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Research Article

Critical thinking, epistemological beliefs, and the science-pseudoscience distinction among teachers

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This study used the structural equation model to examine teachers' scientific epistemological beliefs, critical thinking skills, and beliefs about the distinction between science and pseudoscience. The study involved 730 teachers from 26 different subjects in different regions of Türkiye. Descriptive analyses showed a significant relationship between teachers' level of interest in scientific studies and their critical thinking skills. It was also concluded that critical thinking skills were high, but non-traditional understanding beliefs were low. Path analysis results showed that critical thinking skills were negatively related to traditional scientific beliefs. Furthermore, non-traditional understanding beliefs were found to be negatively correlated with pseudoscience beliefs. The results obtained were discussed in the light of the literature and suggestions were made considering the limitations.

Keywords: Critical thinking disposition; Epistemological beliefs; Pseudoscience; teachers

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1. Introduction

Epistemological beliefs reflect an individual's beliefs about the nature of knowledge and knowing (Hofer, 2001; Schommer-Aikins, 1990). As an ephemeral concept, epistemological beliefs describe how knowledge is defined, how it is structured and evaluated, where it is located, and how it is known (Adak & Bakır, 2017; Kelly, 2021). They have been of particular interest to psychologists and educators since it was believed that epistemological beliefs were necessary for the production of knowledge (Liang & Tsai, 2010). It is a life-long process for students to develop and learn beliefs in order to produce knowledge (Hofer, 2001), and teachers are the primary actors who provide that change for students. A study by Duffy et al. (2016) shows that the epistemological beliefs of undergraduate students affect their learning approaches. In order to examine these relationships, researchers included variables related to epistemological beliefs (Banerjee & Chua, 2021; Getahun et al., 2016; Özbay & Köksal, 2021). Dahl et al. (2005), on the other hand, pointed out a close relationship between epistemological beliefs and critical thinking. Individuals' epistemological beliefs are determinative in their approach to knowledge and the meanings derived from

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knowledge (Chan et al., 2011). In fact, critical thinking skills rely on the individual's ability to reflect these beliefs and actions in a reasonable manner in approaching and producing knowledge (Ennis, 2015). According to Dyer and Hall (2019), individuals should be taught critical thinking skills to recognize and avoid pseudoscience beliefs that do not support science and even contradict scientific evidence. It is vital for students to develop critical thinking skills at this point, and teachers play a major role in this process (Franco & Vieira, 2019). Therefore, the goal of our research was to contribute to the existing literature by examining the relationship between the belief structures of teachers and critical thinking skills.

1.1. Theoretical Background

1.1.1. Critical thinking

In the literature, critical thinking, which is regarded as a life skill of people in the twenty-first century (Saleh, 2019), is defined in various ways. Ennis (2009) defines critical thinking as different ways of cutting the same conceptual cake. According to Facione (1990), critical thinking involves purposeful decision-making and self-regulated judgment, based on explanations of evidence, concepts, methods, criteria, and contexts, as well as interpretation, analysis, evaluation, and inferences. Accordingly, critical thinking is considered from two dimensions: skill and tendency. While the skill dimension of critical thinking includes the processes of analysis, interpretation, and inference (Chan, 2019), the tendency dimension includes practical applications of these skills (Facione et al., 1995). In practice, the skill dimension is useful since the tendency dimension is strong (Chen et al., 2020). Different learning models were used to study students' critical thinking skills, and it was observed that these skills developed most along with skill level (Chusni et al., 2022; Hsu et al., 2022; Sutiani et al., 2021). According to Huerta et al. (2022), individuals who are more prone to critical thinking display a stronger creative self-concept and are more open to diversity and challenges. Moreover, critical thinking has a direct effect on creativity and innovation (Saavedra et al., 2022). Additionally, critical thinking has been linked to scientific literacy (Vieira & Tenreiro-Vieira, 2016).

1.1.2. Scientific epistemological beliefs

A person's epistemological belief is their understanding of knowledge--what it is, how it is gathered, where it is gathered, and how certain, accurate, and reliable it is (Perry, 1981). Researchers interested in epistemology have proposed different development models. Perry (1970) classified epistemological belief development into four levels: dualism, multiplicity, relativism, and commitment. Schommer-Aikins (1994) developed a five-dimensional model of epistemological beliefs, which includes certainty of knowledge, structure of knowledge, source of knowledge, control of knowledge acquisition, and speed of knowledge acquisition. According to Hofer and Pintrich (1997), the last two dimensions presented by Schommer-Aikins are directly related to learning and cannot be included in the scope of personal epistemology. After a period of time, Schommer-Aikins (2004) justified these criticisms by stating that the epistemological beliefs dimensions in the first three dimensions affect the other two dimensions related to learning. In other words, epistemological beliefs significantly affect understanding and learning (Hofer & Pintrich, 1997). Several researchers working on epistemological beliefs emphasized the need to address beliefs specific to a particular field (Buehl & Alexander, 2006; Palmer & Marra, 2008), and many have examined scientific epistemological belief systems (Conley et al., 2004; Özbay & Köksal, 2021).

Scientific epistemological beliefs are based on the positivist understanding, which accepts that knowledge is certain and unchangeable and is considered the representation of traditional beliefs, and the constructivist understanding of science, which accepts that dreams, intuition, and perspective are important in science (Pomeroy, 1993). These understandings are at the extremes of each other. The traditional understanding of science is that scientific knowledge is based on observation and experiment, and that this knowledge is certain and unalterable. According to the constructivist view of science, however, scientific knowledge is subjective and subject to change. Studies examining teachers' scientific epistemological beliefs revealed that they mostly have a traditional view of science (Adak & Bakır, 2017). Furthermore, different studies have shown that epistemological beliefs affect academic achievement (Alkış Küçükaydın & Gökbulut, 2020; Ricco et al., 2010), metacognitive learning (Alpaslan, 2017), and problem-solving skills (Hıdıroğlu Özkan & Hıdıroğlu, 2016). In these studies, scientific epistemological beliefs were found to interact with cognitive factors.

1.1.3. The science—pseudoscience distinction

Scientists can easily draw the boundaries between science and pseudoscience based on epistemological criteria. Astrology, for instance, is a pseudoscientific concept, while astronomy is a science. As an alternative, while evolution is a theory, creationism is not a theory (Hansson, 2013). However, not everyone can clearly distinguish the boundaries between science and pseudoscience (Alkış Küçükaydın, 2020; Schmaltz & Lilienfeld, 2014). For many years, philosophers of science have attempted to clarify the boundaries between science and pseudoscience (Boudry, 2021; Tvrdy, 2021). The results of these initiatives led to the conclusion that science is reproducible, experimental, cumulative, progressive, objective, factual, and predictable (Cortinas-Rovira et al., 2015). Pseudoscience, on the other hand, is defined as unconfirmed, static knowledge and beliefs that imitate scientific terms, removed from scientific methods and hypotheses (Solbes et al., 2018). Pseudoscientific claims that sound scientific and impressive are based on unproven concepts that are misleading or misused (Schmaltz & Lilienfeld, 2014).

Pseudoscientific concepts that are supported by scientific statements but contain unproven claims or topics that have nothing to do with science have been described by scientists as bad, unimportant, crazy, or even nonsense (Shermer, 2013). Although pseudoscience, which is far removed from scientific methods and theories, is not completely bad, fraudulent, or unscientific, it has been sincerely adopted by pseudoscientists. For example, expressions such as "energy therapies", "biological feedback", or "quantum energies" used for the solution of psychological problems are far removed from science, however impressive they may seem (Schmaltz & Lilienfeld, 2014). Although pseudoscientific beliefs that are not based on epistemology are sometimes harmless, it should not be ignored that these beliefs can often cause significant damage to society (Boudry, 2021). Pseudoscientific beliefs, which appear to be harmless and unaffected, are capable of affecting large numbers of people and causing negative effects. For example, beliefs that vaccines cause disease can lead to increased anti-vaccine movements and endanger public health (Tvrdy, 2021).

Throughout their lives, people read and hear scientific, pseudoscientific, and non-scientific arguments about phenomena they have acquired from their teachers, the environment, mass media, and social media (Losh & Nzekwe, 2011; Metin et al., 2020; Wilson, 2018). Teachers play a huge role in raising scientifically literate individuals who understand science and the processes of accessing scientific knowledge against so-called scientific or non-scientific beliefs (Metin et al., 2020). Teachers can pass on their tendency to accept information without assessing its scientific validity to students if they accept it without evaluating its scientific validity (Losh & Nzekwe, 2011). Thus, it is crucial to find out how teachers perceive the difference between science and pseudoscience. A review of the relevant literature reveals that most studies examine preservice teachers' science and pseudoscience beliefs (Fuertes-Prieto et al., 2020; Losh & Nzekwe, 2011) as well as in-service science teachers (Karaman, 2023; Solbes et al., 2018); therefore, there are limited studies on teachers from different disciplines. Because students will interact with teachers from a variety of disciplines throughout their education life, it is important to examine the science and pseudoscience beliefs of teachers from different disciplines (Losh & Nzekwe, 2011).

1.1.4. The relationship between critical thinking, scientific epistemological beliefs, and the science—pseudoscience distinction

In the rapidly developing information age, critical thinkers with the ability to question information accuracy are needed (Vieira & Tenreiro-Vieira, 2016). People are being exposed to different information from television, movies, and social media without knowing whether it is true or false (Wilson, 2018). Critical thinking skills are lacking in pseudoscience beliefs lacking scientific knowledge and methods (Losh & Nizekwe, 2011). In a study by Wilson (2018) revealed that students who participated in a critical thinking course had fewer beliefs about paranormal and pseudoscientific issues at the end of the course. Designing a critical thinking learning environment, Dyer and Hall (2019) found significant reductions in beliefs about pseudoscience on certain subjects (health and extraordinary lifestyles). In a study investigating the prevalence of pseudoscientific beliefs and fake news during the Coronavirus epidemic, it was found that individuals with critical thinking and skeptical attitudes experienced less stress, did not believe in fake news, and had a less distant view of pseudoscience (Escolà-Gascón et al., 2021).

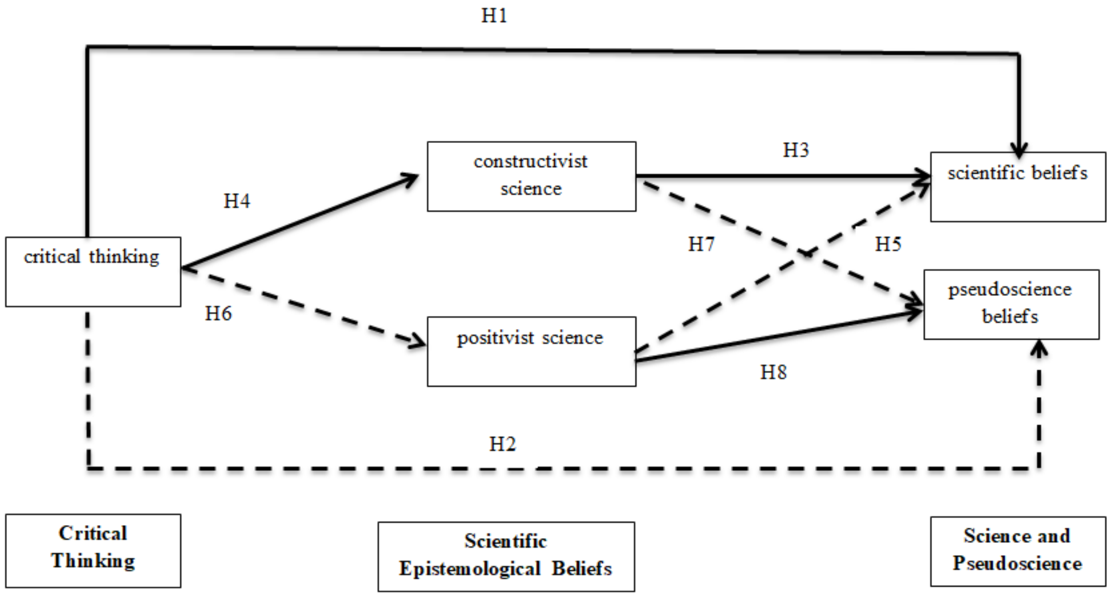
Critical thinking, one of the key components of reflective thinking, is closely related to epistemological beliefs that challenge knowledge's nature. As stated by Chan et al. (2011), people who believe in sophisticated science can think more flexibly and have a more positive relationship with critical thinking when they learn science from a constructivist perspective. Moreover, Dahl et al. (2005) examined the relationship between critical thinking and epistemological beliefs and found a negative relationship between the traditional understanding of science and critical thinking. As Hofer (2001) suggests, epistemological beliefs develop when individuals are given the opportunity to reflect on and evaluate their thoughts.

Studies have shown that scientific epistemological beliefs are associated with beliefs about the distinction between science and pseudoscience, as well as critical thinking skills. However, a clear relationship has not been demonstrated between these three variables. This study attempted to fill this gap by modeling the relationship between teachers' epistemological beliefs, their beliefs about the science-pseudoscience distinction, and their critical thinking skills.

1.2. Present Study

The study examined the relationship between teachers' scientific epistemological beliefs, science-pseudoscience beliefs, and critical thinking skills. In determining their scientific epistemological beliefs, the traditional understanding of science (positivism) described by Pomeroy (1993) and the non-traditional understanding of science (constructivism) were adopted. In the relevant literature it is pointed out that scientific belief structure and cognitive structure are related (Chan et al., 2011; Dahl et al., 2005). Accordingly, critical thinking disposition has a significant effect on both epistemological beliefs and the distinction between science and pseudoscience (Escolà-Gascón et al., 2021; Wilson, 2018). However, the relationship between these three variables has not yet been addressed in the literature. The present study explored the interrelationships between the variables by considering their subdimensions. The purpose of this study was to examine the relationship between critical thinking, scientific epistemological beliefs, and science-pseudoscience variables among teachers. Figure 1 illustrates the model, which includes the hypotheses developed for this purpose.

Figure 1
The hypothetical model of structural relations between critical thinking, scientific epistemological beliefs, and science–pseudoscience



Note. Dashed arrows reflect a negative relationship, while linear arrows show a positive relationship.

The relationships between hypotheses regarding the theoretical model are shown in Fig. 1. In this context, the hypotheses of the research are presented below.

H1: Teachers' critical thinking skills are positively related to their scientific beliefs.

H2: Teachers' critical thinking skills are negatively related to their pseudoscience beliefs.

H3: Teachers' constructivist understanding of science is positively related to their scientific beliefs.

H4: Teachers' critical thinking skills are positively related to their constructivist understanding of science.

H5: Teachers' positivist understanding of science is negatively related to their scientific beliefs.

H6: Teachers' critical thinking skills are negatively related to their positivist understanding of science.

H7: Teachers' constructivist understanding of science is negatively related to their pseudoscience beliefs.

H8: Teachers' positivist understanding of science is positively related to their pseudoscience beliefs.

2. Method

This study examined the relationship between critical thinking, scientific epistemological beliefs, and science-pseudoscience beliefs among teachers. The relational survey model describes a situation or event as it is and then determines the relationship between the variables that cause this situation, their effects, and their degrees (Karasar, 2005). To reveal the relationship between critical thinking, epistemological beliefs, and science-pseudoscience, a relational survey model was adopted, which shows the relationship between two or more datasets.

2.1. Study Group

Study participants included Turkish teachers. It included 26 different subjects (primary school teaching, English, guidance and psychological counseling, science, mathematics, physical education, technology, design, computers, philosophy, special education, Turkish language, Turkish, social studies, music, chemistry, physics, biology, religious culture, German, accounting, geography, literature, health, and history) and 730 teachers, ages ranged from 23 to 63 (M=38.99, SD=9.02), participated in the study. There is a wide range of seniority and geography among the teachers participating. The demographic information of the study group is presented in Table 1.

Table 1
Descriptive Information of the Teachers Participating in the Study

Variables	*f*	%
Gender		
Female	472	64.7
Male	258	35.3
Year of Experience		
0-5 years	111	15.1
6-11 years	185	25.2
12-17 years	158	21.6
18-23 years	116	15.9
24+	162	22.2
Teaching Subject		
Accounting	20	2.7
Biology	23	3.2
Chemistry	25	3.4
Computers	20	2.7
English	51	7.0
Geography	21	2.9
German	20	2.7
Guidance and psychological counseling	41	5.6
Health	28	3.8
History	20	2.7
Literature	21	2.9
Mathematics	24	3.3
Music	24	3.3
Philosophy	30	4.1
Physical education	25	3.4
Physics	23	3.2
Pre-school education	30	4.1
Primary school teaching	59	8.2
Religious culture	27	3.7
Science	28	3.8
Social studies	23	3.2
Special education	28	3.8
Technology and design	26	3.6
Turkish	50	6.8
Turkish language	20	2.7
Visual arts	23	3.2
Level of Interest in Scientific Studies		
Little interest	27	3.7
Some interest	138	18.9
Moderate interest	450	61.6
Very high interest	115	15.8

2.2. Procedure

First, the ethics committee permission procedures were completed. An ethical committee proposal was submitted to the Selçuk University Ethical Committee before data collection, and it was approved with a commission date and number of 2021/26. With the assistance of the institution managers, the scales were then converted into a single form using Google Forms and emailed to the teachers via their corporate emails. Participants were asked for demographic information before the survey began, and were given permission to withdraw at any time. The science-pseudoscience scale, scientific epistemological beliefs scale, and critical thinking scale were included in the continuation of the form. Volunteer teachers were expected to fill out the relevant form shared on their social media accounts. The study was completely voluntary and no rewards were offered. Data were collected between 26 February and 21 March 2022.

2.3. Instruments

2.3.1. Critical thinking disposition scale

Taking into account the criticisms of the California critical thinking disposition inventory (Facione & Facione, 1992), this scale was developed by Sosu (2013). In total, there are 11 items on the scale, divided into two sub-dimensions, critical openness, and reflective skepticism. When applied to undergraduate students, Cronbach's alpha coefficient was .79, and when applied to graduate students, it was .81. The Turkish adaptation of the scale was performed by Akın et al. (2015), who applied it to university students. There is no reverse-coded item in the 5-Likert type scale (1: absolutely disagree…5: absolutely agree), and it is considered that the tendency to think critically increases as the score gets higher. Based on the adaptation studies, Cronbach's alpha coefficient for the scale, which is composed of two factors, critical openness and reflective skepticism, was .78. For this study, Cronbach's alpha coefficient was .79 for critical openness, .81 for reflective skepticism, and .87 for the whole scale. As a result of the confirmatory factor analysis, the following model fit values were obtained: χ^2/df =4.46; RMSEA =.06; SRMR =.03, IFI =.96; CFI = .96; GFI =.96; AGFI =.93; NFI =.95. These results indicated that the measurement tool used in the study was valid and reliable.

2.3.2. Scientific epistemological beliefs survey

The scientific epistemological beliefs survey, developed by Pomeroy (1993), was adapted into Turkish by Deryakulu and Hazır-Bıkmaz (2003). The adaptation resulted in a structure consisting of two sub-dimensions, constructivist science and positivist science, with 30 items. On a 5-point Likert scale, there are 22 items reflecting the traditional understanding of science (positivist science). The reverse coding of eight items reflects a nontraditional understanding of science (constructivism science). Scores on the scale indicate whether one believes in a traditional understanding of science or a nontraditional understanding. Cronbach's alpha coefficients in the present study were .72 and .84, respectively, for the sub-dimensions and .88 for the whole scale. According to the confirmatory factor analysis, the measurement tool was valid and reliable based on its model fit values χ^2/df = 3.83; RMSEA =.06; SRMR = .06, IFI =.90; CFI = .91; GFI =.85; AGFI =.93; NFI =.96).

2.3.3. Science and pseudoscience scale

The science–pseudoscience distinction scale was originally developed by Oothoudt (2008) and adapted into Turkish by Kirman-Çetinkaya et al. (2013). This scale was originally constructed with 32 items and three sub-dimensions. These dimensions are science as a process of inquiry, belief in pseudoscientific beliefs, and applying the parameters of pseudoscience. The adaptation resulted in two dimensions, science and pseudoscience, and 23 items. Since items 1, 9, 14, 19, and 21 on the scale were problematic, these items were removed. Accordingly, in the current study, Cronbach's alpha values of the scale were calculated as .72 and .68 for the sub-dimensions, and .73 for the whole scale. After the confirmatory factor analysis on the scale, the model fit values were as follows: χ^2/df = 4.36; RMSEA =.07; SRMR =. 07, IFI =.90; CFI =.90; GFI =.90; AGFI =.98; NFI =.96. These values indicated that the measurement tool used in the study was valid and reliable.

2.4. Data Analysis

For descriptive statistics, SPSS 26 was used, and AMOS 26 was used for model analysis. During data analysis, it is necessary to correct erroneous and missing data (Field, 2009; Pallant, 2007). The series mean method was used to remove missing data in the dataset. After conducting univariate and multivariate normal distribution checks on the dataset, structural equation modeling was performed (Byrne, 2010). To examine the univariate normality assumption for the dataset, skewness and kurtosis values between +2 and -2 were considered (George & Mallery, 2010). Accordingly, the skewness and kurtosis values were found to be .993 and −.576 for the critical thinking disposition scale, −.483 and −.181 for the scientific epistemological beliefs scale, and .130 and 1.50 for the science–pseudoscience scale. Therefore, it is seen that the scale scores show a normal distribution. In comparisons between groups, the eta squared (η^2) value was used for the effect size and, accordingly, a value between .01 and .06 was interpreted as a small, between .06 and .13 as a medium, and above .14 as a large effect (Cohen, 1988). In correlation analyses between variables, an r-value between .10 and .29 was interpreted as a low, between .30 and .49 as a medium, and of .50 and above as a high correlation. Using the structural equation modeling approach (Eray Çelik & Yılmaz, 2013), confirmatory factor analysis was performed for each scale in the first stage. In the second step, AMOS was used to draw paths between the variables in the model. The maximum likelihood method was used at this stage of the analysis. The values adopted in the examination of model fit values are as follows: χ^2/df <5; RMSEA <.08; SRMR<.08, IFI ≥.90; CFI ≥.90; GFI ≥.90; AGFI ≥.85; NFI ≥.90 (Bollen, 1989; Schermelleh-Engel et al., 2003).

3. Findings

Relationships between variables were analyzed in the study. First, descriptive statistical analyses were conducted. Table 2 presents the variables and results of the descriptive statistical analyses of teachers' critical thinking, scientific epistemological beliefs, and science-pseudoscience beliefs. The results revealed that, teachers' critical thinking (t[728]=1.55, *p*>.05), scientific epistemological beliefs (t[728]= .34, *p*>.05), and science–pseudoscience beliefs (t[728]= 3.87, *p*>.05) did not differ by gender. To examine the relationship between teachers' years of professional seniority, critical thinking, scientific epistemological beliefs, and science-pseudoscience beliefs, a one-way analysis of variance (ANOVA) was conducted. Accordingly, no significant relationship was found between the years of professional seniority of the teachers and their critical thinking skills (F[4,725]= .89, *p*>.05), scientific epistemological beliefs (F[4,725]= 1.21, *p*>.05), or science–pseudoscience beliefs (F[4,725]= .54, *p*>.05). Similarly, no significant relationship was found between teachers' levels of interest in scientific studies and scientific epistemological beliefs (F[3,726]= 1.49, *p*>.05) or science–pseudoscience beliefs (F[3,726]= .34, *p*>.05). There was, however, a significant relationship between teachers' interest in scientific studies and their critical thinking skills. The effect size of this relationship is low, and the significant relationship is between those with a high level of interest in scientific studies and those with a low level of interest (F[3,726]= 7.89, *p*<.05; η^2 = .03). That is, teachers with a high level of interest in scientific studies (M=4.33) have higher critical thinking skills than those with a low level of interest (M=3.93).

The correlation values between critical thinking, scientific epistemological beliefs, and science–pseudoscience variables in the study are presented in Table 3. According to Table 3, teachers' critical thinking skills (M = 45.98, M/k = 4.18, SD = .53) and their level of belief in pseudoscience (M = 6.56, M/k = 3.42, SD = .43) were high. It is accepted that as the score obtained from the scientific epistemological beliefs scale increases, the level of belief in traditional scientific beliefs also increases (Deryakulu & Hazır-Bıkmaz, 2003). Accordingly, teachers' high scores on the scientific epistemological beliefs scale (M = 116.70, M/k = 3.892, SD = .47) mean that their traditional scientific beliefs are high.

Table 2

T-test and ANOVA Results for Teachers' Critical Thinking, Scientific Epistemological Beliefs, and Science–Pseudoscience Scores

Variables	*Categories*	*M/k*	*SD*	*df*	*t/F*	*p*
Critical Thinking Disposition						
Gender	Female	4.20	.50	728	1.55	.82
	Male	4.13	.58			
Professional Seniority Years	0-5 years	4.25	.55	Between groups: 4	.89	.46
	6-11 years	4.18	.53	Within groups: 725		
	12-17 years	4.13	.48			
	18-23 years	4.18	.56			
	24+	4.15	.54			
Level of interest in scientific studies	Little interest	3.93	.80	Between groups: 3	7.89	.00*
	Some interest	4.05	.49	Within groups: 726		
	Moderate interest	4.19	.50			
	Very high interest	4.33	.57			
Scientific Epistemological Beliefs						
Gender	Female	3.89	.46	728	.347	.96
	Male	3.88	.49			
Professional Seniority Years	0-5 years	3.93	.46	Between groups: 4	1.21	.30
	6-11 years	3.89	.46	Within groups: 725		
	12-17 years	3.91	.46			
	18-23 years	3.90	.46			
	24+	3.89	.49			
Level of interest for scientific studies	Little interest	3.72	.53	Between groups: 3	1.49	.21
	Some interest	3.87	.47	Within groups: 726		
	Moderate interest	3.90	.45			
	Very high interest	3.92	.52			
Science and Pseudoscience						
Gender	Female	3.47	.42	728	3.87	.59
	Male	3.34	.43			
Professional Seniority Years	0-5 years	3.43	.38	Between groups: 4	.54	.70
	6-11 years	3.43	.44	Within groups: 725		
	12-17 years	3.38	.42			
	18-23 years	3.26	.45			
	24+	3.42	.43			
Level of interest in scientific studies	Little interest	3.42	.36	Between groups: 3	.34	.79
	Some interest	3.42	.39	Within groups: 726		
	Moderate interest	3.43	.43			
	Very high interest	3.39	.48			

Note. k : number of items

Table 3

Correlation Values between Variables

Variables	*M*	*M/k*	*SD*	*1*	*2*	*3*
Critical thinking (1)	45.98	4.18	.53	–		
Scientific epistemological beliefs (2)	116.70	3.89	.47	–.56**	–	
Science and pseudoscience (3)	61.56	3.42	.43	–.27**	.41**	–

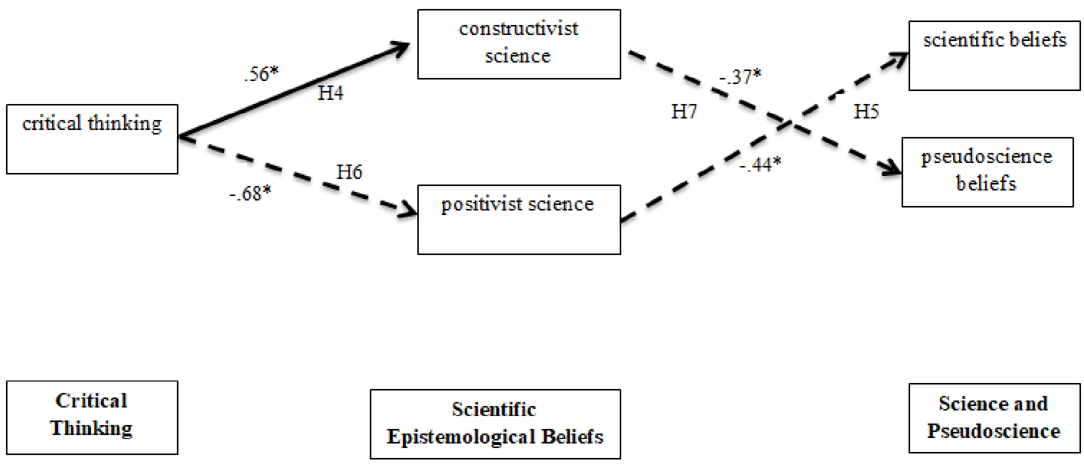
Note. k : number of items; **Correlation is significant at the 0.01 level (2-tailed).

It was concluded that all the variables in the study were related to each other. According to this, there is a negative and low correlation between scientific- pseudoscientific beliefs and critical thinking skills (r = –.27, *p*<.01), while there is a positive and moderate relationship between scientific epistemological beliefs (r = .41, *p*<.01). The relationship between critical thinking skills and scientific epistemological beliefs was also high and negative (r = –.56, *p*<.01).

In the second stage of the study, path analysis was performed to reveal the hidden structure between the variables. The final model that emerged as a result of the analysis is presented in Figure 2, and the values of the standardized regression coefficients of this model and the significance of the regression coefficients are presented in Table 4.

Figure 2

Path Diagram of the Final Model



Note. **p* < .05

Figure 2 presents the final model of the study, which excludes paths that were not statistically significant. Accordingly, critical thinking has both negative and positive effects on the explanation of the sub-dimensions of scientific epistemological beliefs (β= .56, R2=.31; β= -.68, R2 = .46, *p*<.05). These results support hypotheses H4 and H6. Scientific-pseudoscientific beliefs are also in a significant relationship with constructivist and traditional epistemological beliefs. This relationship is negative (β= –.37, R2=.13; β= -.44, R2 = .19, *p*<.05) and these results support the H5 and H7 hypotheses. Nevertheless, the H1 and H2 hypotheses explaining the relationship between critical thinking skills and science-pseudoscience beliefs are not supported. It has been seen that the sub-dimensions of scientific epistemological beliefs act as a mediator between critical thinking skills and science beliefs (β=–.20, 95% CI [.110; .323]) with critical thinking skills and pseudoscience beliefs (β= .29, 95% CI [.245; .424]).

Table 4

Analysis Results Related to the Model

Relationships between Variables	β	S.E.	C.R.	*p*
Critical thinking - constructivist science	.56	.05	10.61	<.05
Critical thinking- positivist science	–.68	.06	11.25	<.05
Positivist science- scientific beliefs	–.37	.05	7.86	<.05
Constructivist science- pseudoscience beliefs	–.44	.11	3.37	<.05

Four of the eight hypotheses involving the structural equation model, whose theoretical basis was established, were accepted, while four were rejected (see Table 5). In the structural equation model, the goodness of fit values is one of the criteria used to determine whether a model will be accepted after testing. The goodness of fit values of the final model obtained as a result of the analyses are as follows: χ^2/df = 3.45; RMSEA = .05; SRMR = .07, IFI = .91; CFI =. 92; GFI =. 96; AGFI =. 94; NFI = .92. Based on these values, the model was accepted.

Table 5
Evaluation of the Hypotheses of the Research Model

Hypotheses		*Result*
H1	Teachers' critical thinking skills are positively related to their scientific beliefs.	Reject
H2	Teachers' critical thinking skills are negatively related to their pseudoscience beliefs.	Reject
H3	Teachers' constructivist understanding of science is positively related to their scientific beliefs.	Reject
H4	Teachers' critical thinking skills are positively related to their constructivist understanding of science.	Accept
H5	Teachers' positivist understanding of science is negatively related to their scientific beliefs.	Accept
H6	Teachers' critical thinking skills are negatively related to their positivist understanding of science.	Accept
H7	Teachers' constructivist understanding of science is negatively related to their pseudoscience beliefs.	Accept
H8	Teachers' positivist understanding of science is positively related to their pseudoscience beliefs.	Reject

4. Discussion and Conclusion

The objective of the present study was to reveal the relationship between Turkish teachers' critical thinking skills, scientific epistemological beliefs, and science–pseudoscience beliefs. The results showed that teachers' critical thinking skills were related to their interest in scientific studies. Individuals' interest in scientific studies affects their critical thinking skills (Bahri & Corebima, 2015) because curiosity and interest lead the individual to think critically (Zubaidah et al., 2018). Thus, teachers' critical thinking skills are related to their interest in scientific publications.

Based on the scores obtained from the measurement tools, it appeared that there was a negative relationship between scientific-pseudoscientific beliefs and critical thinking. Moore (1992) reported that pseudoscience is more in demand where critical thinking does not develop, and Beyerstein (1995) stated that critical thinking cannot develop in a climate dominated by pseudoscience. Furthermore, it is stated in the current literature that critical thinking skills weaken pseudoscientific beliefs (Wilson, 2018). As a result, the literature supports the finding that critical thinking is negatively correlated with pseudoscience beliefs. Teachers in this research were also found to have traditional scientific beliefs. Maggioni and Parkinson (2008) examined the effect of epistemological beliefs on teachers' knowledge, experience, and instructional practices and made recommendations regarding teacher education. These results indicate that teachers generally adhere to traditional scientific beliefs.

Four of the eight hypotheses tested within the scope of the research were rejected, while four were supported. The related model rejected the direct relationship between critical thinking and scientific-pseudoscientific beliefs, but epistemological beliefs were found to be a mediator. There exists a relationship between belief and thinking in this case. As a matter of fact, it was observed that critical thinking skills have a positive relationship with the constructivist understanding of science (H4). According to Sinatra et al. (2014), individuals with a traditional (positivist) understanding of science have the view that knowledge is simple and disconnected from each other, while individuals with a constructivist belief that shows an advanced understanding of science have the view that knowledge is complex and interrelated. Similarly, Alpaslan et al. (2016) explained that individuals who have a constructivist understanding of science that can define the complex structure of knowledge approach knowledge with a more questioning perspective, and this understanding is similar to the structure of critical thinking. According to Escolà-Gascón et al. (2021), critical thinking skills are associated with the ability to question information. In the opinion of the teacher who questions and thinks critically, scientific knowledge does not provide infallible answers obtained by universal methods, that is, observation and experimentation. Those who hold a positivist understanding of science, based on dogmatic structures, believe knowledge is unchanging, whereas those who hold a constructivist understanding of science, based on a variable structure, believe knowledge can change over time. Kuhn et al. (2008) argue that a lack of belief that data can change in the light of new evidence indicates a lack of reflective and critical thinking skills. One may be unable to analyze data and make decisions effectively without these assumptions. In view of this understanding, it is possible to say that critical thinking skills require recognizing the permeability of knowledge. Thus, reasonable thinking (Ennis, 2009), which affects individuals' beliefs and decision-making processes, supports a constructivist understanding of science.

According to the epistemological development stages of knowledge, individuals who accept knowledge directly have traditional epistemological beliefs, whereas individuals who have constructivist epistemological beliefs analyze information through reasoning (Koyunlu Unlu & Dokme, 2017). Individuals with advanced epistemological beliefs can develop critical thinking skills through experimental studies (Getahun et al., 2016). Thus, it can be argued that knowledge can change in a constructivist science environment through the use of new information based on the constructivist understanding of science (Chan & Elliott, 2004). Conley et al. (2004) state that critical thinking skills develop in constructivist and questioning lab environments. At the same time, it has been stated that epistemological beliefs can develop in constructivist science environments where individuals are given the opportunity to think creatively and evaluate their own ideas. This demonstrates that the critical thinking structure of teachers allows them to transcend traditional beliefs about knowledge.

The study supports the hypothesis that critical thinking skills are negatively related to the traditional understanding of science (H5). Palmaquist and Finley (1997) assert that traditional understanding of science claim knowledge is always correct, cannot be altered, and can be proven by direct observation. Individuals with critical thinking are expressed as trusting in reason, open-minded, flexible in thought, impartial in evaluation, diligent in seeking information, and persistent in seeking results as long as research conditions allow (Facione, 1990). In the study of Şıvgın (2019), it was determined that high school students' critical thinking skills affected epistemological beliefs. Furthermore, Hyytinen et al. (2014) found that students' constructivist epistemological beliefs influence their critical thinking skills.

Critical thinking is one of the higher-order thinking skills associated with constructivist epistemology (Comerford, 1999). It involves the complex evaluation of different opinions or evidence that may not be completely true or false for a given topic (Cheng & Wan, 2017). On the other hand, individuals possessing traditional epistemological beliefs with an absolutist disposition cannot engage in complex intellectual activities to evaluate different and conflicting views or evidence (Kuhn et al., 2008). In the study, the hypothesis that teachers' constructivist understanding of science is in a negative relationship with pseudoscientific beliefs was accepted (H6). In their study, Metin et al. (2020) found that individuals who are unable to critically evaluate pseudoscientific claims hold less constructivist epistemological beliefs. It can therefore be said that teachers who have a constructivist understanding of science are more cautious about pseudoscientific beliefs. According to Alpaslan et al. (2016), individuals with constructivist scientific beliefs are skeptical about the accuracy of information and believe that information is subjective, evolving and changeable. Therefore, due to their higher level of curiosity, these individuals will tend to confirm scientific information from reliable sources.

According to Turgut et al. (2010), pre-service teachers have misconceptions about scientific laws and theories, their relationship, and the temporal nature of scientific knowledge. Due to such misperceptions regarding scientific concepts, individuals may be unable to distinguish between real science and pseudoscience, which parallels the positivist understanding of science. In another hypothesis of the study (H7), these claims were also confirmed. This hypothesis maintains that the traditional understanding of science and the real understanding of science (not pseudoscience) is in a negative relationship. According to Alpaslan et al. (2016), an individual with a traditional understanding of science trusts only one source. In contrast, individuals who subscribe to a constructivist mindset are more likely to seek a variety of sources, analyze evidence, and evaluate authorities. When an individual accepts information directly without checking it, it indicates that s/he is more likely to accept pseudoscientific claims as fact. It is argued in relevant literature that the positivist perspective, which is accepted as a traditional understanding of science, represents a limited understanding (Karaman, 2023). Essentially, this limited understanding of science contradicts the constructivist view of science, which holds that scientific knowledge is subjective, temporary, and evolving. From another point of view, an individual with a traditional understanding of science, who has the impression that science is absolute, may learn to distrust scientific claims when they one day learn that a scientific claim has been refuted. However, the fact that this individual has a contrary understanding will enable him/her to see the refutation of a scientific claim as proof of its reliability (Kohut, 2019). This shows that the epistemological views of individuals with traditional understanding of science about the nature of science may cause them to move away from real scientific knowledge. As opposed to science, pseudoscience avoids making risky predictions that can be disproven empirically. Progress in science is achieved by eliminating scientific theories that have been proven false and strengthening those which resist refutation (Karaman, 2023).

It is emphasized in general science standards that future citizens should be scientifically literate, able to acquire scientific knowledge, and understand the interactions between science and society (Cofré et al., 2019). To achieve this, teachers should introduce their students to science representations in accordance with contemporary education standards. It is the teacher's responsibility to protect students from all kinds of unscientific claims and pseudoscientific thoughts and to expose them to a realistic understanding of science (Karaman, 2023). This means that teachers with advanced scientific beliefs can make a significant contribution to educating students who are science-literate, who understand what science is, how it is done, and how scientific knowledge is constructed and justified (Metin et al., 2020). Assuming that constructivist scientific epistemology is built through individual thinking and logical reasoning (Pamuk et al. (2017), teachers who possess this skill should be able to distinguish real from pseudoscience science.

5. Limitations and Educational Implications

This study examined the relationship between teachers' critical thinking skills, scientific epistemological beliefs, and beliefs about the science–pseudoscience distinction. Results from the structural equation model analysis showed that teachers' scientific beliefs were negatively related to their traditional epistemological beliefs. Furthermore, teachers' critical thinking skills were negatively related to their positivist understanding of science. Despite being new to the literature, the research has some limitations. In the study in which relationships between the variables were discussed, only Turkish teachers participated. Since culture is one of the most important contexts, different results may be obtained when the research is conducted with teachers from different ethnicities and cultures. Western cultures accept the principle of questioning authority and distrusting it as a fundamental epistemological belief. Turkish culture, however, does not always apply to the same situation. This validity needs to be tested through longitudinal studies. In addition, the relationship between self-construal (Kağıtçıbaşı, 2007) and epistemological beliefs, which are significantly affected by cultural contexts, can be discussed. Additionally, intercultural research can offer a broader perspective.

Self-report scales were used to collect data within the scope of the research. There is a risk of biased answers being given in this situation. In order to reduce this risk and get to the root of beliefs, different research designs can be used. The belief structures of teachers and teacher candidates can be investigated in this context by preparing scenarios reflecting pseudoscience and traditional scientific beliefs. Thus, individuals' critical thinking skills may also be revealed in evaluating a relevant scenario.

This study shows that traditional scientific beliefs are negatively related to critical thinking skills. Hence, learning activities can be developed that support critical thinking skills and their effects on changing constructivist scientific beliefs can be assessed. An experiment design can establish a link between critical thinking skills and beliefs in such research.

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