional
21 years and above	7	2.50	.098	Fairly Contemporary
Field of Specialization				
General Science	17	2.46	.218	Fairly Traditional
Physical science	10	2.45	.054	Fairly Traditional
Biology	12	2.47	.212	Fairly Traditional
Chemistry	8	2.48	.051	Fairly Traditional
Physics	7	2.55	.053	Fairly Contemporary
Highest Educational Attainment				
Bachelor's Degree	41	2.47	.133	Fairly Traditional
Master's Degree	13	2.42	.025	Fairly Traditional

Table 3: Scientific Epistemological Beliefs of Teachers Based on Their Profile Variables

The SEB of the teachers, when grouped according to their profile variables, is also determined. Table 3 shows that those teachers who are 51 years old and above hold fairly contemporary beliefs of science epistemologies, while those who are 50 and below exhibit fairly traditional beliefs. Those who are teaching science, ranging from 21 and above, exhibit fairly contemporary beliefs. On specialization, those who specialized in physics show fairly contemporary SEBs. On the other hand, those who specialized in physical science, biology, general science, and chemistry exhibited fairly traditional beliefs.

On teachers' educational attainment, both bachelor's and master's degree holders hold fairly traditional SEB.

To further explain the teachers' SEB results, their correlation with the different profile variables was determined. Pearson's *r* and Spearman's rho (r_s) correlation coefficients were identified to explore which profile variable correlates with teachers' SEB.

Teacher Profile	r_s	*p*	Correlation Strength
Age[r]	0.420*	.013	Moderate
No. of Years Teaching Science	0.486*	.015	Moderate
Specialization	0.255	.143	Very weak
Highest Educational Attainment	-0.158	.335	Very weak

Table 4: Correlation Between Teachers' Scientific Epistemological Beliefs and Their Profile Variables

Table 4 shows that specialization and educational attainment did not show a significant correlation with teachers' SEB. This suggests that these profile variables are not necessarily related to teachers' beliefs about the nature of scientific knowledge. Of the profile variables identified, age (r = .420, p = .013) and the number of years in teaching science (r_s = 0.486, p_x = 0.015) show a significant correlation with teachers' SEB. The findings suggest both a positive and moderate correlation, which implies that the longer the time spent teaching science and the older the teacher is, the higher the tendency to develop a more contemporary belief in scientific knowledge. On the other hand, younger and novice teachers tend to show more traditional beliefs in science epistemologies.

The mean for each scientific belief dimension was computed and described in Table 5 to determine the overall depth of teachers' understanding of scientific epistemologies.

Scientific Epistemology	*N*	Mean	SD	Qualitative Description
Role and Images of Scientists	54	2.687	0.328	Fairly Contemporary
Scientific Knowledge	54	2.529	0.136	Fairly Contemporary
Scientific Method	54	2.243	0.204	Fairly Traditional
Scientific Law	54	2.243	0.342	Fairly Traditional
Overall SEB	54	2.445	0.114	Fairly Traditional

Table 5: Secondary School Teachers' General Scientific Epistemological Beliefs (SEBs)

Table 5 shows that teachers' beliefs on the role and images of scientists (M = 2.687, SD = 0.328) and scientific knowledge (M = 2.529, SD = 0.136) are fairly contemporary. On the other hand, their beliefs on both the scientific method (M = 2.243, SD = 0.204) and scientific law (M = 2.243, SD = 0.342) are fairly traditional. Their overall SEB (M = 2.445, SD = 0.114) was categorized as fairly traditional, suggesting that the teachers may not fully embrace the dynamic nature of science in their educational philosophy.

Secondary School Teachers' Approaches to Teaching

Teachers' approaches to teaching were also determined. Table 6 shows the number of teachers using the different teaching approaches.

Approaches to Teaching	Frequency	Percent
Approach A: Knowledge transmission	0	0
Approach B: Knowledge acquisition	7	12.96
Approach C: Transitional Stage	32	59.26
Approach D: Conceptual Development	15	27.78
Approach E: Conceptual Change	0	0
Total	54	100.0

Table 6: Classification of Secondary School Teachers' Approaches to Teaching

Scores fall within the range of approaches B to D, with most teachers (59.26%) falling into the transitional category. This suggests that most teachers employ a combination of teacher- and student-focused strategies, which aim for students to grasp the concepts of the discipline. Around a quarter (27.78%) are adopting conceptual development approaches, focusing on nurturing students' understanding of science. Nevertheless, 12.96% still rely on knowledge acquisition teaching methods. No teacher falls into the knowledge transmission category, and none scored high enough to be classified under the conceptual change category.

Correlation of Teachers' Scientific Epistemological Beliefs and their Teaching Approaches

Table 7 shows the correlation between teachers' scientific epistemological beliefs and the components of their teaching approaches.

Teachers' SEB	*r*	*p*	Significance	Correlation Strength
Role and Images of Scientists	.146	.460	Not significant	Very Weak
Scientific Knowledge and Theory	.550*	.002	Significant	Moderate
Scientific Method	.244	.211	Not significant	Weak
Scientific Law	-.120	.544	Not significant	Very Weak
Teachers' Mean SEB	.404*	.033	Significant	Moderate

Table 7: Significant Correlation between Teachers' Scientific Epistemological Beliefs and their Teaching Approaches

As shown in Table 7, only two components of SEB – scientific knowledge and theory and the mean SEB – showed statistically significant correlations with teaching approaches. The belief in scientific knowledge and theory has a moderate positive correlation ($r = 0.550$, $p = 0.002$), suggesting that teachers with more contemporary views on science tend to adopt more conceptual development and change-based teaching approaches. Additionally, the overall mean SEB showed a moderate and significant correlation ($r = 0.404$, $p = 0.033$), indicating that a teacher's broader scientific beliefs are linked to their choice of teaching method. However, none of the other SEB components – such as the role and images of scientists, scientific method, or scientific law – demonstrated significant correlations with teaching approaches. These results highlight the complex nature of how scientific beliefs influence teaching practices and suggest that, while certain beliefs may be associated with specific teaching strategies, the connections are not uniform across all SEB components. However, it is important to approach these findings cautiously, and further research could help clarify the nuances of these relationships. Future quantitative studies may be conducted to confirm these findings.

DISCUSSION

Integration of Qualitative and Quantitative Data on Teaching Beliefs, Teachers' Epistemological Beliefs and Approaches to Teaching

The analysis of both qualitative and quantitative findings revealed both convergence and discordance in the results. Interviews indicated that while science teachers hold exceptionally positive beliefs about reform-based teaching, they are often impeded from enacting these beliefs due to the current educational policies in the country. Implementing reform-based principles and standards, including changes to science assessment, could provide the necessary impetus to bridge the gap between beliefs and practices in science education. However, this study revealed that not all teachers' beliefs translate into classroom practices. While most teachers believe in reform-based teaching roles, many default to traditional methods when deciding what to teach, highlighting significant barriers.

The discordance appears to be influenced by the Department of Education's policies, particularly the mandate that "competencies are non-negotiable." Such policies may hinder the adoption of 'productive pedagogies' that emphasize real-world connections and investigative learning. The focus on standardized testing, such as the National Achievement Test (NAT), often compels educators to prioritize high test scores over fostering critical thinking or encouraging deeper exploration of ideas. This policy-driven tension between reform-oriented beliefs and traditional practices is a growing concern, especially in science education.

To address these inconsistencies, school administrators should support teachers in creatively navigating these constraints and adopting strategies to align their practices with their beliefs. Additionally, the Department of Education and other relevant authorities should consider minimizing these barriers by shifting the educational system's focus from examination-oriented outcomes to learning-oriented goals. This shift would empower teachers to embrace innovative, reform-based approaches and enhance the quality of science education.

Regarding the teachers' scientific epistemological beliefs, the findings of this study indicate that, despite teaching in a 21st-century setting, their views on science epistemology still align with a positivist perspective. The results confirm previous studies on science teachers' understanding of NOS (García and Sebastian, 2011; Lederman, 2013; Liang et al., 2009; and Tsai, 2007). Results reflect, unfortunately, naïve patterns of epistemological beliefs similar to those that had been observed in previous years, such as those of Abd-El-Khalick and Lederman (2000), Lederman (1992), and Nott and Wellington (1993). The results imply that for these past decades, conceptions of scientific epistemologies have still not elevated from the traditional perspectives and conceptions of the NOS.

There is a prevailing assumption that older teachers tend to adhere more to traditional teaching approaches than newer ones. However, the findings of the present study challenge this notion. Younger teachers have demonstrated more traditional beliefs than older ones. It is suggested that these results may be attributed to the length of time teachers have been exposed to teaching science and its concepts rather than simply age. Older teachers have likely encountered more changes in scientific concepts and advancements over their careers than newer teachers. Additionally, experienced educators have often participated in various professional development opportunities such as training, seminars, and workshops, which may have contributed to refining their beliefs regarding the epistemological foundations of scientific knowledge. They have likely witnessed first-hand the dynamic nature of scientific knowledge, understanding that what was taught years ago may have evolved or even been disproven by current scientific understanding. In contrast, newer or novices may still hold more idealistic views about their teaching practices, as they have yet to accumulate the same level of experience and exposure to the ever-changing landscape of science education. Their possible lack of exposure to the evolution of scientific knowledge may lead them to view science education as more static or idealized than it truly is. Educators' beliefs about knowledge, content, and curriculum are shaped by repeated teaching experiences (Kim and Hannafin, 2008). Without an extensive "case library" to draw from, Novice teachers may struggle to form their own beliefs about science and its

teaching. Experience helps teachers develop a set of beliefs that influence their instructional practices. This aligns with Hofer and Pintrich's (1997) observation of a positive correlation between age and epistemological development, though the exact starting point of this development remains unclear.

Numerous studies have highlighted science teachers' inadequate comprehension of scientific epistemologies. The result of this study, for example, lends support to the claims of Celik and Bayrakçeken (2006), Irez (2006), and Yalvac et al. (2007) who found out that science teachers, in general, hold mythical anthropocentric and instrumentalist beliefs of science, such as that technology is an application of science, that science describes nature, or that science provides material benefits. The results of the interviews (qualitative) and surveys (quantitative) show that science teachers have not managed to accept the subjective components of science or the tentative and provisional nature of scientific knowledge that emerges from the scientific community. Similarly, they do not understand the differences among scientific theories, laws, and hypotheses, the characteristics of the scientific method, and the different status of observations, inferences, and empirical evidence.

The present study's findings show that most teachers are still in the transitional stage between traditional and contemporary teaching approaches. These results support Madronio's findings (2015) regarding teachers' use of various instructional strategies and methods in Nueva Vizcaya, Philippines. Teachers use a combination of traditional methods and outcome-based teaching and learning methods. This may have been a consequence of what appeared in the interview with regard to their teaching beliefs. Science teachers across the province hold optimistic views regarding reform-based teaching methodologies. However, existing educational policies within the country hinder their ability to implement these innovative approaches in the classroom. The findings align with Smith (2010), who highlighted the prevalence of lecture-based instruction, with survey respondents ranking simulation activities and one-on-one discussions as highly effective. This echoes Qablan et al. (2010) and Al-Amoush et al. (2014), who found entrenched teacher-centered beliefs among Jordanian primary and secondary school teachers, respectively. The present study's results parallel those of Lindblad and Sahlstrom (2001), who observed a shift towards increased student engagement in classroom discourse and reduced reliance on whole-class teaching over two decades ago. However, the current study suggests that teachers have not significantly progressed from the transition between traditional and contemporary teaching approaches since then, indicating a persistent reliance on traditional methods.

The results of the present study highlight a positive correlation between teachers' approaches to teaching and their scientific epistemological beliefs (SEBs), reflecting the influence of constructivist beliefs on contemporary views of scientific knowledge. Constructivist teachers emphasize active student participation and the co-construction of understanding, which directly shapes their instructional planning and strategies. These findings align with several studies conducted by other researchers. For instance, Yildizli (2019) suggests that teachers' beliefs about their teaching objectives are critical factors influencing instructional practices. Teachers who view science as static tend to rely on textbook instructions and prioritize correct answers, whereas those who see science as evolving are more likely to foster student discussions (Brickhouse, 1990). Schraw and Olafson (2002) emphasize that teachers' epistemological beliefs strongly influence instructional decisions. Further research indicates a positive correlation between teachers' SEBs and their instructional approaches (Tsai, 2002) as well as student learning outcomes (Polly et al., 2013). Additionally, teachers who perceive scientific knowledge as fixed are more inclined to use transmissionist methods, while those who view it as tentative tend to adopt constructivist approaches (Chai et al., 2010).

More recent research indicates that teachers' choice of teaching methods is strongly influenced by their epistemic beliefs (EBs). Teachers' ontological and epistemological beliefs significantly impact their teaching approaches, particularly in inquiry-based settings (Kelly, 2021), their choice of constructivist teaching methods (Uslu, 2018), and their predominant teaching style (Soleimani, 2020), though teachers' EBs may be resistant to change (Küçükaydin & Gökbulut, 2020). Moreover, EBs are vital in shaping attitudes toward education research (Guilfoyle et al., 2020) and scientific literacy (Vieira et al., 2017). Guo et al. (2022) further support this notion, indicating that adaptive epistemic beliefs are associated with higher science motivation, achievement, and career aspirations. Yucel (2018) provides a different perspective, highlighting the intricate interplay between scientists' ontological and epistemological views and advocating for a balanced approach to science education. Hence, it is deemed significant to reevaluate the role of scientific epistemological beliefs in science education and their impact on attitudes, motivation, and achievement.

Implications

Identifying specific individual beliefs may lead to better comprehension of belief frameworks in general and their often integral inconsistencies and contradictions. A comprehension of an individual's beliefs can help with the design and advancement of professional advancement sessions.

The results of this study suggest several potential avenues for improving teacher education in the country. These include a review of the science teacher education curriculum, increased self-assessment of science teachers' beliefs, amplified communication among science educators, and a more frequent update regarding the changes in the existing scientific knowledge. Teachers' scientific epistemic beliefs were found to be significantly correlated with their teaching approaches. With this relationship, the importance of developing teachers' sets of beliefs and taking into account these beliefs when designing professional development programs for teachers should always be regarded as a point for consideration. A separate course focused on the philosophy and nature of science should be offered in the teacher education programs (undergraduate, master's, and doctorate degrees) in the country to inform the teachers of the very nature of epistemologies and origins of science knowledge. This is to reform, redirect, and reconstruct teachers' set of beliefs about the true nature of scientific knowledge.

Therefore, this study's results call for curriculum developers to include the NOS in the pre-service teachers' curriculum. It is usually acknowledged that teachers' pedagogical actions are guided overall by their general conceptions of teaching and learning, and these conceptions, in turn, depend on the teachers' developmental stage (Mellado, 1998; Abd-El-Khalick, 2006; Lederman, 2013). Hence, including NOS and scientific epistemologies in the curriculum is encouraged.

Teachers' conceptions of the nature of science (NOS) play a vital role in science education, not only due to NOS's significance in scientific literacy but also because these conceptions shape instructional practices and curriculum decisions (DeBoer, 2000; Lederman, 2013; Millar, 2006). Research indicates that student teachers bring with them beliefs about teaching and learning from prior experiences, which influence their perceptions of relevance and usefulness during teacher education courses (Goodman, 1988; Markic and Eilks, 2008; Smith, 2005). To foster change and overcome traditional beliefs, teacher education programs must provide relevant information, appropriate pedagogies, and personal experiences (Choi and Ramsey, 2010). Recognizing and understanding teachers' beliefs is crucial for enhancing teacher education programs and facilitating pre-service teachers' personal learning and professional development (Bryan, 2003; Bursal, 2010; Putnam and Borko, 1997). Similarly, acknowledging teachers' beliefs is increasingly recognized as essential during educational reforms (Justi and Van Driel, 2006).

All teachers operate based on a personal theory of teaching, influencing instructional choices, classroom management practices, and curriculum translation (Luft and Roehrig, 2007; Önen, 2011; Pajares, 1992; Shinde and Karekatti, 2012; Splitter, 2010). These beliefs are often implicit, with teachers unaware of their influence on behavior (Patrick and Pintrich, 2001). Consequently, teachers' beliefs affect educational innovation and reform programs (Johnson, 2006; Milner et al., 2012; Van Driel et al., 2007). Educational reform initiatives rely heavily on teachers' beliefs, which are less malleable than knowledge systems, making them essential for the success of reforms (Oppell and Aldridge, 2015). As Keys and Bryan (2001) claimed, each element of the teaching process is formed by and framed from teachers' epistemic beliefs (EBs). Hence, with a reformed set of epistemic beliefs, choices of strategies and teaching approaches might improve, which, in turn, could lead to improved and enhanced scientific literacy in the country.

CONCLUSION

Teachers' interview responses highlight a wide spectrum of instructional beliefs, with instructive and transitional orientations particularly prominent. The majority of science teachers prefer fairly traditional scientific epistemological beliefs, indicating that teachers in the province adhere to conventional perspectives regarding the origin and characteristics of scientific knowledge. Most of these teachers utilize transitional approaches to teaching science. Additionally, there are noteworthy correlations between teachers' teaching approaches and their scientific epistemological beliefs, indicating a relationship between instructional methods and underlying views on the nature of scientific knowledge. The results also provide quantitative evidence that teachers' set of scientific epistemological beliefs relate to their choice of student-centered or learner-focused teaching approaches, suggesting that those who hold naïve conceptions about the real nature of science tend to use information transfer/teacher-focused approaches to teaching. In contrast, those who hold sophisticated beliefs about the nature of science or those who believe in the tentative nature of scientific knowledge tend to use conceptual change/student-focused approaches to teaching science.

REFERENCES

Abd-El-Khalick, F. (2006) 'Over and Over and Over Again: College Students' Views of Nature of Science', in Flick, L.B. and Lederman, N.G. (ed.), *Scientific Inquiry and Nature of Science: Science & Technology Education Library*, Netherlands: Springer.

Bell, R. L., Lederman, N. G. and Abd-El-Khalick, F. (2000) 'Developing and Acting Upon One's Conception of the Nature of Science: A Follow-Up Study', *Journal of Research in Science Teaching*, Vol. 37, No. 6, pp. 563–581. https://doi.org/10.1002/1098-2736(200008)37:6<563::AID-TEA4>3.0.CO;2-N

Al-Amoush, S., Markic, S., Usak, M., Erdogan, M. and Eilks, I. (2014) 'Beliefs About Chemistry Teaching and Learning - A Comparison of Teachers' and Student Teachers' Beliefs from Jordan, Turkey and Germany', *International Journal of Science and Mathematics Education*, Vol. 12, No. 4, pp. 767–792. https://doi.org/10.1007/s10763-013-9435-7

Baliton, M. (2005) *Curriculum, Scientific Epistemological Views and Student Achievement and Attitude in High School Chemistry*, University of the Philippines: The National Library.

Bencze, J. L., Alsop, S. and Bowen, G. M. (2009) 'Student-Teachers' Inquiry-Based Actions to Address Socioscientifc Issues', *Journal for Activist Science and Technology Education*, Vol. 1, No. 2. Retrieved from: https://jps.library.utoronto.ca/index.php/jaste/article/view/21186

Bråten, I. and Strømsø, H. I. (2005), 'The relationship between epistemological beliefs, implicit theories of intelligence, and self-regulated learning among Norwegian postsecondary students', *British Journal of Educational Psychology*, Vol. 75, No. 4, pp. 539–565. https://doi.org/10.1348/000709905X25067

Brickhouse, N. W. (1990) 'Teachers' Beliefs about the Nature of Science and their Relationship to Classroom Practice', *Journal of Teacher Education*, Vol. 41, No. 3, pp. 53–62. https://doi.org/10.1177/002248719004100307

Bryan, L. A. (2003) 'Nestedness of Beliefs: Examining a Prospective Elementary Teacher's Belief System About Science Teaching and Learning', *Journal of Research in Science Teaching*, Vol. 40, No. 9, pp. 835–868. https://doi.org/10.1002/tea.10113

Bursal, M. (2010) 'Turkish pre-service elementary teachers' self-efficacy beliefs regarding mathematics and science teaching', *International Journal of Science and Mathematics Education'*, Vol. 8, No. 4, pp. 649–666. https://doi.org/10.1007/s10763-009-9179-6

Celik, S. and Bayrakçeken, S. (2006) 'The Effect of a "Science, Technology and Society" Course on Prospective Teachers' Conceptions of the Nature of Science', *Research in Science & Technological Education*, Vol. 24, No. 2, pp. 255–273. https://doi.org/10.1080/02635140600811692

Chai, C. S., Teo, T. K. G., and Lee, C. B. (2010) 'Modelling the Relationships Among Beliefs About Learning, Knowledge, and Teaching of Pre-Service Teachers in Singapore', *The Asia-Pacific Education Researcher*, Vol. 19, No. 1, pp. 25–42. https://doi.org/10.3860/taper.v19i1.1507

Chen, J. A. and Pajares, F. (2010) 'Implicit Theories of Ability of Grade 6 Science Students: Relation to Epistemological Beliefs and Academic Motivation and Achievement in Science', *Contemporary Educational Psychology*, Vol. 35, No. 1, pp. 75–87. https://doi.org/10.1016/j.cedpsych.2009.10.003

Chen, J. A., Morris, D. B. and Mansour, N. (2014) 'Science Teachers' Beliefs: Perceptions of Efficacy and the Nature of Scientific Knowledge and Knowing' in Fives, H. and Gill, M. G. (ed.), International Handbook of Research on Teachers' Beliefs: Routledge.

Choi, S. and Ramsey, J. (2009) 'Constructing Elementary Teachers' Beliefs, Attitudes, and Practical Knowledge Through an Inquiry-Based Elementary Science Course', *School Science and Mathematics,* Vol. 109, No. 6, pp. 313–324. https://doi.org/10.1111/j.1949-8594.2009.tb18101.x

DeBoer, G. E. (2000) 'Scientific Literacy: Another Look at its Historical and Contemporary Meanings and its Relationship to Science Education Reform', *Journal of Research in Science Teaching*, Vol. 37, No. 6, pp. 582–601. https://doi.org/10.1002/1098-2736(200008)37:6<582::AID-TEA5>3.0.CO;2-L

Donnelly, J. (1999) 'Interpreting Differences: The Educational Aims of Teachers of Science and History, and their Implications', *Journal of Curriculum Studies*, Vol. 31, No. 1, pp. 17–41. https://doi.org/10.1080/002202799183278

Fetters, M. D., Curry, L. A. and Creswell, J. W. (2013) 'Achieving Integration in Mixed Methods Designs — Principles and Practices', *Health Services Research,* Vol. 48, No 6pt2, pp. 2134–2156. https://doi.org/10.1111/1475-6773.12117

García, M. R. and Sebastián, C. (2011) 'Creencias Epistemológicas De Estudiantes De Pedagogía En Educación Parvularia, Básica Y Media:¿ Diferencias En La Formación Inicial Docente?', *Psykhe (Santiago)*, Vol. 20, No. 1, pp. 29–43. https://doi.org/10.4067/s0718-22282011000100003

Goodman, J. (1988) 'Constructing a Practical Philosophy of Teaching: A Study of Pre-Service Teachers' Professional Perspectives', *Teaching and Teacher Education*, Vol. 4, No. 2, pp. 121–137. https://doi.org/10.1016/0742-051x(88)90013-3

Guilfoyle, L., McCormack, O. and Erduran, S. (2020) 'The" Tipping Point" for Educational Research: The Role of Pre-Service Science Teachers' Epistemic Beliefs in Evaluating the Professional Utility of Educational Research', *Teaching and Teacher Education*, Vol. 90, pp. 103033. https://doi.org/10.1016/j.tate.2020.103033

Guo, J., Hu, X., Marsh, H. W. and Pekrun, R. (2022) 'Relations of Epistemic Beliefs with Motivation, Achievement, and Aspirations in Science: Generalizability Across 72 Societies', *Journal of Educational Psychology*, Vol. 114, No. 4, pp. 734–751. https://doi.org/10.1037/edu0000660

Gustafson, B. and Rowell, P. (1995) 'Elementary Pre-service Teachers: Constructing Conceptions About Learning Science, Teaching Science and The Nature of Science', *International Journal of Science Education*, Vol. 17, No. 5, pp. 589–605. https://doi.org/10.1080/0950069950170504

Hashweh, M. Z. (1996). Effects of Science Teachers' Epistemological Beliefs in Teaching. *Journal of Research in Science Teaching*, Vol. 33, No. 1, pp. 47–63. https://doi.org/10.1002/(SICI)1098-2736(199601)33:1<47::AID-TEA3>3.0.CO;2-P

Hidayatullah, A. and Csíkos, C. (2023) 'Exploring Students' Mathematical Beliefs: Gender, Grade, and Culture Differences', *Journal on Efficiency and Responsibility in Education and Science*, Vol. 16, No. 3, pp. 186–195. https://doi.org/10.7160/eriesj.2023.160303

Hofer, B. K., and Pintrich, P. R. (1997) 'The Development of Epistemological Theories: Beliefs About Knowledge and Knowing and their Relation to Learning', *Review of Educational Research*, Vol. 67, No. 1, pp. 88–140. https://doi.org/10.3102/00346543067001088

Irez, S. (2006) 'Are We Prepared? An Assessment of Pre-Service Science Teacher Educators' Beliefs About Nature of Science', *Science Education*, Vol. 90, No. 6, pp. 1113–1143. https://doi.org/10.1002/sce.20156

Johnson, C. C. (2006) 'Effective Professional Development and Change in Practice: Barriers Science Teachers Encounter and Implications for Reform', *School Science and Mathematics*, Vol. 106, No. 3, pp. 150–161. https://doi.org/10.1111/j.1949-8594.2006.tb18172.x

Justi, R. and van Driel, J. (2006) 'The Use of the Interconnected Model of Teacher Professional Growth for Understanding the Development of Science Teachers' Knowledge on Models and Modelling', *Teaching and Teacher Education,* Vol. 22, No. 4, pp. 437–450. https://doi.org/10.1016/j.tate.2005.11.011

Kelly, M. (2021) 'Epistemology, Epistemic Belief, Personal Epistemology, and Epistemics: A Review of Concepts as They Impact Information Behavior Research', *Journal of the Association for Information Science and Technology*, Vol. 72, No. 4, pp. 507–519. https://doi.org/10.1002/asi.24422

Keys, C. W. and Bryan, L. A. (2001) 'Co-constructing Inquiry-Base Science with Teachers: Essential Research for Lasting Reform', *Journal of Research in Science Teaching*, Vol. 38, No. 6, pp. 631–645. https://doi.org/10.1002/tea.1023

Kim, H., and Hannafin, M. (2008) 'Situated Case-Based Knowledge: An Emerging Framework for Prospective Teacher Learning', *Teaching and Teacher Education,* Vol. 24, No. 7, pp. 1837–1845. https://doi.org/10.1016/j.tate.2008.02.025

Koballa Jr., T.R., Crawley, F.E. and Shrigley, R.L. (1990) 'A summary of science education-1988', *Science Education*, Vol. 74, No. 3, pp. 369–381.

Küçükaydin, M.A. and Gökbulut, Y. (2020) 'The Impact of a Research Methods Course on Teacher Candidates' Epistemological Beliefs', *Australian Journal of Teacher Education (Online),* Vol. 45, No. 3, pp. 18–33. https://doi.org/10.14221/ajte.2020v45n3.2

Lederman, N. G. (1992) 'Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research', *Journal of Research in Science Teaching*, Vol. 29, No. 4, pp. 331–359. https://doi.org/10.1002/tea.3660290404

Lederman, N.G. (2013) 'Nature of science: past, present, and future', in Fraser, B.J., Tobin, K.G. and McRobbie, C.J. (Ed.) *Handbook of research on science education*. Vol. 2. New York: Routledge, pp. 831–879.

Liang, L. L., Chen, S., Chen, X., Kaya, O. N., Adams, A. D., Macklin, M. and Ebenezer, J. (2009), 'Preservice Teachers' Views About Nature of Scientific Knowledge Development: An International Collaborative Study', *International Journal of Science and Mathematics Education*, Vol. 7, No. 5, pp. 987–1012. https://doi.org/10.1007/s10763-008-9140-0

Lindblad, S., and Sahlström, F. (2001) *Interaktion i pedagogiska sammanhang [Interaction in a pedagogical context; in Swedish],* Stockholm: Liber.

Luft, J. A., and Roehrig, G. H. (2007) 'Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview', *The Electronic Journal of Science Education*, Vol. 11, No. 2, pp. 38–63.

Madronio, E. (2015) *Chemistry Learning Environment, Attitude and Proficiency of Generation Z Learners*, Saint Mary's University: Philippines.

Mansour, N. (2009) 'Science Teachers' Beliefs and Practices: Issues, Implications and Research Agenda', *International Journal of Environmental and Science Education*, Vol. 4, No. 1, pp. 25–48. Retrieved from: https://files.eric.ed.gov/fulltext/EJ884384.pdf

Markic, S. and Eilks, I. (2008) 'A Case Study on German First Year Chemistry Student Teachers Beliefs About Chemistry Teaching, and their Comparison with Student Teachers from other Science Teaching Domains', *Chemistry Education Research and Practice*, Vol. 9, No. 1, pp. 25–34. https://doi.org/10.1039/B801288C

Mellado, V. (1998) 'The Classroom Practice of Pre-Service Teachers and their Conceptions of Teaching and Learning Science', *Science Education,* Vol. 82, No. 2, pp. 197–214. https://doi.org/10.1002/(SICI)1098-237X(199804)82:2<197::AID-SCE5>3.0.CO;2-9

Millar, R. (2006) 'Twenty First Century Science: Insights from the Design and Implementation of a Scientific Literacy Approach in School Science', *International Journal of Science Education*, Vol. 28, No. 13, pp. 1499–1521. https://doi.org/10.1080/09500690600718344

Milner, A. R., Sondergeld, T. A., Demir, A., Johnson, C. C. and Czerniak, C. M. (2012) 'Elementary Teachers' Beliefs about Teaching Science and Classroom Practice: An Examination of Pre/Post NCLB Testing in Science', *Journal of Science Teacher Education*, Vol. 23, No. 2, 111–132. https://doi.org/10.1007/s10972-011-9230-7

Nott, M. and Wellington, J. (1993) 'Science Education Notes: Your Nature of Science Profile - An Activity for Science Teachers', *School Science Review,* Vol. 75, No. 270, pp. 109–112.

Olafson, L. and Schraw, G. (2010) 'Beyond Epistemology: Assessing Teachers' Epistemological and Ontological Worldviews', in Bendixen, L. D. and Feucht, F. C. (ed.), *Personal Epistemology in the Classroom: Theory, Research, and Implications for Practice,* Cambridge, UK: Cambridge University Press.

Önen, A. S. (2011) 'The Effect of Candidate Teachers' Educational and Epistemological Beliefs on Proffessional Attitudes', *Journal of Education*, Vol. 41, No. 41, pp. 293–301. Retrieved from: https://dergipark.org.tr/tr/download/article-file/87405

Oppell, M. V. and Aldridge, J. (2015) 'Teacher Beliefs and Education Reform in Abu Dhabi: 21st Century Skills?', *Muğla Sıtkı Koçman Üniversitesi Eğitim Fakültesi Dergisi*, Vol. 1, No. 3. Retrieved from: http://www.edergi.mu.edu.tr/index.php/efdergi/article/view/116

Pajares, M. F. (1992) 'Teachers' Beliefs and Educational Research: Cleaning Up a Messy Construct', *Review of Educational Research*, Vol. 62, No. 3, pp. 307–332. https://doi.org/10.3102/00346543062003307

Patrick, H. and Pintrich, P. R. (2001) 'Conceptual Change in Teachers' Intuitive Conceptions of Learning, Motivation, and Instruction: The Role of Motivational and Epistemological Beliefs', in Torff, B. and Sternberg, R. J. (ed.), *Understanding and teaching the intuitive mind: Student and teacher learning*, Mahwah: Lawrence Erlbaum.

Patton, M. Q. (1990) *Qualitative Evaluation and Research Methods,* 2nd Ed., Beverly Hills, CA: Sage.

Polly, D., McGee, J. R., Wang, C., McGee, Jennifer R, R. G., Pugalee, D. K. and Johnson, S. (2013) 'The Association Between Teachers' Beliefs, Enacted Practices, and Student Learning in Mathematics', *Mathematics Educator*, Vol. 22, No. 2, pp. 11–30. https://doi.org/10.63301/tme.v22i2.1979

Putnam, R. T. and Borko, H. (1997) 'Teacher learning: Implications of new views of cognition', in Biddle, B. J., Good, T. L. and Goodson, I. F. (ed.*), International Handbook of Teachers and Teaching,* Netherlands: Springer.

Qablan, A., Jaradat, S. and Al-Momani, I. (2010) 'Elementary Science Teachers' Perceptions of Educational Reform in Relation to Science Teaching in Jordan', *Jordan Journal of Educational Sciences*, Vol. 6, No. 2, pp. 161–173. Retrieved from: https://jjes.yu.edu.jo/index.php/jjes/article/view/949

Schraw, G. and Olafson, L. (2002) 'Teachers' Epistemological World Views and Educational Practices', *Journal of Cognitive Education and Psychology*, Vol. 3, No. 2, pp. 178–235. https://doi.org/10.1891/194589503787383109

Shinde, M. B. and Karekatti, T. (2012) 'Pre-Service Teachers' Beliefs About Teaching English to Primary School Children', *International Journal of Instruction*, Vol. 5, No. 1, pp. 69–86. Retrieved from: https://files.eric.ed.gov/fulltext/ED529115.pdf

Smith, B. P. (2010) 'Instructional Strategies in Family and Consumer Sciences: Implementing the Contextual Teaching and Learning Pedagogical Model', *Journal of Family and Consumer Sciences Education,* Vol. 28, No. 1, pp. 23–38.

Smith, L. K. (2005) 'The Impact of Early Life History on Teachers' Beliefs: In-School and Out-Of-School Experiences as Learners and Knowers of Science', *Teachers and Teaching*, Vol. 11, No. 1, pp. 5–36. https://doi.org/10.1080/1354060042000337075

Soleimani, N. (2020) 'ELT Teachers' Epistemological Beliefs and Dominant Teaching Style: A Mixed Method Research', *Asian-Pacific Journal of Second and Foreign Language Education*, Vol. 5, No. 1, pp. 1–20. https://doi.org/10.1186/s40862-020-00094-y

Splitter, L. J. (2010) 'Dispositions in Education: Nonentities Worth Talking About', *Educational Theory*, Vol. 60, No. 2, pp. 203–230. https://doi.org/10.1111/j.1741-5446.2010.00354.x

Tebabal, A. and Kahssay, G. (2011) 'The Effects of Student-Centered Approach in Improving Students' Graphical Interpretation Skills and Conceptual Understanding of Kinematical Motion', *Latin American Journal of Physical Education,* Vol. 5, No. 2, pp. 374–381. Retrieved from: http://www.lajpe.org/june11/9_LAJPE_509_Ambelu_Tebabal_preprint_corr_f.pdf

Trigwell, K. and Prosser, M. (2004) 'Development and Use of the Approaches to Teaching Inventory', *Educational Psychology Review*, Vol. 16, No. 4, pp. 409–424. https://doi.org/10.1007/s10648-004-0007-9

Tsai, C.-C. (2002) 'Nested Epistemologies: Science Teachers' Beliefs of Teaching, Learning and Science', *International Journal of Science Education*, Vol. 24, No. 8, pp. 771–783. https://doi.org/10.1080/09500690110049132

Tsai, C.-C. (2006) 'Teachers' Scientific Epistemological Views: The Coherence with Instruction and Students' Views', *Science Education*, Vol. 91, No. 2, pp. 222–43. https://doi.org/10.1002/sce.20175

Uslu, O. (2018) 'Analysis of Variables That Affect Teaching Learning Approaches and Epistemological Beliefs of Pre-Service Teachers by Structural Equation Model', *International Journal of Research in Education and Science*, Vol. 4, No. 1, pp. 237–251. https://doi.org/10.21890/IJRES.383167

Van Driel, J. H., Bulte, A. M. W. and Verloop, N. (2007) 'The Relationships Between Teachers' General Beliefs About Teaching and Learning and their Domain Specific Curricular Beliefs', *Learning and Instruction*, Vol. 17, No. 2, pp. 156–171. https://doi.org/10.1016/j.learninstruc.2007.01.010

Vieira, R. D., Melo, V. D., Avraamidou, L. and Lobato, J. A. (2017) 'Reconceptualizing Scientific Literacy: The Role of Students' Epistemological Profiles', *Education Sciences*, Vol. 7, No. 2, p. 47. https://doi.org/10.3390/EDUCSCI7020047

Wallace, C. S. and Kang, N. (2004) 'An Investigation of Experienced Secondary Science Teachers' Beliefs About Inquiry: An Examination of Competing Belief Sets', *Journal of Research in Science Teaching*, Vol. 41, No. 9, pp. 936–960. https://doi.org/10.1002/tea.20032

Yalvac, B., Tekkaya, C., Cakiroglu, J. and Kahyaoglu, E. (2007) 'Turkish Pre-Service Science Teachers' Views on Science–Technology–Society Issues', *International Journal of Science Education*, Vol. 29, No. 3, pp. 331–348. https://doi.org/10.1080/09500690600708667

Yildizli, H. (2019) 'Structural Relationships among Teachers' Goal Orientations for Teaching, Self-Efficacy, Burnout, and Attitudes towards Teaching', *Journal on Efficiency and Responsibility in Education and Science,* Vol. 12, No. 4, pp. 111–125. https://doi.org/10.7160/eriesj.2019.120402

Yucel, R. (2018) 'Scientists' Ontological and Epistemological Views About Science from the Perspective of Critical Realism', *Science and Education,* Vol. 27, No. 5–6, pp. 407–433. https://doi.org/10.1007/S11191-018-9983-X