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Research Article

Effects of the Activities Designed in the Context of Science-Pseudoscience Distinction on the 7th Grade Students' Pseudoscientific Beliefs, Criteria for Scientific Validity and Critical Thinking Skills

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Abstract

The present study aims to determine the effects of teaching activities designed for science-pseudoscience distinction on pseudoscientific beliefs and critical thinking skills of 7th-grade students, in addition to revealing their correct and incorrect criteria for scientific validity. A mixed research method was employed in this study. There are 59 students (29 students in the experimental group and 30 students in the control group) in the quantitative section of this study. Those in the experimental group were included in the qualitative section. Data collection was performed by using the Student Interview Forms prepared by the author, the Pseudoscience Belief Scale (PBS), and the Critical Thinking Scales Set (CTSS). Given the results achieved, the students were found to have a moderate level of critical thinking skills and a high level of pseudoscientific beliefs. The designed teaching activities enhanced their critical thinking skills and reduced their pseudoscientific beliefs.

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Introduction

Throughout human history, knowledge has been among the most valuable and hard-to-get assets. With the invention of the printing press, knowledge began to spread to the masses, and it entered people's homes through the proliferation of radio and television. Today, with the widespread use of the internet and social media, coupled with their ease of access and reduced costs, individuals can access vast amounts of information within short periods and easily. Moreover, individuals have not only become consumers of information but also active producers and disseminators. In addition, many books, magazines, films, and documentaries are available, and new resources are continuously added. With the advancement of technology, humanity has acquired increasingly vast amounts of information and the capacity to store it using high-capacity memory devices.

As stated by Aristotle, humans naturally desire to know. However, is there a downside to having infinite information available at the click of a button? The answer is undoubtedly yes. The existence of boundless information gives rise to several significant challenges, one of which is information pollution. Even well-educated individuals may struggle to distinguish scientific information from non-scientific one in the face of such pollution (Yalçınkaya, 2016). Information pollution impedes the accurate interpretation of knowledge (Gülseçen, 2014). Another significant challenge is the difficulty of accessing high-quality and reliable information. In recent years, social media has become a popular source for news and information acquisition. Unfortunately, information distortion on social media platforms continues to grow (Yegen, 2018). Even though there is an abundance of sources available on almost any subject, the ability to discern the accurate and reliable ones has become one of the critical skills of this era. In the limited span of human life, individuals increasingly find themselves confused about which information meets their needs, which information is true, and how to differentiate accurate information from inaccurate information. These have become some of the most pressing questions of our time. At this point, the concepts of science, scientific validity, and the scientific method become very important. Scientific knowledge has the characteristics of objectivity, universally applicable principles, reliance on reason, logic, and criticism, as well as testability and reliability (Tutar, 2014). These characteristics are among the reasons why science and scientific thinking are held in such high esteem.

Examining the concept of science, it can be seen that there are many definitions across various sources, with no single definition universally agreed upon (Yaşar, 1998). For instance, Türkmen (2006) described science as "humanity's efforts to understand and explain the physical universe," whereas Can (2013) defined it as "an accumulation of knowledge produced by humans through specific methods." The Turkish Language Institution (TDK) dictionary provides three definitions of science:

"Systematic knowledge that selects a portion of the universe or events as its subject and attempts to draw conclusions through experimental methods and empirical reality."

"Methodical and systematic knowledge characterized by general validity and certainty."

"A process of acquiring knowledge and conducting methodical research, driven by the desire to understand a specific subject and oriented toward a particular goal."

Even though there are multiple definitions, they largely support one another. The most prominent concepts across these definitions include the possession of systematic knowledge, the ability to generalize, a focus on understanding, a reliance on evidence, and having specific methods. Rather than seeking a single comprehensive definition of science, it may be more meaningful to focus on understanding the nature of science (Çepni, 2006). Understanding the nature of science requires familiarity with its processes, methodologies, and criteria for scientific validity.

The diversity observed in definitions of science naturally extends to the criteria for scientific validity. Philosophers of science and scientists alike have long engaged in philosophical debates over what science is and which criteria should be used. These discussions continue today. Some of the widely accepted criteria among contemporary scholars include causality, determinism, measurability, consistency, testability, empiricism, logical coherence, reproducibility, openness to revision, disinterestedness, organized skepticism, fecundity (fruitfulness), and universality (Tutar, 2014). These criteria serve to distinguish science from non-scientific domains. Understanding what science is not can help prevent confusion and misinterpretation regarding scientific claims.

People often experience difficulties in distinguishing science from pseudoscience (Ayvacı & Bağ, 2016; Çekbaş, 2017; Duruk et al., 2023). A scientist might claim, "I can tell the difference between science and pseudoscience when I see it." However, it is not that easy (Simanek, 2005). Two primary factors contributing to this difficulty are the ease of access to pseudoscientific content through media channels and the tactics used by proponents of pseudoscientific claims, who often present unverifiable success stories to persuade the public. Moreover, examples of pseudoscience tend to be engaging and trigger curiosity (Çetinkaya et al., 2015b). Individuals who lack the knowledge and skills necessary to distinguish science from pseudoscience can be easily influenced by those contents. This situation signifies the critical importance of developing the ability to differentiate science from pseudoscience.

The objectives of the science curriculum include fostering individuals who can solve problems, ascertain how scientific knowledge is created and the processes of science, demonstrate reasoning skills, think scientifically, and make informed decisions. The objectives of this study are consistent with those specified in the middle school curriculum for science and elective science applications courses. Specifically, this study aims to identify students' pseudoscientific beliefs and critical thinking skills, determine the types of reasoning they use when distinguishing science from pseudoscience, reveal which scientific criteria they have, identify any misconceptions related to scientific criteria, and evaluate the effectiveness of the instructional activities designed and implemented within the scope of the study.

The research problem is: "What is the impact of an educational intervention, based on instructional activities designed around the science-pseudoscience distinction, on 7th-grade students' pseudoscientific beliefs, scientific criteria, and critical thinking skills?"

For this purpose, the following sub-questions were established:

1. What is the level of critical thinking skills among 7th-grade students?
2. Do the instructional activities designed around the distinction between science and pseudoscience have a significant impact on 7th-grade students' critical thinking skills?
3. What is the level of pseudoscientific beliefs among 7th-grade students?
4. Do the instructional activities designed around the science-pseudoscience distinction have a significant effect on 7th-grade students' levels of pseudoscientific beliefs?
5. What scientific and incorrect scientific criteria do 7th-grade students possess?
6. To what extent do the activities designed in the context of differentiating science from pseudoscience affect 7th-grade students' scientific and incorrect scientific criteria?

Method

This section details the methodology employed in this study, including the research design, formation of the study groups, data collection instruments, procedures applied to the experimental and control groups, the implementation process, and the statistical methods used for collecting and analyzing the data.

Study Design

This study employs the embedded design which is one of the mixed-methods. Mixed-methods design combines both qualitative and quantitative approaches to improve the depth of understanding and validation. As a third methodological movement, mixed methods research addresses the limitations of purely qualitative or quantitative designs, offers more comprehensive evidence for problem-solving, and enables the investigation of research questions that cannot be adequately addressed through either method alone. Furthermore, it reflects a pragmatic approach, a paradigm encompassing both qualitative and quantitative research, allowing researchers to draw upon all available methodologies in addressing a research problem (Creswell & Clark, 2018, pp. 14-15). Inductive and deductive reasoning can be employed simultaneously in mixed-methods studies (Teddlie & Tashakkori, 2015, pp. 32-33).

In mixed-methods research, the focus lies not on the method itself but on the research problem, the outcomes, and the use of multiple data collection techniques. Therefore, it is pluralistic in nature. It is related to pragmatism, which can integrate deductive and inductive reasoning (Creswell & Clark, 2018).

Study Groups

The participants consisted of 7th-grade students studying in a public middle school located in Kocaeli, Türkiye. The school was selected since the researcher works there. Several factors influenced the selection of 7th-grade students: (i) their curriculum includes an elective course on scientific practices, (ii) they have the abstract reasoning skills required to critically examine criteria of scientific reasoning, and (iii) unlike 8th-grade students, they are not under the pressure of central examination anxiety.

Cluster sampling, which is a probability-based method, was utilized for sampling. This method is useful when the population consists of naturally or artificially formed groups that exhibit similar characteristics (Yıldırım & Şimşek, 2016, p. 117). Two 7th-grade classes from the same school were included in this study. One of these classes was randomly assigned as the experimental group, whereas the other served as the control group. The quantitative sample consisted of a total of 59 students across these two sections. The qualitative sample consisted of one of the two classes, selected by random draw, with 29 students enrolled. This class also constituted the experimental group.

Data Collection Instruments

In this study, data were collected using the Pseudoscientific Belief Scale, the Critical Thinking Scales Set, and the Student Interview Form.

Pseudoscientific Belief Scale (PBS)

This scale, introduced by Çetinkaya and Taşar (2018), was employed to assess students' beliefs regarding pseudoscience. This instrument is a 22-item, 5-point Likert-type scale. The items are scored between (5) "strongly agree" and (1) "strongly disagree." The total score ranges between 22 and 110. Considering their scores, students' beliefs in pseudoscience can be categorized as high, moderate, or low.

Critical Thinking Scales Set (CTSS)

The CTSS, developed by Demir (2006), was utilized to examine middle school students' critical thinking skills. It consists of six subscales and 56 items in total. Except for the self-regulation subscale, the other subscales consist of dichotomous items coded as 0 and 1. The self-regulation subscale is a 3-point Likert-type scale. The Analysis, Evaluation, and Inference subscales include items with correct and incorrect answer choices and are scored as 0 or 1. The Interpretation and Explanation subscales contain multiple-choice items, also scored as 0 or 1. The Self-Regulation subscale is scored on a 3-point Likert scale, scored as 0, 1, and 2.

Student Interview Form

In line with the objective of this study, a semi-structured interview form was designed by the author to investigate students' perceptions of the distinction between science and pseudoscience. The form includes various types of pseudoscientific topics such as DNA rejuvenation, ancient astronaut theory, astrology, anti-vaccine beliefs, quantum healing hypnosis therapy, perpetual motion machines, and numerology. Semi-structured interviews were conducted before and after the activities. The interview form was developed following a review of the relevant literature and was reviewed by experts to ensure content validity. A pilot study was carried out with five students, matched in age but not included in the main study sample, to assess the clarity and comprehensibility of the interview questions. The form was given its final form considering this pilot study. During the interviews, students were anonymized using codes such as S1, S2, etc.

Data Collection Process

In this study, since the aim was to investigate the effects of activities designed within the context of the science–pseudoscience distinction, and incorporating various pseudoscientific contents, on students' pseudoscientific beliefs, critical thinking skills, and criteria for scientific validity, it was considered appropriate to collect data before, during, and after the implementation. This study lasted a total of 20 class hours, carried out over 10 weeks at a rate of two class hours per week. Data were collected by the researcher during the elective Science Applications course taught in the seventh grade of middle school.

Data Analysis

This section outlines the analytical procedures applied to both quantitative and qualitative data.

Quantitative Data Analysis

Quantitative data were analyzed using SPSS version 18.0. The statistical methods and techniques employed in analyzing the sub-problems are shown in Table 1.

Table 1. Statistical methods and techniques used in the analysis of the sub-problems

Scales	Sub-Problems	Analysis conducted
CTSS	Sub-problem 1 Sub-problem 2	Two-way mixed ANOVA
PBS	Sub-problem 3 Sub-problem 4	Two-way mixed ANOVA and paired samples t-test

As shown in Table 1, the sub-problems were analyzed using the corresponding statistical methods and techniques.

Since PBS is a 5-point Likert-type scale, the Cronbach's α coefficient, which is particularly used for scoring systems based on rating scales (Can, 2013, p. 388), was used in calculating the reliability coefficient. Moreover, the results of the Shapiro-Wilk and Kolmogorov-Smirnov tests were examined to ascertain whether the scores obtained from the pre-test and post-test followed a normal distribution. Levene's test and Box's M test were also conducted, and the data were determined to be suitable for parametric testing. Then, a two-way mixed-design analysis of variance (2x2 ANOVA) was performed. In order to assess the significance of the slight increase found in the arithmetic mean of the control group, a paired samples t-test was applied.

As the CTSS consists of a set of scales involving different types of measurement formats, both the Kuder-Richardson Formula 20 (KR-20) and Cronbach's α coefficients were used to calculate internal consistency reliability. Furthermore, the Shapiro-Wilk and Kolmogorov-Smirnov tests were employed to determine whether the scores from the pre-test and post-test followed a normal distribution. Following the application of Levene's test and Box's M test, the data were again deemed appropriate for parametric analyses. A two-way mixed-design ANOVA (2x2) was then conducted.

Following the two-way mixed ANOVA analyses of the quantitative data obtained from this study, effect sizes were calculated for statistically significant findings. In mixed-design ANOVA, effect size can be calculated using either the eta-squared (η^2) or omega-squared (ω^2) formulas (Field, 2005).

Qualitative Data Analysis

Qualitative data analysis involves a multi-step process, including preparing and organizing the data, coding, generating themes, and finally presenting the findings in the form of figures, tables, or narrative discussions (Creswell, 2018, p. 180). Computer-assisted qualitative data analysis facilitates a holistic and systematic approach and offers researchers substantial benefits in searching, linking, and visualizing data due to its database-driven structure (Yurdakul et al., 2016). Therefore, the NVivo 12 qualitative data analysis software was employed for content analysis. The semi-structured pre- and post-interview data were analyzed employing content analysis.

In the content analysis, the student interview forms completed during student interviews were transcribed verbatim into a digital format. All data were uploaded into the NVivo software. Student responses were examined in depth, and codes were generated from semantically meaningful units within the data. After all data were coded, a code list was generated and compared with a second list developed independently by another expert. An intercoder agreement formula was utilized to ensure the reliability of the content analysis. In the literature, an agreement rate of at least 70% is considered acceptable (Huberman & Miles, 1994). The intercoder agreement rate was calculated as 85% in this study. The generated codes were then rechecked repeatedly to finalize the coding process.

Findings

Quantitative and qualitative findings are examined under separate headings in this section.

Quantitative Findings

Findings related to students' critical thinking skills

Reliability coefficients of the scales are shown in Table 2

Table 2. Pretest and posttest reliability coefficients of CTSS

Factor	Groups	KR-20	Cronbach α
Analysis	Pretest	.59	
	Posttest	.72	
Assessment	Pretest	.68	
	Posttest	.80	
Inference	Pretest	.60	
	Posttest	.52	
Interpretation	Pretest	.57	
	Posttest	.51	

Explanation	Pretest	.54	
	Posttest	.53	
Self-regulation	Pretest		.65
	Posttest		.66

Cronbach's alpha is generally used in cases where scoring is based on a rating scale (Can, 2013, p. 388). Accordingly, KR-20 coefficients were calculated for the first five factors, whereas Cronbach's alpha was computed for the final factor. A KR-20 reliability coefficient of ≥.50 is considered acceptable for short tests consisting of 10-15 items, whereas values of ≥.80 are required for tests with >50 items (Tan & Erdoğan, 2001). A Cronbach's alpha coefficient >.70 indicates that the results obtained from the items are reliable (Büyüköztürk, 2018). Although alpha values of ≥.70 are generally considered satisfactory, in subscales with fewer items, values of ≥.60 may also be accepted (Durmuş et al., 2018).

Shapiro-Wilk and Kolmogorov-Smirnov tests were performed to determine whether the scores obtained from the CTSS pretest and posttest administered after the instructional activities designed in the context of the science-pseudoscience distinction had a normal distribution. These tests assess the null hypothesis that "the data do not deviate significantly from a normal distribution" (Can, 2013, p. 88). The findings are presented in Table 3.

Table 3. Kolmogorov-Smirnov and Shapiro-Wilk normality test findings of CTSS

Tests		**Kolmogorov-Smirnov**			**Shapiro-Wilk**		
		Statistic	df	p	Statistic	df	p
Pretest	Exper.	.161	29	.054	.936	29	.080
	control	.107	30	.200	.961	30	.327
Posttest	Exper.	.144	29	.127	.950	29	.178
	Control	.117	30	.200	.972	30	.581

As shown in Table 3, the pretest and posttest scores are normally distributed ($p > .05$).

The findings of Levene's test, conducted to determine the equality of variances across groups, are presented in Table 4.

Table 4. Homogeneity of variance test findings for CTSS pretest and sosttest scores from experimental and control groups

Tests	F	sd1	sd2	p
CTSS Pretest	1.500	1	57	.226
CTSS Posttest	.041	1	57	.840

Table 4 indicates that there were no statistically significant differences in variances ($p > .05$).

Box's M test was performed to examine the equality of covariance matrices among the paired measurement sets. Since the resulting p-value was .387, the null hypothesis stating that "there is no significant difference between the covariances" was accepted ($p > .05$). It was concluded that all assumptions required to conduct a two-way mixed ANOVA were met.

Given the findings of normality and homogeneity analyses on CTSS pretest and posttest scores, it was decided to proceed with parametric tests. Accordingly, a two-way mixed analysis of variance (2x2 ANOVA) was conducted on the scores obtained by the students in both groups from the data collection instruments.

The arithmetic means and standard deviations of the academic success scores obtained by students in both groups before and after the intervention are shown in Table 5.

Table 5. Descriptive statistics of CTSS scores in the experimental and control groups

Groups	Pretest			Posttest		
	N	$\bar{X}$	S	N	$\bar{X}$	S
Experimental	29	44.52	4.41	29	51.79	5.97
Control	30	44.33	5.86	30	46.67	6.41
Total	59	44.42	5.16	59	49.19	6.66

Table 5 shows that the CTSS pretest scores of students in both groups were approximately 44. Furthermore, the average CTSS score of the experimental group, which participated in instructional activities designed considering the science-pseudoscience distinction, increased from 44.52 to 51.79. In contrast, the average CTSS score in the control group, which received instruction in line with the Ministry of National Education (MoNE) curriculum, increased from 44.33 to 46.67.

To assess the statistical significance of the differences between the groups, the findings of a two-way mixed ANOVA are presented in Table 6.

As shown in Table 6, there was no statistically significant difference in the overall pretest–posttest scores between the groups [$F_{(1, 57)}$ = 4.77, p > .01]. However, the difference between pretest and posttest scores across all students was statistically significant [$F_{(1, 57)}$ = 31.14, p < .01], with a large effect size (η^2 = .35). Additionally, the change in students' scores from pretest to posttest significantly differed based on group assignment (experimental vs. control).

Table 6. Findings of the two-way mixed ANOVA for CTSS pretest and posttest scores of the experimental and control groups

Source of variance	**Sum of Squares**	**Sd**	**Mean Square**	**F**	**p**	**η^2**
Between subjects						
Group (experimental/control)	207.914	1	207.914	4.769	.033	
Error	2485.103	57	43.598			
Within-Subjects						
Pretest-Posttest	680.787	1	680.787	31.138	.000	.35
Pretest-Posttest *being in the experimental / control group	180.109	1	180.109	8.238	.006	.13
Error	1246.230	57	21.864			

[$F_{(1\text{-}57)}$ =8,24, p<.01]. Based on these findings, it can be concluded that the instruction designed around the distinction between science and pseudoscience had a statistically significant effect on improving students' critical thinking skills. This effect is considered moderate in magnitude (η^2=.13)(η^2 = .13)(η^2=.13). As stated by Cohen (1988), an eta squared value between .0588 and .1379 corresponds to a medium effect size.

Findings regarding students' pseudoscientific beliefs

PBS was administered twice, once before and once after the instructional activities. Both the Shapiro-Wilk and Kolmogorov-Smirnov tests were conducted to determine whether the PBS pretest and posttest scores were normally distributed. The findings are presented in Table 7.

Table 7. Kolmogorov–Smirnov and Shapiro–Wilk normality test findings for the PBS

Test		**Kolmogorov-Smirnov**			**Shapiro-Wilk**		
		Statistic	df	P	Statistic	df	p
Pretest	Exper.	.111	29	.200	.960	29	.337
	control	.105	30	.200	.972	30	.597
Posttest	Exper.	.116	29	.200	.948	29	.161
	control	.116	30	.200	.946	30	.135

As shown in Table 7, the findings of both normality tests indicate that the pretest and posttest data are normally distributed (p>.05)(p >.05)(p>.05).

Levene's test was conducted to examine the equality of variances between the groups. The findings are presented in Table 8.

Table 8. Homogeneity of variance test findings for PBS pretest and posttest scores in the experimental and control groups

Tests	**F**	**sd1**	**sd2**	**p**
PBS Pretest	1.400	1	57	.242
PBS Posttest	.995	1	57	.323

Table 8 indicates that there was no significant difference in variances between groups (p>.05)(p > .05)(p>.05).

Box's M test was performed to examine the homogeneity of covariances for the pairwise combinations of the measurement sets. As the p-value was found to be .061, the null hypothesis of equal covariances indicating no significant difference in covariances was accepted (p>.05)(p > .05)(p>.05). Descriptive statistics for the PBS pretest and posttest scores of students are shown in Table 9.

Table 9. Descriptive statistics for PBS

Groups	**Pretest**			**Posttest**		
	N	$\bar{\textbf{X}}$	**S**	**N**	$\bar{\textbf{X}}$	**S**
Experimental	29	75.55	10.83	29	65.59	12.88
Control	30	74.70	16.76	30	77.33	15.56
Total	59	75.11	14.05	59	71.56	15.37

As shown in Table 9, the mean PBS score decreased from 75.55 to 65.59 in the experimental group and from .74.70 to 77.33 in the control group.

The findings of the two-way mixed ANOVA conducted to determine whether the difference between the PBS scores of the groups was statistically significant are presented in Table 10.

Table 10. Findings of the two-factor mixed measures ANOVA for the PBS pretest and posttest scores of the groups

Source of variance	Sum of Squares	Sd	Mean Square	F	p	η^2
Between subjects						
Group (experimental/control)	875.23	1	875.23	3.47	.068	
Error	14365.21	57	252.02			
Within-Subjects						
Pretest-Posttest	396.373	1	396.373	185.93	.118	
Pretest-Posttest *being in the experimental / control group	1170.31	1	1170.31	7.63	.008	.12
Error	8742.97	57	153.40			

Examining Table 10, it can be seen that there is no statistically significant difference between the total pretest and posttest scores of the groups [$F_{(1, 57)} = 3.47$, $p > .01$]. Similarly, no significant difference is found between the pretest and posttest scores of all participants [$F_{(1, 57)} = 185.93$, $p > .01$]. However, the interaction effect between time (Pretest vs. Posttest) and group membership (experimental vs. control) is statistically significant in favor of the experimental group [$F_{(1, 57)} = 7.63$, $p < .01$], indicating that the change in scores differed meaningfully between the two groups.

Qualitative Findings

Findings regarding the DNA renewal activity

This section presents an analysis of the pre- and post-interviews conducted for the DNA Renewal activity. In the semi-structured interviews, students were asked the following question: “Do you think the claims about DNA renewal have scientific validity? If yes, what is the basis of your judgment? If not, why do you think they are not scientific? If you are unsure, what makes you uncertain?” It was aimed to assess students’ views on scientific reasoning and their ability to distinguish pseudoscientific content. Furthermore, the effect of in-class discussions held between the pre- and post-interviews was also evaluated. The themes, subthemes, categories, and codes identified from the pre-interview and post-interview analyses are presented below. It was observed that most student responses included multiple codes, and all of these responses were included in the analysis.

In the post-interviews, no students expressed uncertainty. A comparison of the pre- and post-interview findings for the DNA Renewal activity is presented in Table 11.

Table 11. Comparison of pre- and post-interview findings for the DNA renewal activity

Themes and Sub-themes	Category	Code	Pre-Interview f	Post-Interview F
Scientific			15	2
Incorrect Criteria for Scientific Validity	Effectiveness	Individual effect Being useful	9	2
	Inclusion of Scientific Concepts	Inclusion of scientific concepts Association with science Inclusion of research	4	-
	Relying on Authority	University graduate Scientist opinion	3	-
	Incorporation of Resource	Having a resource Heard from someone	2	-
Non-scientific			13	27
	Irrationality	Impossibility Implausibility Irrationality	10	20
	Provability	Inclusion of sufficient information Carrying out a sufficient number of studies Having scientific evidence	6	16
	Support from the Scientific Community	Being supported by many scientists Support from experts	5	9
	Reproducibility	Producing the same result for everyone	1	1
	Testability	Being experimental	-	3
Indecisive			1	-

Examining Table 11, it is seen that in the pre-interviews, 15 students believed that the claims related to DNA renewal, a pseudoscientific content, were scientifically valid, whereas only 2 students maintained that belief in the post-interviews. Furthermore, while 13 students initially stated that the claims were not scientific, this number increased to 27 in the post-interviews.

In the pre-interview findings, students employed four categories of incorrect criteria for scientific validity, whereas this number had dropped to one in the post-interviews. Additionally, among students who considered the claims unscientific, the number of criteria for scientific validity they cited increased from four to five, with the inclusion of the category "testability."

Findings regarding the ancient astronaut theory activity

This section presents an analysis of the pre- and post-interviews conducted during the activity titled Ancient Astronaut Theory. In the semi-structured interviews, students were asked the following question: "Do you think the claims made by the Ancient Astronaut Theory have scientific merit? If you believe they do, what leads you to that conclusion? If you believe they do not, on what grounds did you reach that conclusion? If you are undecided, why do you feel uncertain?" These questions aimed to identify students' perspectives on scientific validity and their ability to distinguish between scientific and pseudoscientific content.

Table 12 displays a comparison of the scientific and incorrect criteria for scientific validity identified in the pre- and post-interview findings related to the Ancient Astronaut Theory activity.

Examining Table 12, it can be seen that classroom discussions led to a positive shift in students' perceptions of scientific credibility. While 15 students initially regarded the Ancient Astronaut Theory, a pseudoscientific claim, as scientific, only 4 students maintained this belief in the post-interview. Moreover, the number of students who considered theory unscientific increased from 6 in the pre-interview to 12 in the post-interview. Notably, there was also an increase in the number of students who reported being undecided. Further analysis revealed that 6 students who had initially judged the theory to be scientific later stated it was not, while 5 students shifted to an undecided stance.

Table 12. Comparison of pre- and post-interview findings on the ancient astronaut theory activity

Theme and Sub-Themes	**Category**	**Code**	**Pre-Interview (f)**	**Post-Interview (f)**
Scientific			15	4
Incorrect Criteria for Scientific Validity	Rationalization	Plausibility Impossibility of the contrary	13	6
	Inclusion of References	Presence of photographs Newspaper articles	14	4
	Use of Scientific Concepts	Association with science Reference to scientific content	2	-
	Relying on Authority	Author's opinion	2	-
Not scientific			6	12
Criteria for Scientific Validity	Provability	Availability of sufficient evidence Use of reliable sources	6	19
	Support from the Scientific Community	Supported by many scientists Lack of scientific research on the topic	2	4
	Irrationality	Impossibility Fabricated nature	6	7
Undecided			8	13

Students' incorrect criteria for scientific validity were categorized under four themes in the pre-interviews, whereas only two categories emerged from the post-interviews.

Findings regarding the anti-vaccination activity

This section presents the analysis of the pre- and post-interviews conducted during the Anti-Vaccination activity. In the semi-structured interviews, students were asked the following questions: "Do you think the claims made by people against vaccination have scientific content? If yes, what is the basis for your conclusion? If not, what led you to that conclusion? If you are undecided, why?" These questions were designed to assess students' views on scientific validity and their ability to distinguish pseudoscientific content. The analyses revealed that students often expressed views containing multiple codes; all such responses were included in the analysis.

Following the completion of the large-group classroom discussion, students were asked to share their views again. The aim was to determine whether the in-class discussion influenced students' perceptions of scientific validity and whether it led to any changes in their modes of thinking and decision-making about what constitutes science. The findings of the post-interviews are presented in Table 13.

Upon examining Table 13, it becomes evident that the only incorrect criteria for scientific validity observed in students' responses was reliance on authority. The legitimate scientific criteria cited by students, in order of frequency, included provability, support from the scientific community, irrationality, testability, and reproducibility.

Table 13 provides a comparison of the scientific and pseudoscientific reasoning criteria identified in students' responses during the pre- and post-interviews related to the anti-vaccination activity.

Table 13. Comparison of pre- and post-interview findings from the anti-vaccination activity

Theme and Sub-Themes	Category	Code	Pre-Interview (f)	Post-Interview (f)
Scientific			18	1
Incorrect Criteria for Scientific Validity	Relying on Authority	Doctor's opinion Prosecutor's opinion	10	1
	Inclusion of References	Internet news Newspaper articles	8	-
	Rationalization	Reasonability	5	-
	Inclusion of Scientific Concepts	Use of science Association with medicine	2	-
Not scientific			7	28
Criteria for Scientific Validity	Provability	Inclusion of sufficient evidence Inclusion of reliable resources	5	24
	Irrationality	Irrationality	**2**	7
	Support from the Scientific Community	Supported by many scientists Supported by many doctors Results reported in scientific articles	4	7

	Reproducibility	Producing the same result as anyone	1	2
	Testability	Relying on experiment and observation Use of scientific data	-	4
Undecided			4	-

Table 13 shows that in the pre-interview, 18 students believed that anti-vaccination claims, despite being pseudoscientific, were scientific. In contrast, only one student maintained this belief in the post-interview. Additionally, the number of students who viewed the content as unscientific increased from 7 in the pre-interview to 28 in the post-interview.

The incorrect criteria for scientific reasoning mentioned by students in the pre-interview were grouped into four categories, whereas in the post-interview, only one such category remained. This finding highlights that, as a result of the in-class discussion, students who had previously considered the content scientific due to its use of logical plausibility, scientific terminology, or referenced sources, abandoned these views.

An examination of the scientific criteria cited by students who identified the content as unscientific reveals that while their responses in the pre-interview fell into four categories, in the post-interview, they were distributed across five categories. Notably, the criterion of testability, which was entirely absent in the pre-interviews, appeared in the post-interviews in the responses of four students, an especially significant development.

Findings regarding astrology activity

This section presents the analyses of the pre- and post-interviews conducted during the activity titled Astrology. The semi-structured interviews aimed to explore students' views on scientific validity and their ability to distinguish between scientific and pseudoscientific content. Students were asked the following question: "Do you think the claims of astrology contain scientific content? If yes, what is your reasoning? If not, what is your reasoning? If you are undecided, what makes it difficult for you to decide?"

The comparison of scientific and incorrect scientific reasoning criteria identified in the pre- and post-interviews related to the astrology activity is presented in Table 14.

As shown in Table 14, during the pre-interviews, 15 students considered astrology (a pseudoscientific domain) to be scientific, whereas only 2 students maintained this view in the post-interviews. Furthermore, while only 2 students initially regarded astrology as unscientific, this number rose to 25 in the post-interviews. The analysis revealed that 12 students who initially believed astrology was scientific changed their stance in the post-interviews, stating that astrology is not scientific, while 2 students reported being undecided. The incorrect scientific criteria used by students were classified into six categories in the pre-interviews and into two categories in the post-interviews. Meanwhile, the students' correct use of scientific criteria expanded from three categories in the pre-interviews to five in the post-interviews.

Table 14. Comparison of pre- and post-interview findings from the astrology activity

Theme and Sub-Themes	**Category**	**Code**	**Pre-Interview (f)**	**Post-Interview (f)**
Scientific			15	2
Incorrect Criteria for Scientific Validity	Effectiveness	I believe in horoscopes Descriptions explain me	14	1
	Use of Scientific Concepts	Constellations, planets, and space Astrology is related with science Research-based	6	2
	Previous Information	It has existed for a long time There were head astrologers in palaces	5	-
	Inclusion of References	Presence of references Newspaper articles	4	-
	Opinion of the Majority	Presence of professions in this field Encountering everywhere	4	-
	Relying on Authority	Astrologer's opinion Studies of scientists	4	-
Not scientific			2	25
Criteria for Scientific Validity	Provability	Inclusion of sufficient evidence Inclusion of reliable resources	3	12
	Consistency	Explanations that fit everyone	1	16
	Irrationality	Irrationality Not fitting to an	8	6

		individual Impossibility		
	Reproducibility	Producing the same results as anyone	-	4
	Testability	Relying on experiment and observation Use of scientific data	-	2
Undecided			12	2

Findings regarding perpetual motion machines activity

This section presents the analyses of the pre- and post-interviews conducted during the Perpetual Motion Machines activity. Similar to the previous activity, semi-structured interviews were held to assess students' perceptions of scientific validity and their ability to differentiate scientific claims from pseudoscientific ones. The following question was posed: "Do you think perpetual motion machines involve scientific content? If yes, what is your reasoning? If not, what is your reasoning? If you are undecided, what makes it difficult for you to decide?"

The comparison of scientific and incorrect scientific reasoning criteria identified in the pre- and post-interviews for the perpetual motion machines activity is presented in Table 15. As Table 15 indicates, 11 students considered perpetual motion machines, a classic pseudoscientific concept, to be scientific in the pre-interviews. However, no students continued to hold this belief in the post-interviews. The number of students who viewed the concept as unscientific increased from 16 in the pre-interviews to 27 in the post-interviews. Moreover, two students remained undecided in both the pre- and post-interviews.

Table 15. Comparison of pre- and post-interview findings on the perpetual motion machine activity

Theme and Sub-Themes	**Category**	**Code**	**Pre-Interview (f)**	**Post-Interview (f)**
Scientific			11	-
Incorrect Criteria for Scientific Validity	Effectiveness	Individual effect Being useful	5	-
	Previous Information	Being present for a long time Taking a long time to develop	5	-
	Rationalization	Rationality	4	-

	Inclusion of References	Having reference Having photo	4	-
	Inclusion of Scientific Concepts	Inclusion of scientific concepts	4	-
Not scientific			16	27
Criteria for Scientific Validity	Provability	Inclusion of sufficient information Presence of enough studies Presence of scientific evidence	14	17
	Irrationality	Absurdity Impossibility Irrationality	11	22
	Support from the Scientific Community	Supported by many scientists Supported by experts	3	4
	Testability	Being experimental	-	4
Undecided			2	2

It is observed that the number of students who identified the perpetual motion machine activity as non-scientific based on scientific criteria increased from 3 to 4 with the inclusion of the testability category.

Findings regarding the quantum healing hypnosis therapy activity

This section presents the analysis of pre- and post-interviews conducted during the Quantum Healing Hypnosis Therapy activity. In the semi-structured interviews, students were asked the following questions to assess their views on scientific validity and their ability to distinguish pseudoscientific content: “Do you think Quantum Healing Hypnosis Therapy involves scientific content? If you believe it does, what is the basis for your conclusion? If you believe it does not, what is the basis for your conclusion? If you are undecided, what makes you uncertain?”

The comparison of scientific and faulty scientific criteria identified in the pre- and post-interviews regarding the Quantum Healing Hypnosis Therapy activity is presented in Table 16.

Table 16. Comparison of pre- and post-interview findings regarding the quantum healing hypnosis therapy activity

Theme and Sub-Themes	Category	Code	Pre-Interview (f)	Post-Interview (f)
Scientific			6	1
Incorrect Criteria for Scientific Validity	Effectiveness	Individual effect Being useful	6	-
	Inclusion of Scientific Concepts	Association with science Inclusion of studies	4	2
	Relying on Authority	Opinion of a known author	1	-
	Inclusion of References	Media coverage	1	-
Not scientific			17	27
Criteria for Scientific Validity	Provability	Inclusion of sufficient information Presence of enough studies Presence of scientific evidence	11	26
	Irrationality	Irrationality	13	8
	Reproducibility	Producing the same result as anyone	2	3
	Support from the Scientific Community	Supported by many scientists	1	8
	Testability	Being experimental	-	9
Undecided			5	1

Upon examining Table 16, it is evident that in the pre-interview phase, six students considered the pseudoscientific content of Quantum Healing Hypnosis Therapy to be scientific. However, in the post-interview phase, only one student maintained this view. Moreover, while 17 students initially regarded the activity as unscientific, this number increased to 27 in the post-interview. The number of undecided students decreased from five in the pre-interview to two in the post-interview.

It is also observed that while faulty scientific criteria were cited under four distinct categories in the pre-interview responses, this number dropped to one category in the post-interview. Moreover, the number of scientific criteria cited by students who considered the therapy unscientific increased from 4 to 5, with the inclusion of the testability category.

Findings regarding the numerology activity

Under this heading, analyses of the pre- and post-interviews conducted during the activity titled "Numerology" are presented. In the semi-structured interviews, students were asked the following questions to assess their views on scientific validity and their ability to distinguish between scientific and pseudoscientific content: "Do you think numerology contains scientific content? If you believe it does, on what basis did you reach that conclusion? If you believe it does not, on what basis did you reach that conclusion? If you are undecided, why are you undecided?"

The activity on numerology and the corresponding student responses from the pre- and post-interviews are compared in Table 17. An examination of the table reveals that following the classroom discussion, students' perceptions of scientific validity shifted in a positive direction. While 1 student initially believed that numerology, a form of pseudoscientific content, was scientific, none of the students considered it scientific in the post-interview.

Table 17. Comparison of pre- and post-interview findings on the numerology activity

Theme and Sub-Themes	**Category**	**Code**	**Pre-Interview (f)**	**Post-Interview (f)**
Scientific			1	-
	Inclusion of References	Internet news Newspaper articles	1	-
Not scientific			28	29

	Provability	Presence of enough evidence Presence of reliable references	16	21
	Irrationality	Irrationality Not fitting to an individual	21	10
	Testability	Being experimental	2	7
Criteria for Scientific Validity	Consistency	Explanations fitting anyone	2	-
	Reproducibility	Producing the same results as anyone	1	1
	Support from the Scientific Community	Supported by many scientists	-	3
	Intended Scientific Terminology	Use of foreign words Use of the suffix "-logy" Scientific image	1	12

In the pre-interview, students' inaccurate scientific criteria were grouped into a single category. By the post-interview, however, no such misconceptions remained, as all students identified the content as unscientific.

Discussion and Conclusion

In this section, results related to pseudoscientific beliefs, scientific criteria, and critical thinking, as addressed in the research, are discussed in relation to the existing literature from multiple perspectives. The discussion is organized around the sub-research questions.

Discussion on Critical Thinking Skills

Critical thinking is a skill that can be developed through education and significantly contributes to an individual's personal and intellectual growth (Akgün & Duruk, 2016). It constitutes a cornerstone of modern and student-centered education (Şenşekerci & Bilgin, 2008). In educational contexts, fostering critical thinking skills is not optional or merely a desirable trait; it represents the ideal aim of education (Norris, 1985, cited by Gülveren, 2007). Moreover, enhancing critical thinking skills also fosters a sense of responsibility in individuals (Gülveren, 2007). Therefore, the development of critical thinking cannot be dissociated from education. The present study contributed to the development of students' critical thinking skills.

The first and second sub-questions of this study aim to determine (1) the level of critical thinking among 7th-grade students and (2) whether teaching activities designed within the context of the science–pseudoscience distinction have a significant impact on students' critical thinking skills. Analyses conducted in this context indicate that these activities positively contribute to the development of students' critical thinking abilities. The instructional activities implemented with both groups led to improvements in critical thinking in both cohorts; however, the increase observed in the experimental group was found to be significantly greater than that of the control group (Tables 5 and 6). Furthermore, qualitative data revealed that as students engaged with activities designed around the science–pseudoscience distinction, their commentary became more comprehensive and critically reflective. Distinguishing pseudoscientific content from scientific content is not always straightforward. Despite claims to scientific legitimacy, content that lacks a critical mindset and resists inquiry constitutes pseudoscience (Yardımcı, 2019). The ability to make such distinctions necessitates critical thinking skills. Many scholars emphasized the necessity of critical thinking in discerning science from pseudoscience (Sagan, 1998). In the present study, students who engaged in critical inquiry demonstrated greater success in differentiating science from pseudoscience. Similar results were reported in other studies, which show that students with well-developed critical thinking skills are more adept at distinguishing scientific claims from pseudoscientific ones (Canan, 2019; Turgut, 2009).

Presenting only the results or products of science, without employing a critical approach, hinders the average person's ability to distinguish science from pseudoscience. Without critical inquiry, science becomes indistinguishable from pseudoscience (Sagan, 1998, p. 37). The results achieved in the present study, particularly the development of students' critical thinking skills during instructional processes involving the evaluation of pseudoscientific content, align with these claims in the literature. Learning environments that explore pseudoscientific topics or examine the demarcation between science and pseudoscience were shown to contribute positively to the development of critical thinking skills (Adam & Manson, 2014). Moreover, studies emphasized that incorporating controversial topics into instruction can further enhance students' critical thinking (Yücel & Köçer, 2019). Thus, it is not surprising that the activities designed around the science-pseudoscience distinction in the present study supported the development of students' critical thinking skills and, concurrently, improved their ability to make that distinction through critical inquiry.

However, it is widely believed that the most ideal period for developing critical thinking skills is during the school years. Knowledge acquired during early or primary socialization forms the foundation for future learning and tends to be the most resistant to change (Tan, 1989, cited by Yıldırım, 2009). Therefore, providing critical thinking education during this stage is likely to have more lasting effects. Moreover, critical thinking skills are susceptible to atrophy if not exercised during childhood (Şenşekerci & Bilgin, 2008). In the present study, the instructional intervention was implemented with 7th-grade middle school students, an age group considered optimal for the development of critical thinking skills. The findings from both the relevant literature and this study, which demonstrated an increase in students' critical thinking abilities, support this notion.

Critical thinking and the ability to distinguish between science and pseudoscience are mutually reinforcing competencies. In a study carried out with pre-service teachers, Turgut (2009) and Polat and Taşar (2013) concluded that their critical thinking and pseudoscientific demarcation skills were inadequate. Similarly, Ayvacı and Bağ (2016) suggested that the pseudoscientific beliefs observed in pre-service teachers may stem from a lack of critical thinking. Çekbaş (2017) found that during an argumentation-based astronomy instruction focused on the science-pseudoscience distinction, pre-service teachers also showed improvement in their critical thinking abilities. These results indicate a parallel relationship between critical thinking skills and the ability to distinguish science from pseudoscience. Consistent with these results, the instructional activities designed within the framework of science-pseudoscience demarcation in the present study were also found to contribute to the development of students' critical thinking skills.

Discussion on Pseudoscientific Beliefs

The third and fourth sub-research questions of this study ("What is the level of pseudoscientific beliefs among seventh-grade students?" and "Do the lesson activities designed within the context of the science–pseudoscience distinction have a significant effect on the level of pseudoscientific beliefs among seventh-grade students?") are believed to offer valuable insights in addressing this critical need.

Examining the students' scores on the PBS, administered at the beginning of the process, a high level of pseudoscientific belief was observed among the participants (see

Table 9). A substantial body of literature indicates that individuals from various professional and age groups struggle to distinguish between science and pseudoscience (Ağlarcı & Kabapınar, 2016; Allum, 2011; Ayvacı & Bağ, 2016; Çekbaş, 2017; Çetinkaya, 2017; Duruk et al., 2023). In one study involving 300 educators, it was found that a significant portion of them subscribed to astrological content and believed both astrology and astronomy to be scientific disciplines. This finding suggests that even educators often lack the ability to adequately distinguish between science and pseudoscience (Kallery, 2001).

Considering the results achieved in this study, the level of pseudoscientific beliefs among the students in the experimental group decreased from a high to a moderate level, whereas the level of pseudoscientific beliefs among the students in the control group remained high. Through various studies and analyses, it was found that the designed activities led to a reduction in the students' pseudoscientific beliefs. According to the instructional activities conducted with the students in both the experimental and control groups, a decrease in pseudoscientific beliefs was observed among the students in the experimental group (Tables 9 and 10). Furthermore, qualitative data analysis revealed that over time, students' tendency to believe in pseudoscientific claims diminished, and their ability to distinguish between science and pseudoscience improved. These findings indicate that such activities are effective in helping students develop the skill to distinguish between science and pseudoscience and in reducing pseudoscientific beliefs. A review of the literature reveals similar results. In a study carried out by Ağlarcı and Kabapınar (2016) with chemistry teacher candidates, direct-reflective teaching activities designed to foster the distinction between science and pseudoscience increased the students' ability to differentiate between pseudoscience. In a study carried out by Çetinkaya et al. (2015a), activities targeting the science-pseudoscience distinction were designed for middle school students, and the findings indicated that students' ability to differentiate had improved at the end of the process, and their tendency to make decisions without inquiry had decreased. In a qualitative study carried out by Turgut et al. (2010) with science teacher candidates, activities focused on the science-pseudoscience distinction were designed, and the results showed that these activities enhanced the candidates' perceptions of scientificity.

The teaching activities used in the present study are considered a good example in this context because they help develop students' scientific criteria, reduce incorrect scientific criteria, decrease pseudoscientific beliefs (Table 10), and simultaneously improve critical thinking skills (Table 6).

Discussion on Scientific and Incorrect Scientific Criteria

To answer the research subproblems 5 and 6, which are "What are the scientific and incorrect scientific criteria of 7th-grade students?" and "What is the impact of the activities designed in the context of science-pseudoscience distinction on 7th-grade students' correct and incorrect criteria for scientific validity?", several activities containing pseudoscientific content were designed. The results from the analyses revealed that the incorrect criteria for scientific validity identified in student opinions included rationalization, effectiveness, inclusion of scientific concepts, reliance on authority, inclusion of references, knowledge passed down from the past, and majority opinion (Table 17). The scientific criteria identified in student opinions included verifiability, testability, consistency, reproducibility, support from the scientific community, logical coherence, and intended scientific terminology.

The analysis of preliminary interviews conducted with students indicates that their comments and inquiries regarding scientific issues are insufficient, and they tend to believe in pseudoscientific claims. Many studies in the literature reported similar results (Arık, 2016; Canan, 2019). Furthermore, as the process progressed, it was observed that the occurrence of pseudoscientific activities and the questioning of their scientific validity led to a decrease in the identification of incorrect criteria for scientific validity over time, while the number of valid criteria for scientific validity increased. It was also noted that the quality of the comments regarding the scientific nature of the content improved, becoming more qualitative and comprehensive. Moreover, in the last two activities, which were designed around the distinction between science and pseudoscience, namely quantum healing hypnotherapy and numerology activities, it was observed that the majority of students correctly assessed the scientific validity of the content. This improvement is thought to result from the positive contribution of the activities to students' skills in distinguishing between science and pseudoscience. Similarly, previous studies showed that educational activities designed to teach the distinction between science and pseudoscience contribute to the development of students' skills in distinguishing between the two (Arık, 2016; Saka & Sürmeli, 2017; Turgut, 2009).

One of the incorrect criteria for scientific validity identified in this study is the effectiveness category, in which student opinions are classified as perceiving the claims in the content as scientific because they believe it is useful or think it will work (Tables 11, 14, 15, 16). In a study, Canan (2017) reported similar student opinions and categorized them under the pragmatic category.

Another incorrect criterion for scientific validity identified in this study is the logic category, where students considered claims scientific because, despite not being consistent with facts, they seemed rational or plausible to them (Tables 12, 13, 15). Similarly, Wynn and Wiggins (2008) noted that individuals tend to believe in pseudoscientific content, adapting the claims to fit their logical reasoning.

Another incorrect criteria for scientific validity identified in this study is the inclusion of scientific terms (Tables 11, 12, 13, 14, 15, and 16). In this category, students who believed that pseudoscientific claims were scientific based on the presence of science-related concepts such as science-related terms, science terms, the word "research," "educational" references, or associations with medicine were evaluated. Similarly, Arık (2016) found that students were confused when distinguishing pseudoscientific claims containing scientific concepts. In Canan's (2019) study, it was also found that students examined whether content contained scientific concepts when deciding on its scientific validity.

One of the identified incorrect scientific criteria in this study is the reliance on an authority category. In this category, student opinions were classified based on the belief that a claim is scientific simply because it is the view of a scientist, an expert's explanation, or the statement of an author or a professional, without considering the views of other scientists or field experts (Tables 11, 12, 13, 14, and 16). Similar results were also presented by Çetinkaya (2017). Çetinkaya found that excessive trust in authority figures, such as doctors, prosecutors, and journalists, caused students to avoid questioning the scientific validity of pseudoscientific content. In a study carried out by Çetinkaya et al. (2015a), an activity on iridology, which is a pseudoscientific topic, was used to examine middle school students' perceptions of scientific validity. It was observed that students frequently used authority-based criteria when determining the scientific nature of content in this study as well. Similarly, Turgut (2009) found in his study examining prospective teachers' perceptions of pseudoscientific distinctions that the vast majority of prospective teachers made decisions regarding the scientific validity of content based on trust rather than evidence, relying on sources and authority figures categorized as "author," which they considered psychological criteria. Moreover, Miandji (2019) identified the authority-based characteristic in his study on the credibility techniques of pseudoscientific content.

Another incorrect scientific criterion identified in this study is the reference inclusion category. In this category, student opinions were classified based on the belief that pseudoscientific claims are scientific because they are supported by a photo, newspaper article, internet news, or reference (Tables 12, 13, 14, 15, 16, and 17). It was notable that students did not question the reliability of sources such as newspaper articles, internet news, or other references when making these classifications. Similarly, Canan (2017) determined that some students considered content scientific simply because they had seen it on TV, whereas others believed that content being written in a book was sufficient for it to be scientific.

The least identified incorrect criteria for scientific validity in student opinions were "knowledge from the past" and "majority opinion." The infrequent use of these criteria can be attributed to the fact that their application is contingent on the content in question. For example, in an activity related to astrology, students' opinions such as "Something widely accepted and followed by everyone is scientific. If it weren't scientific, it wouldn't be so widespread" suggest that they were using the majority opinion as a criterion when determining the scientific nature of content. This criterion overlaps with the incorrect scientific criterion "what is accepted by the majority is scientific" found in a study carried out by Çetinkaya (2017). Similarly, the "knowledge from the past" criterion was observed in activities related to topics with a long historical background, such as perpetual motion machines and astrology. Student opinions like "A claim that has existed for so many years must be scientific" or "Ancient people knew better than we do about many things, so it must be scientific" indicate that students were using the presence of past knowledge as a criterion when determining the scientific validity of a content. This criterion aligns with the finding reported by Çetinkaya (2017), in which students trusted ancient knowledge. These findings suggest that the scientific criteria identified in student opinions vary depending on the topic of the pseudoscientific content being examined.

Regarding the scientific criteria identified in this study, one of the most frequently used criteria is verifiability. In the verifiability category, student opinions were classified based on the necessity for content to have sufficient research, reliable sources, and scientific evidence to be considered scientific (Tables 11, 12, 13, 14, 15, 16, and 17). In his study, Arık

(2016) found that when deciding on the scientific nature of content, students paid attention to whether the same statement appeared in every source and the reliability of the sources. However, Arık classified views regarding the uniform expression of statements across sources under the universality category. In the present study, such views were classified under the verifiability category as they were evaluated in relation to source reliability. Additionally, in studies where the scientific nature of content was questioned, the verifiability criterion was found among the scientific criteria identified in participants' opinions (Canan, 2019; Çetinkaya et al., 2015a; Saka & Sürmeli, 2017; Turgut, 2009).

One of the frequently identified scientific criteria in this study is the category of logical inconsistency, where student opinions that recognized the illogical, unreasonable, and nonsensical aspects within the claims of pseudoscientific content were assessed, thereby determining the content's lack of scientific validity (Tables 11, 12, 13, 14, 15, 16, 17). A literature review revealed studies where the logical inconsistency criterion was identified among the scientific criteria based on their work with students (Arık, 2016; Canan, 2019).

Another scientific criterion identified in this study is the category of support from the scientific community, where student opinions were classified based on whether the claims within a content are accepted within the scientific community, supported by many scientists, and accepted by experts when deciding on the scientific validity of a content (Tables 11, 12, 13, 14, 15, 16, 17). In a study, Arık (2016) reported that opinions expressed as "accepted by the entire scientific world" or "universally accepted" were categorized under the universality category, whereas in the present study, they fall under the support from the scientific community category. Additionally, Çetinkaya et al. (2015a) found that one of the scientific criteria developed by students at the end of their process, acceptance in the scientific community, aligns with the findings of the present study. Furthermore, Turgut (2009) identified in a study examining prospective teachers' perceptions of pseudoscientific distinction that a small portion of teacher candidates critically evaluated research methods and the ways in which data were obtained and interpreted, while also considering whether the content was accepted in the scientific community. Saka and Sürmeli (2017) discovered that, in their study aiming to identify the scientific criteria used by science teacher candidates when making the science-pseudoscience distinction, candidates often relied on the approval of various individuals, such as healthcare institutions, experts, and researchers, to determine the scientific validity of a claim. This criterion is also one of those proposed by Thagard

(1978), a philosopher of science. Actually, in the very process of producing scientific knowledge, historical examples also make reference to, or are grounded in, particular scientific communities.

Another scientific criterion identified in this study is the consistency category, where student opinions that highlighted the necessity of a claim being scientifically valid without variability based on individuals or circumstances and avoiding overly general and universally applicable statements were classified (Tables 14 and 17). The consistency criterion, developed by students at the end of the process in the study carried out by Çetinkaya et al. (2015a), aligns with the results achieved in the present study.

In this study, student views classified under the category of testability, one of the identified scientific criteria, emphasize that for content to be considered scientific, it must be open to experimentation and observation, and supported by scientific research data (Tables 11, 13, 14, 15, 16, and 17). Turgut (2009) found in his study that a large majority of teacher candidates prioritize the criterion of experimentality when assessing the scientific nature of content. Saka and Sürmeli (2017), in their study aiming to identify the scientific criteria of science teacher candidates, found that the candidates employed criteria such as using scientific methods, conducting experiments and observations, and incorporating scientific research. These results align with the testability category observed in the present study. Other studies in the literature also identified the same scientific criterion (Arık, 2016; Canan, 2019; Çetinkaya et al., 2015a). This criterion is widely accepted by most philosophers of science.

Under the category of reproducibility, one of the scientific criteria observed in this study, student views were classified based on the belief that a scientific claim should produce the same result for everyone; if it is valid for one person, it should be valid for all (Tables 11, 13, 14, 15, 16, and 17). This same criterion was also identified by Canan (2019) in a study using concept cartoons, where it was observed among a few students' views. Moreover, this criterion is one of the scientific standards proposed by Vollmer, a philosopher of science (Mahner, 2007).

Under the category of intentional scientific terminology, one of the criteria for scientific validity observed in this study, student views were classified considering the belief that scientific and foreign-origin terms, when used unnecessarily and intentionally to give the impression of science, are deceptive and render content unscientific. Allum (2011) noted that the majority of people mistakenly perceive astrology as science simply due to the '-logy' suffix.

When comparing the impact of pseudoscientific content on individuals during the activities examined in this study, astrology and the ancient astronaut theory emerge as the most influential. This conclusion stems from the fact that these two activities involve the greatest use of incorrect scientific criteria. In the astrology activity, the causes of the incorrect interpretations were identified as the students' frequent encounters with astrological content across multiple platforms and the inclusion of many scientific concepts such as stars, space, and eclipses in the content. It was reported in the literature that many individuals believe astrology to be scientific (Arık, 2016; Kallery, 2001). In the case of the ancient astronaut theory, many misconceptions were determined to originate from the pseudoscientific content incorporating various scientific concepts, using elements like aliens (intriguing but not definitively disproven) and linking them to historical artifacts such as pyramids, whose full details are not entirely understood. Pseudoscience studies in the literature similarly identified individuals who believe in alien visitations (Eve & Harrold, 1986). Furthermore, in subsequent interviews regarding the ancient astronaut theory, it was observed that the students exhibited a higher number of incorrect criteria for scientific validity in their views when compared to other activities. This suggests that the ancient astronaut theory may be the most resistant pseudoscience among the examined content. Additionally, the outcomes of the classroom activity on astrology are thought to have undermined the students' trust in its scientific validity. In the activity, students were given horoscope cards, and the names on these cards were altered. The students were not informed of this modification. When asked whether the information on the cards matched their own profiles, the majority of students reported that it did. Only then was it revealed that the cards had been altered. As a result, many students' trust in astrology decreased significantly (Table 14).

At the end of the process, it was observed that most students began to consider various features when determining the scientific validity of a content, such as whether the content was supported by reliable information sources, whether it was based on experiments and observations, what the opinions of many scientists were on the subject, and whether the claims were universally applicable under all conditions. Arık (2016) also found that there was a decrease in the perception of the internet as a reliable source in a study involving pseudoscientific activities.

As the activities progressed, it became clear that different criteria for scientific validity started to be applied. This finding aligns with other studies in the literature (Arık, 2016; Çetinkaya et al., 2015a). The activities that showed the most frequent use of scientific validity criteria were the last two activities, "quantum healing hypnosis therapy" and "numerology." For instance, in the category of intentional scientific jargon identified only in the final activity, students who recognized that a content was pseudoscientific observed that pseudoscientists often unnecessarily inserted scientific terms into their arguments. In the numerology activity, student comments such as "they add the suffix 'logy' at the end to make something believable" or "they try to influence people by using scientific or foreign-sounding terms" indicate that the students had developed the ability to differentiate. This brings to mind the reasoning suggested by the famous physicist Richard Feynman to distinguish science from pseudoscience: "If someone explains something to you using scientific terminology that you cannot understand, ask them to explain it in plain English (everyday language) and check if it still makes sense" (Feynman, 2016).

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Author Contribution Statement

***Gülşah ATASOY**: Conceptualization, literature review, data curation, methodology, implementation, data analysis, original draft, language editing, organization, and writing.*

***Doğan GÜLLÜ**: Conceptualization, literature review, data curation, methodology, implementation, data analysis, original draft, language editing, organization, and writing.*

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