JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

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CRITICAL AND CREATIVE THINKING IN SCIENCE TEACHERS: THE MODERATING ROLE OF EPISTEMOLOGY

Savaş Varlık

Abstract. *This study examines the role of epistemological beliefs in moderating the relationship between critical and creative thinking among science teachers. It aims to explore how advancements in understanding knowledge influence these cognitive skills. The primary focus is on the extent to which epistemological beliefs impact critical and creative thinking, highlighting the need for a deeper grasp of knowledge to foster these skills. A mixed-methods approach is used, combining qualitative and quantitative data within a pragmatic framework to provide a comprehensive view. The sample includes science teachers from Selçuklu, Meram, and Karatay districts in Konya, Türkiye. Quantitative data were gathered using the Epistemological Beliefs Scale, the Critical Thinking Scale, and the Creative Thinking Scale. Results show that epistemological beliefs significantly influence critical and creative thinking, suggesting that these skills are closely tied to epistemological development. Qualitative findings support this, indicating that a solid epistemological foundation is essential for both types of thinking. Additionally, the study finds that authoritarian teaching methods suppress critical thinking, while student-centered strategies enhance it. To promote critical and creative thinking, science teachers should develop their epistemological beliefs and create an environment that encourages open discussion and diverse perspectives.*

Keywords: *critical and creative thinking, epistemological development, mixed-methods research, science education*

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Introduction

Due to the nature of science, it is not solely based on experimental data. This is because conceptual change has also found its place in the formation of knowledge. The concept of the nature of science is used to express assumptions about "scientific knowledge and the development of scientific knowledge" (Allchin, 2013; Lederman & Lederman, 2004; McComas, 2002; Tan & Temiz, 2003). The nature of knowledge, on the other hand, is explained through the branch of philosophy called epistemology. Epistemology is an important branch of philosophy that attempts to explain the reality of knowledge as a concept, the definition of knowledge, and the process of acquiring knowledge (Arslan, 2017; Arslantaş, 2016; Demir & Akınoğlu, 2010; Yazıcı, 2016). Epistemological beliefs are a set of beliefs about knowledge and knowing (Conley et al., 2004; Oschatz, 2015). For a proposition to be considered knowledge, there must be belief in that proposition, and its truth must be justified (Başdemir, 2011; Hofer, 2001; Reiner, 2000). Individuals who believe that knowledge is relative and can change over time have a developed epistemological perspective (Schommer, 1993; Schommer, 1994; Schommer et al., 1992). In contrast, individuals with undeveloped epistemological perspectives see knowledge as absolute and unchanging (Kuzgun & Deryakulu, 2017). The development of epistemological beliefs enables individuals to develop critical and creative thinking skills (Demir & Akınoğlu, 2010; Lumsdaine & Lumsdaine, 1995). Critical thinking is a higher-order thinking skill that involves a decision-making process about what to do or believe in a given context (Facione, 1998; Janjua et al., 2014). It actually involves the use of different thinking skills (Lai, 2011). On the other hand, argumentation is one of the most important features of critical thinking. In science education, argumentation not only helps in constructing a logical process between new ideas and prior knowledge but also enhances creative thinking (Sadler, 1989). Furthermore, critical thinking is a reasoned, purposeful, and goal-directed set of actions. It encompasses problem-solving, probability calculation, decision-making, and the steps of problem-solving (Alper, 2010). Therefore, critical thinking requires being open to mental change and having alternative perspectives (Maloney, 2007; Tümkaya et al., 2009). The beginning of critical thinking is asking questions and obtaining results by answering the question (Nussbaum & Edwards, 2011). Belief in the results is a criterion for critical thinking. If you do not believe in the results, it means that you have not internalized the logic you

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

have created and that something is missing (Nosich, 2012). Teachers who cannot think critically may have fixed ideas about subjects and may not accept that knowledge can be updated over time (Toulmin, 2003). Therefore, their mental organizations are scattered, and they have difficulty reaching the truth (Facione, 1990). This situation can also hinder creative thinking in individuals. Creative thinking is defined as generating various ideas in the face of problems, looking at problems from different perspectives, and producing original ideas (Emanuel & Challons-Lipton, 2012). However, emotional, cultural, perception and discrimination, rigid programs, and cultural elements hinder creative thinking in individuals (Gökalp, 2018). In addition to these obstacles, in schools, the priority given to knowledge transfer prevents the development of creative thinking skills (Aslan et al., 1997). Therefore, teacher-student interaction should be motivating for students and prioritize creative thinking (Torrance, 1968: Torrance, 1995; Wicaksono and Wasis, 2017). In fact, teachers are guides in the teaching process, not just knowledge transmitters. Given the claim that knowledge is relatively variable, complex information should be provided to students in a way that captures their attention and is related to real life (Sungur, 2001). In this way, updated knowledge can be constructed with students, valuing new ideas (Saliceti, 2015).

Research Problem

During Science Research Symposium in 2023, a question was raised regarding the occurrence of critical and creative thinking in the absence of epistemological development among science teachers. This inquiry underscored the necessity for further investigation to determine whether existing research adequately addresses this topic and whether there is a gap in the literature. Preliminary reviews of relevant studies reveal that research on epistemological beliefs has primarily concentrated on the nature of knowledge (Perry Jr., 1968) and the processes of knowledge acquisition (Schommer, 1990). Additionally, existing studies have often examined epistemological beliefs in isolation (Brownlee, 2001; Chai et al., 2006; Chan & Elliott, 2000; Gill et al., 2000; Howard et al., 2000; Jehng et al., 1993; Schommer & Dunnel, 1997; Schommer & Walker, 1997). This observation suggests a potential gap in the literature concerning the correlation between epistemological development and the cultivation of critical and creative thinking in science educators, warranting further exploration. Existing research has explored the intersection of epistemological beliefs with various educational constructs, including learning strategies (Deryakulu, 2004), philosophical approaches (Kahramanoğlu & Özbakış, 2018), thinking styles (Schommer-Aikins & Hutter, 2002), learning approaches (Phan, 2008), academic achievement (Rodriguez & Cano, 2006), metacognition (Bedel & Çakır, 2013), teaching competencies (Vecaldo, 2017), and self-efficacy beliefs (Gürol et al., 2010). Furthermore, studies related to critical thinking skills (Akbıyık & Seferoğlu, 2006; Alper, 2010; Çakmak, 2010; Emir, 2012; Gök & Erdoğan, 2011; Hançer et al., 2003; Karagöl & Bekmezci, 2015; Kırıkkaya & Altan, 2011; Tural & Seçgin, 2012; Tümkaya et al., 2009) have generally focused on teachers and students as a collective group. Research on creative thinking has predominantly examined students and teachers across different educational levels (Erol & Taş, 2010; İşleyen & Küçük, 2013; Siew et al., 2017; Runco et al., 2017). Regarding teaching methods, techniques, and strategies related to creative thinking, several studies are available (Al-Shaikh &Alsalhi, 2023; Wible, 2020; Zhan et al., 2022). However, a closer examination of these studies reveals that their primary focus is on the nature of knowledge and the processes involved in acquiring knowledge within the context of epistemological beliefs. Furthermore, in these studies, the implications of what would happen when there was no epistemological belief or development were often overlooked. Even the analysis of how critical thinking and creative thinking would occur in the absence of epistemological development had not been systematically investigated. Studies on critical thinking and creative thinking typically addressed these topics separately, leaving a noticeable gap in the field. Therefore, it is essential for educational institutions and science teachers that this gap is addressed and filled. Nevertheless, the challenge lies in determining how to address this gap. This challenge is exacerbated by the philosophical perspectives that may be taken when conducting this research. For instance, adopting a realist philosophy as the foundational philosophy and a functional paradigm as the paradigmatic approach in this research would assume that knowledge is relatively unchanging. Conversely, adopting an idealist philosophy and a hermeneutic paradigm as the paradigmatic approach would be based on the belief that knowledge exists as constructed and accepted within an individual's mind. Therefore, conducting this research solely from a quantitative or qualitative standpoint would lead to an epistemological dilemma from the outset. Hence, it is necessary to merge both idealism and realism under the umbrella of pragmatism in the methodology of this research. Moreover, this approach, which combines both quantitative and qualitative methods, allows for a comprehensive view of the bigger picture. This way, the results of this research clearly demonstrate, within the framework of "what-how-why," what happens to

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

critical and creative thinking when there is no epistemological development in science teachers. Additionally, this research provides an in-depth perspective on science teachers' levels of epistemological development, critical thinking, and creative thinking perceptions. Determining the levels of epistemological development in science teachers is crucial for the education ministries of countries. The results of this research can guide educational practices, including teacher training, curriculum development, in-service training programs, and teaching methods, in topics related to the development of advanced skills. This research sheds light on how 21st-century skills, such as critical thinking and creative thinking, are shaped in relation to epistemological development in science teachers, as the primary aim of this research is to examine the correlation between epistemological development in science teachers and the occurrence of critical and creative thinking in their teaching practices. Specifically, the study aimed to determine how the absence of epistemological development affects the ability of science teachers to foster critical and creative thinking in their students. To achieve this aim, the following research questions were addressed.

Research Questions

1. Does epistemological belief play a moderator role in the perception of critical thinking and creative thinking among science teachers?
2. How are epistemological beliefs, critical thinking, and creative thinking defined when evaluated from the perspective of science teachers?
3. How do critical thinking and creative thinking occur when there is no epistemological development, according to the perspective of science teachers? Why?

Research Methodology

Research Design

This study employed a mixed-methods approach, integrating both qualitative and quantitative data. As these data are collected concurrently, the research design follows a convergent parallel format [MMR(f) = quantitative + qualitative]. The qualitative part of the study uses a case study design, which is a qualitative research approach that collects in-depth information and constructs case themes (Yin, 2018). The quantitative part employs a descriptive survey design, which is a quantitative research approach aimed at describing the existing situation or phenomenon as it is (Creswell & Guetterman, 2019). The research is conducted within the philosophical framework of pragmatism, based on the principle of utility (Gunbayi & Sorm, 2020). This framework allows for a comprehensive identification of the problem from both functional and interpretive perspectives. The study focuses on science teachers working in the Selçuklu, Meram, and Karatay districts of Konya Province, Türkiye. It examines the moderation role of epistemology in the correlation between critical thinking and creative thinking among these teachers. The research includes both quantitative data from surveys and qualitative data from case studies. The research was conducted from September 25, 2023, to June 10, 2024.

Sampling

The quantitative sample of the study consisted of science teachers working in the Selçuklu, Meram, and Karatay districts of Konya Province, Türkiye. According to data from the Konya Provincial Directorate of National Education, the number of science teachers in the Selçuklu district is 167, in the Meram district, 127, and in the Karatay district, 141, totaling 435 teachers. To obtain a representative sample with a confidence level of α= .05, a sample size of 204 science teachers was required (Frey, 2018). Given the even distribution of teachers across the districts, the cluster sampling method determined a stratum coefficient of [204/435= .468]. Based on this calculation, the study included approximately 66 science teachers from the Selçuklu district, 60 from the Meram district, and 79 from the Karatay district. The qualitative sample was selected using purposive sampling from the quantitative sample. The inclusion criteria were having at least a graduate-level thesis or research article related to the epistemological development of science teachers and at least fifteen years of professional experience. Nine science teachers meeting these criteria were included in the qualitative phase of the research. Of the science teachers participating in the study, 44.3 % (n = 108) were female and 55,7 % (n = 136) were male. Age distribution was 31.6% (n = 77) 27-38 years, 33.6% (n = 82), 34.8% (n = 85) 49 years and above. Their professional

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

seniority is 29,5% (n = 72) 6-11 years, 48.4% (n = 118) 12-19 years, 22.1% (n = 54) 20 years and above. In terms of career distribution, 14.3 % (n = 35) were teachers, 63,5 % (n=155) were specialist teachers, 22.1 % (n = 54) were head teachers. 30,3 % (n=74) of science teachers work in Karatay district, 29.5 % (n = 72) in Meram district, 40.2 % (n = 98) in Selçuklu district. This research was conducted with the decision taken by Akdeniz University Social and Human Sciences Scientific Research and Publication Ethics Committee on 21.09.2023 with the number 406.

Data Collection Tool

In the quantitative part of the study, three scales were used, while in the qualitative part, a semi-structured interview form was used. The Epistemological Beliefs Scale, developed by Schommer (1990) and adapted to Turkish by Aypay (2011), was employed in the quantitative part. The Critical Thinking Scale was developed by Özdemir (2015), and the Creative Thinking Scale was developed by Özgenel & Çetin (2017). The measurement tools were applied to Science teachers using a "1-Strongly Disagree, 5-Strongly Agree". Since these measurement tools were used based on a single factor, they were subjected to Harman's single-factor test. According to the test results, the Epistemological Beliefs Scale explains 30.36% of the total variance in a single factor, the Critical Thinking Scale explains 43.30%, and the Creative Thinking Scale explains 38.73%. In other words, the explained variances do not exceed the 50% threshold. This confirms that there is no common method variance in the scales used in the research (Aguirre-Urreta & Hu, 2019; Harman, 1968). After this test, the validation of the measurement tools was conducted. The Epistemological Beliefs Scale had a CMIN/DF value of 2.822, a p-value of .024, a GFI value of .982, a CFI value of .983, an RMSEA value of .087, an SRMR value of .012, and a Cronbach's alpha value of .866. The Creative Thinking Scale had a CMIN/DF value of 2.533, a p-value of .055, a GFI value of .988, a CFI value of .981, an RMSEA value of .079, an SRMR value of .024, and a Cronbach's alpha value of .928. The Critical Thinking Scale had a CMIN/DF value of 1.712, a p-value of .144, a GFI value of .989, a CFI value of .997, an RMSEA value of .054, an SRMR value of .004, and a Cronbach's alpha value of .948. Since these values are smaller than both independent and saturated model values, it indicates that the measurement models used in the research are close to reality (Collier, 2020). Cronbach's alpha values above .700 also indicate that the measurement tools used in the research are reliable (Stockemer, 2019). In the qualitative part of the research, a semi-structured interview form was used as the data collection tool. The validity of the semi-structured interview form was ensured through internal and external validity, and the expressions of Science teachers in the descriptive analysis were reported verbatim. In the research, the names of the interviewed Science teachers were coded as "A," "B," "C," "D," "E," "F," "G," "H," and "I."

Data Analysis

Multivariate assumptions, including multivariate normality, linearity, multicollinearity, homoscedasticity, and independence (autocorrelation), were examined. It was determined that all assumptions for multivariate data were met. For the measurement values of the scales, skewness and kurtosis values within the reference range of ±3 were considered. Accordingly, the skewness value of the Epistemological Beliefs Scale was -1.294, the kurtosis value was 1.928; the skewness value of the Critical Thinking Scale was -.293, and the kurtosis value was -.558; the skewness value of the Creative Thinking Scale was -1.821, and the kurtosis value was 2.962. Based on these values, it can be stated that the measurement tools used in the research followed a normal distribution (Denis, 2019). In the research, the exogenous variable "critical thinking" and the endogenous variable "creative thinking" were used, with the mediating variable "epistemological belief" to explore the causal correlation. Mediation analysis is a causal model used to uncover when or why the effect of critical thinking on creative thinking decreases or increases with epistemological belief, or to reveal the reason for this effect (Hayes, 2018). Qualitative data analysis is categorized as "theme analysis, descriptive analysis, content analysis, and analytic generalization" (Gunbayi, 2023, p.1). Accordingly, interviews conducted with Science teachers were subjected to theme, descriptive, and content analyses, and analytic generalization was performed in the discussion section. The codings performed with NVIVO were evaluated by two experts, and the inter-coder reliability coefficient was calculated. According to this, the κ value was .767, the t value was 3.300, and the p-value was .001, indicating a high level of reliability among coders (Landis & Koach, 1977).

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Research Results

Quantitative Results

The distribution levels of critical thinking, creative thinking, and epistemological belief are given in Table 1, and findings on the moderator role of epistemological belief in the effect of critical thinking on creative thinking are given in Table 2.

Table 1
Results of Descriptive Statistical Analysis

Scales	Epistemological Belief	Critical Thinking	Creative Thinking	*M*	*SD*
Epistemological Belief	-			3.79	0.361
Critical Thinking	.618**	-		3.98	0.470
Creative Thinking	.366**	.230**	-	3.54	0.760

Note. Bootstrap *p* values are presented ($p < .01$, $p < .001$).

When Table 1 regarding the research findings is examined, it is observed that science teachers tend to have increasing levels of critical thinking ($M = 3.98$, $SD = 0.47$), epistemological beliefs ($M = 3.79$, $SD = 0.36$), and creative thinking ($M = 3.54$, $SD = 0.76$). When the correlations between variables are examined, a statistically significant and positive correlation is found between epistemological beliefs and critical thinking ($r = .62$, $p < .01$), a statistically significant and positive correlation between epistemological beliefs and creative thinking ($r = .37$, $p < .01$), and a statistically significant and positive correlation between critical thinking and creative thinking ($r = .23$, $p < .01$).

Table 2
Results of An Analysis on The Moderator Role of Epistemological Belief in The Effect of Critical Thinking on Creative Thinking

Variables	*β*	*SE*	*t*	*p*	Creative Thinking (Y)	
					LLCI	*ULCI*
Critical Thinking (X)	.309	.136	2.270	.024*	0.041	0.578
Epistemological Belief (W)	.957	.161	5.956	.001***	0.640	1.273
X*W (Interaction)	.962	.216	4.448	.001***	0.536	1.389

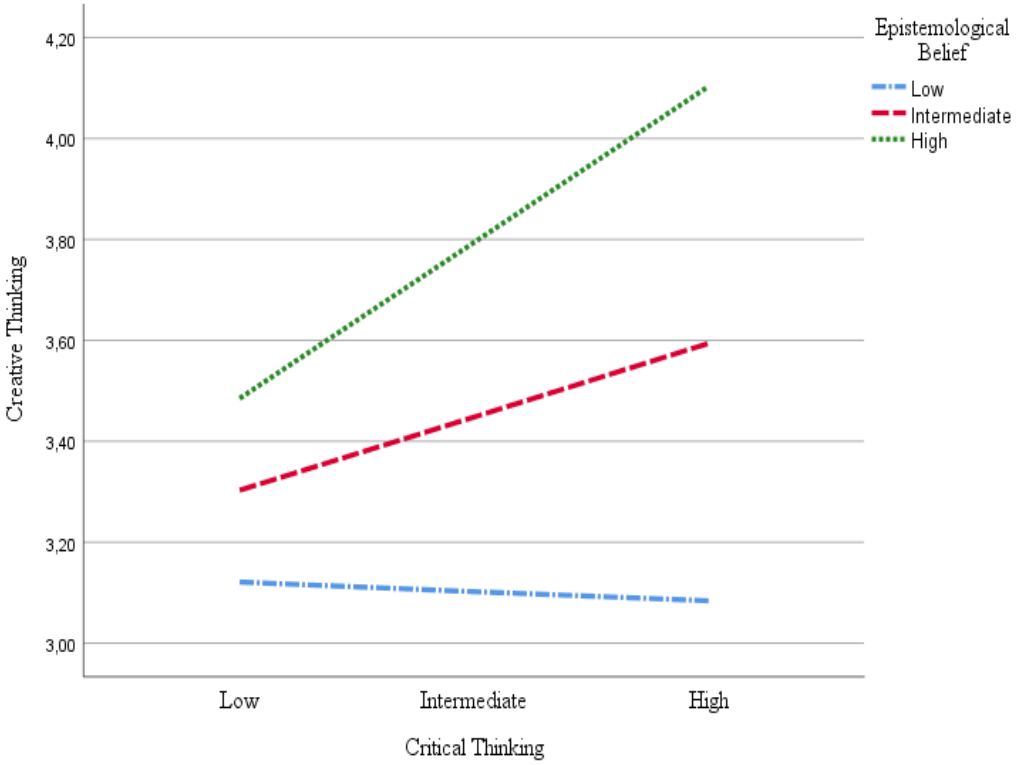
Note. Standardized values (β) are presented. Bootstrap *p* values are presented (*: $p < .01$, **: $p < .001$). *LLCI* = Lower Confidence Interval; *ULCI* = Upper Confidence Interval.

When Table 2 regarding the research findings is examined, it can be seen that critical thinking affects creative thinking [β = .309]. Epistemological beliefs affect creative thinking [β = .957]. The interaction term consisting of critical thinking and epistemological beliefs also affects creative thinking [β = .962]. The model's R-value is .447, and the R^2 value is .200. This value indicates that the variables included in the model contribute to 20.0% of the variance in the endogenous variable, creative thinking. The slope diagram for the model is provided in Figure 1.

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 2
Slope diagram of the moderator effect of epistemological belief



When examining the slope diagram for the model in Figure 1, it can be observed that when the epistemological beliefs of science teachers are at a low level, the correlation between critical thinking and creative thinking is insignificant, and the correlation is negative [β = -.038, t = -.321, p = .748, 95% CI (-0.273, 0.196)]. When the epistemological beliefs of science teachers are at a moderate level, the correlation between critical thinking and creative thinking is significant [β = .309, t = 2.270, p = .024, 95% CI (0.041, 0.578)]. When the epistemological beliefs of science teachers are at a high level, the correlation between critical thinking and creative thinking is significant [β = .657, t = 3.504, p = .001, 95% CI (0.288, 1.026)]. Based on the beta coefficients in the findings, it can be concluded that when the epistemological beliefs of science teachers are high [β = .657], their levels of critical thinking and creative thinking also increase. This finding indicates that without epistemological development in science teachers, critical thinking and creative thinking cannot be fostered.

Qualitative Results

When evaluated from the perspective of science teachers, the findings related to how critical thinking, creative thinking, and epistemological belief are defined are presented in Tables 3, 4, and 5. The findings regarding how critical thinking and creative thinking would be in the absence of epistemological development among science teachers are presented in Table 6.

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 3
Categories and Sub-Themes Related to Critical Thinking

Category	Subtheme	A	B	C	D	E	F	G	H	I
Independent Thinking and Problem Solving	Analyze and solve problems	✓								✓
	Gain problem-solving skills					✓				
	Effectively solve everyday problems					✓				
Questioning Knowledge and Conscious Teaching	Distinguishing between right and wrong		✓							✓
	Become informed and knowledgeable teachers		✓							
	A critical capability in an age of access to information				✓					
Different Perspectives, Empathy and Communication	Promoting empathy			✓						
	Understanding different perspectives			✓						✓
	Communicate and empathize better			✓						
Criticism and Personal Development	Encourage greater openness to criticism						✓		✓	
	To contribute to personal development		✓				✓			
	Provide an opportunity to see and correct errors						✓			
Synthesizing Information and Generating Arguments	Strengthen their ability to synthesize information		✓					✓		
	The ability to combine different information							✓		
	Constructing arguments based on knowledge				✓				✓	

When examining the findings related to the categories and sub-themes created for critical thinking in Table 3, concerning the overarching theme of critical thinking, the following sub-themes emerged:

Independent Thinking and Problem Solving - This category encompasses themes related to analyzing and solving problems, developing problem-solving skills, and effectively addressing daily issues. Here are some statements from science teachers:

> *"...critical thinking helps science teachers enhance their ability to think independently. It increases their capacity to analyze and solve problems on their own. This can aid them in improving their teaching abilities with students more effectively (A)."*
>
> *"...critical thinking improves science teachers' capacity to understand different perspectives, which, in turn, enhances empathy and communication skills. Teachers can better understand students, establish better interactions, and enrich the learning experience (C)."*
>
> *"...critical thinking equips science teachers with problem-solving skills, enabling them to solve daily issues more effectively. It can also make them more competent in teaching problem-solving skills to their students (E)."*

Questioning Knowledge and Conscious Teaching - This category revolves around themes like distinguishing between right and wrong, being conscious and knowledgeable teachers, and recognizing critical thinking as a crucial skill in the age of information access.

Different Perspectives, Empathy, and Communication - This category focuses on themes related to promoting empathy, understanding diverse perspectives, and enhancing communication skills. Science teachers believe that critical thinking fosters empathy and improves their ability to comprehend various viewpoints. Encouraging Openness to Criticism and Personal Development - This category highlights themes associated with encouraging openness to criticism, contributing to personal development, and providing opportunities to identify and rectify mistakes.

Enhancing Synthesis of Knowledge and Argumentation Skills - This category centers on themes that emphasize strengthening the ability to synthesize knowledge, bringing together different pieces of information, and constructing arguments based on evidence.

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 4
Categories and Sub-Themes Related to Creative Thinking

Category	Subtheme	A	B	C	D	E	F	G	H	I
The Importance of Creative Thinking in Science	The basis for problem-solving and discovery in science	✓								
	Questioning information and looking for alternative ways		✓							
	Hypothesize and design experiments						✓			
	Keeping focus on the real world									✓
Encouraging Creative Thinking	Providing opportunities through laboratories and projects			✓						
	Using problem-based learning					✓			✓	
	Encourage you to ask the why and how questions							✓		
	Practical applications and problem solving								✓	
Classroom Environment and Communication	Being open to different opinions in the classroom				✓					
	Approaching the classroom from a different perspective				✓					

When examining the findings related to the categories and sub-themes created for creative thinking in Table 4, concerning the overarching theme of creative thinking, the following sub-themes emerged:

The Significance of Creative Thinking in Science Education - This category encompasses themes such as the foundation of problem-solving and discovery in science, questioning knowledge, seeking alternative pathways, hypothesis formation, and experimental design, as well as focusing on real-world applications. Science teachers emphasize that creative thinking is fundamental to problem-solving and exploration in science.

> *"...creative thinking in science involves questioning known knowledge and exploring alternative solutions. Therefore, science teachers should encourage questioning and exploration rather than just transmitting knowledge (B)."*

Promoting Creative Thinking - This category focuses on themes related to providing opportunities through laboratories and projects, utilizing problem-based learning, encouraging asking "why" and "how" questions, and emphasizing practical applications and problem-solving. Classroom Environment and Communication - This category highlights themes related to maintaining an open-minded classroom environment, encouraging different perspectives and approaches within the classroom.

> *"...creative thinking requires the ability to approach problems from different perspectives in science. Therefore, science teachers should create a classroom environment that is open to different views and ideas (D)."*

> *"...creative thinking is essential in hypothesis formation and experimental design processes in science. Therefore, as science teachers, we should teach these skills to our students (F)."*

Table 5
Categories and Sub-Themes Related to Epistemological Belief

Category	Subtheme	A	B	C	D	E	F	G	H	I
Epistemology and Scientific Knowledge Production	Changing from passive thinker to active thinker	✓								
	Sources of scientific knowledge				✓					
	How and when to teach knowledge							✓		
The Correlation Between Science and Society	Epistemological development and building knowledge		✓							
	Reliability and objectivity of scientific knowledge					✓				
	The applicability of science in everyday life									✓
Critical Thinking and Different Perspectives	Encouraging critical thinking			✓						
	Understand information in context						✓			
	Attitudes and values towards knowledge								✓	

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

When examining the findings related to the categories and sub-themes created for epistemological beliefs in Table 5, concerning the overarching theme of epistemological beliefs, the following sub-themes emerged:

Epistemology and Production of Scientific Knowledge - This category encompasses themes related to transforming passive thinkers into active thinkers, understanding the sources of scientific knowledge, and how and when to teach knowledge. Science teachers emphasize the importance of introducing epistemology to students by showcasing the work of significant scientists in the history of science. They also teach how scientific discoveries are made.

> *"...I introduce epistemology to students by showcasing the work of significant scientists in the history of science. I show examples of how scientific discoveries are made. Epistemological development is the process of students understanding how they learn and when they need to learn. I encourage students to develop their own learning methods (G)."*

Science and Society Correlation - This category focuses on themes related to epistemological development and knowledge construction, the reliability and objectivity of scientific knowledge, and the applicability of science in daily life. Science teachers highlight the importance of teaching students about paradigm shifts in science and different perspectives on knowledge. Promoting Critical Thinking and Different Perspectives - This category emphasizes themes related to promoting critical thinking, understanding knowledge within its context, and attitudes and values towards knowledge. Teachers use epistemology to show students how they can integrate scientific thinking into their daily lives and underscore the applicability of science in daily life.

> *"...I use epistemology to show my students how they can integrate scientific thinking into their daily lives. I emphasize the applicability of science in daily life. Epistemological development includes students' ability to evaluate knowledge based on its sources, contexts, and reliability. This is important for me as a way to promote critical thinking (I)."*

Table 6
Categories and Sub-Themes Related to Critical and Creative Thinking in The Absence of Epistemological Development

Category	Subtheme	A	B	C	D	E	F	G	H	I
Critical Thinking Cannot Exist	Epistemology is the foundation of critical thinking	✓							✓	
	There is no epistemological development in the authoritarian teacher		✓							
	Effective use of epistemology teaching strategies				✓		✓			✓
Creative Thinking Cannot Exist	Epistemology is the foundation of creative thinking	✓				✓				
	Epistemological development inhibits passive receptivity				✓					
	Epistemological development develops different perspectives		✓							✓
	Epistemology promotes discussion and exchange of ideas			✓			✓			

When examining the findings related to the categories and sub-themes created for the absence of epistemological beliefs in Table 6, concerning the overarching theme of the absence of epistemological beliefs, the following sub-themes emerged:

Critical Thinking Cannot Exist - This category encompasses themes related to the idea that epistemology is the foundation of critical thinking, the absence of epistemological development in authoritarian teaching, and the effective use of epistemology in teaching strategies. Teachers emphasize that without epistemological beliefs, critical thinking cannot exist.

> *"...epistemological beliefs influence how science teachers perceive knowledge and convey it to students. Depending on their beliefs, teachers may sometimes grant students more freedom, which can help them think critically and creatively (A)."*

Creative Thinking Cannot Exist - This category focuses on themes related to the notion that epistemology is the foundation of creative thinking, the hindrance of passive receptivity by epistemological development, the development of different perspectives through epistemological development, and the enhancement of discussion and idea exchange through epistemology. Science teachers stress that without epistemological beliefs, creative thinking cannot exist.

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

"...beliefs influence how science teachers perceive knowledge and convey it to students. Depending on their beliefs, teachers may sometimes grant students more freedom, which can help them think critically and creatively (A)."

"...beliefs influence classroom interactions. Science teachers with epistemological flexibility encourage discussions and idea exchanges among students, which can enhance creative thinking (F)."

"...the beliefs have a modeling effect on students. By showing how they access and evaluate knowledge, teachers provide students with the opportunity to develop critical and creative thinking skills (H)."

Discussion

There was a correlation between the epistemological development of science teachers and their critical thinking abilities. This finding aligns with the results of previous studies by Alkın-Şahin et al. (2014), Başbay (2013), Baydar (2021), and Kandemir and Eymir (2020), which also identified a similar connection. Epistemology is a branch of philosophy that examines knowledge and how knowledge is obtained. Epistemological development refers to how an individual understands, evaluates, and structures knowledge (Conley et al., 2004). An individual's epistemological beliefs reflect how they approach and process knowledge. Epistemological development can vary depending on age, experience, and educational level (Gökalp, 2018; Lumsdaine & Lumsdaine, 1995). Critical thinking, on the other hand, refers to the ability to critically engage with, question, and analyze information. This thinking skill involves evaluating the accuracy and reliability of knowledge, arriving at logical conclusions, and considering various perspectives. Critical thinking empowers students to solve complex problems and gain a deeper understanding of knowledge (Lai, 2011). The epistemological development of science teachers can influence how they approach knowledge and how they present it to students. Teachers' epistemological beliefs can determine whether they teach students that knowledge is a fixed and unchanging entity or whether it is continuously evolving and changing. Critical thinking skills can enhance science teachers' abilities to teach students to question, analyze, and approach knowledge with a critical perspective. While there is a correlation between the epistemological development of science teachers and critical thinking, this correlation can be shaped by personal beliefs, education, experience, and other factors. Science teachers can use different approaches to teach critical thinking skills to students based on their own epistemological beliefs. Ultimately, both the epistemological development and critical thinking skills of science teachers can help them provide more effective education to their students. The epistemological development of science teachers is indeed related to creative thinking. This finding is in line with the results of Hong et al. (2009) and Katz-Buonincontro et al. (2020). The connection between these two concepts can influence how teachers think, how they approach knowledge, and how they teach their students. Epistemology, a branch of philosophy, concerns itself with the nature of knowledge and the processes of acquiring it. An individual's epistemological development reflects how they understand, evaluate, and process knowledge (Schommer et al., 1992). Creative thinking, on the other hand, refers to the ability to generate new and original ideas, approach problems from different perspectives, and make unique connections. Creative thinking encourages the discovery of innovative solutions and can help students improve their problem-solving skills (Emanuel & Challons-Lipton, 2012). The epistemological development of a science teacher can shape their fundamental beliefs about how they understand and evaluate knowledge. For example, if a science teacher rigidly accepts knowledge as absolute and unquestionable, this teacher may be less likely to foster creative thinking skills in students. A rigid epistemological approach may not be open to different perspectives and original thoughts. However, a teacher with a more open and flexible epistemological stance may be inclined to encourage creative thinking. A science teacher who epistemologically accepts that knowledge can change and be developed may value different perspectives and original thoughts from their students. In conclusion, there is a correlation between the epistemological development of science teachers and creative thinking. How science teachers approach knowledge can influence their students' creative thinking skills. A flexible and open epistemological approach can encourage students' creative thinking abilities, while a rigid epistemological approach may limit these abilities. Without epistemological development in science teachers, critical and creative thinking would not exist. This result is consistent with the findings of research conducted by Baker and Pomeroy (2001), Chang et al. (2015), and Ülger (2016), which emphasize a meaningful correlation between critical thinking and creative thinking. However, there hasn't been specific research on how critical and creative thinking would be affected when epistemological development is absent. This is because the correlation between these two concepts is quite complex and influenced by multiple factors. An individual teacher's epistemological development reflects their fundamental beliefs about how they approach and evaluate knowledge. If a teacher unquestionably accepts knowledge as absolute and certain, it may limit their critical thinking skills (Janjua et al., 2014). Critical thinking, after all, requires the ability to question knowledge and

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

evaluate it from various perspectives (Nosich, 2012). However, a more open and flexible epistemological approach can encourage the development of critical thinking skills. Creative thinking, on the other hand, is about generating new and original ideas (Emanuel & Challons-Lipton, 2012). A rigid epistemological belief system may restrict creative thinking because creativity is based on different perspectives, original thoughts, and the reevaluation of knowledge. A more open epistemological approach can promote creative thinking. It's important to note that epistemological development is just one factor among many. Teachers' experiences, the educational programs they've been through, their teaching methods, and personal characteristics are also significant factors influencing both critical and creative thinking. For instance, science teachers can enhance these skills by using teaching methods that encourage critical and creative thinking. Epistemological development can indeed affect the critical and creative thinking skills of science teachers. However, it should be seen as just one of several contributing factors. Other factors can also influence the development of these thinking skills, and science teachers can employ various methods to instill these skills in their students.

Conclusions and Implications

The study found that the science teachers who participated in the research had high levels of epistemological beliefs, critical thinking, and creative thinking perceptions. Furthermore, epistemological beliefs, critical thinking, and creative thinking are interconnected concepts, and the presence of one of these variables in science teachers positively influences the other variables. When there is no epistemological development in science teachers, critical thinking and creative thinking are negatively affected, and the direction of the correlation is negative. However, when the levels of epistemological development in science teachers are moderate to high, the levels of critical thinking and creative thinking also increase. Science teachers categorize critical thinking as independent thinking and problem-solving, questioning knowledge and conscious teaching, different perspectives, empathy and communication, criticism and personal development, synthesizing knowledge, and argumentation. They categorize creative thinking as the importance of creative thinking in science, promoting creative thinking, classroom environment, and communication. They categorize epistemological belief as epistemology and the production of scientific knowledge, the correlation between science and society, critical thinking, and different perspectives. When the quantitative and qualitative results of the research are considered together, it can be concluded that without epistemological development in science teachers, critical and creative thinking cannot exist.

Recommendations

In this research, an attempt was made to determine how critical thinking and creative thinking would be when there is no epistemological development in science teachers. The conclusion was reached that without epistemological development in science teachers, critical and creative thinking cannot exist. Based on this, Education Ministries of countries should pay special attention to the issue of epistemological development in various aspects such as undergraduate education, the teacher training process, in-service programs, teaching and curriculum design, textbooks, etc., for science teachers. This is because critical thinking and creative thinking, which are 21st-century skills, depend on the epistemological development of science teachers. Furthermore, in this research, measurement tools for epistemological development, critical thinking, and creative thinking were used as ready-made instruments. For future research, these measurement tools should be updated and adapted for educational institutions and teachers, possibly through a mixed-methods research approach with a scale development sub-design and exploratory sequential design.

Limitations

The biggest limitation of this research was explaining how a variable played a moderating role for science teachers. This limitation was overcome by associating it with current examples. The second limitation was related to the difficulty in finding science teachers with postgraduate studies, research articles related to the subject, and fifteen years or more of experience to represent the variables of critical thinking, creative thinking, and epistemological belief.

https://doi.org/10.33225/jbse/24.23.964

ISSN 1648–3898 /Print/
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Data Availability

The data that support the findings of this study is available from the author, upon reasonable request.

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Received: *July 17, 2024* Revised: *August 30, 2024* Accepted: *September 18, 2024*

Cite as: Varlik, S. (2024). Critical and creative thinking in science teachers: The moderating role of epistemology. *Journal of Baltic Science Education*, *23*(5), 964–978. https://doi.org/10.33225/jbse/24.23.964

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