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The Impact of Concept Cartoons on Students' Understanding of the Nature of Science[1]

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Abstract

This study investigated the effect of concept cartoons on students' understanding of the nature of science (NoS). The sample consisted of 100 eighth graders from Hatay, Türkiye. Participants were divided into experimental (n=50) and control (n=50) groups. The researcher collaborated with experts and designed four concept cartoons aimed at imparting the essential components of NoS. These components include observation and inference, subjectivity, creativity and imagination, and the mutability of scientific knowledge. The researcher created NoS activities based on those cartoons (intervention). She consulted three experts and developed scales to assess NoS components before (pretest) and after (posttest) the intervention. She also drew up a checklist to ensure the validity and reliability of the scales. The intervention consisted of open-ended fill-in-the-blank questions about NoS. Data were analyzed using a rubric developed by the researcher based on expert feedback. Furthermore, the consensus coefficients of the coders who assessed the internal consistency were calculated to ensure the reliability of the evaluation criteria. The experimental group underwent the intervention, while the control group received an education based on the curriculum devised by the Ministry of National Education. The results showed that the intervention was better at teaching the essential components of NoS than the curriculum.

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Introduction

Throughout the centuries, people have engaged in scientific endeavors, leading to diverse and evolving definitions of science. Initially, scientists situated science within a more positivist framework, but over time, they came to recognize it as a profoundly human activity (Çelik, 2016). Each definition of science is intricately intertwined with the philosophical views and perspectives of the individual formulating it. These philosophical underpinnings shape how science is perceived, practiced, and understood by different scholars and researchers throughout history. Epistemology is a branch of philosophy that delves into the fundamental questions surrounding knowledge. It focuses on understanding the nature of knowledge, its sources, the conditions of its possibility, and the criteria for determining its accuracy or truthfulness. Unlike cognitive psychology, which examines how knowledge is formed in cognitive processes, epistemology provides a more abstract and philosophical inquiry into the nature of knowledge itself (Nalçin, & Can, 2016). According to Norman G. Lederman's perspective in 1992, while epistemology may not serve as a precise description of the Nature of Science (NoS), it does reveal the accumulation of values and beliefs that influence the development of scientific knowledge. The definition of NoS is a topic of ongoing debate and discussion among philosophers of science, historians of science, science educators, and other scholars. Therefore, there is no single, universally agreed-upon definition that encompasses all aspects of the NoS. An alternative perspective on the NoS encompasses inquiries into the purpose of science, the methodologies employed by scientists, and the impact of social and cultural factors on scientific pursuits (McComas & Olson, 2000). The NoS involves metacognition, unveiling the process of scientific accumulation, the roles of scientists, their methodologies, and the impact of historical periods and social/cultural environments on the formation and existence of scientific knowledge. Acquiring a precise

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understanding of the NoS is of paramount importance in contemporary science education. To facilitate students' comprehension of the NoS, it is imperative to engage them in participative learning processes, employ concrete examples to elucidate abstract concepts and utilize methods that foster connections between intricate scientific principles and everyday life phenomena (Canan, 2019). Target the NoS components can be listed as follows. Students should know that:

- Scientific knowledge is open to change
- Scientific knowledge contains subjectivity,
- Scientific knowledge is influenced by the creativity of scientists,
- Scientific knowledge is influenced by sociocultural factors,
- Science and technology are different concepts,
- Science cannot answer every question,
- Scientists do not use a single scientific method (Lederman, 1999).

The aim of the NoS education is to transform students into science literates. Science literacy and NoS are inseparable concepts. A scientifically literate individual comprehends the NoS and grasps the structure, formation process, and malleability of scientific knowledge (Abd-El-Khalick & Lederman, 2000). In this respect, Türkiye, like other countries, bases its instructional development curricula on the concepts of science literacy and the NoS [Ministry of National Education (MoNE), 2004, 2009]. On the other hand, research shows that students who demonstrate competence in understanding the NoS tend to develop positive attitudes toward science courses, leading to enhanced academic performance in those courses (Arslan, 1995; Morgil et al., 2009). Students develop some scientific misconceptions because they do not understand the NoS. However, they can dispel those misconceptions if teachers use effective methods to deliver science lessons. Some of those misconceptions are as follows:

- Scientific knowledge is certain and unchanging,
- Scientists are completely objective,
- Science is not about creativity, but it is about following procedures,
- Science can answer every question,
- Science and technology are the same,
- There is only one universal scientific method (Rubba & Andersen, 1978; Lederman, 1992).

The effective and appropriate implementation of the NoS teaching relies on the utilization of modern learning tools. The utilization of conceptual cartoons in the NoS teaching represents a valuable application of constructivist instructional methods. Concept cartoons add humor as well as visual support, making lessons more fun. By employing concept cartoons, we can assist students in dispelling misconceptions and foster more positive attitudes, reducing timidity and anxiety towards science lessons. Scientific and technical cartoons, being engaging and interesting, have the potential to facilitate students' ease of learning and promote better retention of subject matter (Arıkan, 2004).
Keogh and Naylor (1999) developed concept cartoons as a constructivism-based learning-teaching technique in science education. These concept cartoons (cartoon heroes or human or animal characters) encourage students to discuss subject matters. While conventional humorous cartoons primarily intend to evoke laughter and entertainment, concept cartoons serve a dual purpose of both engaging students through entertainment and prompting them to critically question their knowledge (Keogh & Naylor, 1999).

In concept cartoons, each character is portrayed as advocating various ideas, but only one of these ideas is the correct one. Students engage in discussions about the topic by aligning themselves with the perspectives of one or more of these characters. The objective is to facilitate a collective process in which all students arrive at the correct conclusion throughout the course of the discussion. The discussions serve as a catalyst for students to concentrate on and explore the topic more deeply (Keogh et al., 2003).

Concept cartoons serve as visual tools that empower students to adopt a scientific mindset and actively engage in the knowledge-construction process (Balım, İnel, & Evrekli, 2008). The constructivist approach has led to a diversification in the ways conceptual cartoons are utilized in education. Concept cartoons can be employed to enhance students' inclination to ask questions and foster curiosity. They also prove valuable in identifying and rectifying misconceptions among students (Keogh & Naylor, 1999; Kabapınar, 2005; Ekici, Ekici, & Aydın, 2007; Akamca, Ellez, & Hamurcu, 2009). Concept cartoons are also utilized to assess and uncover students' prior knowledge (İnel, Balım, & Evrekli, 2009), promoting lively discussions among them (Naylor, Downing, & Keogh, 2001). Moreover, they serve as a catalyst for generating scientific ideas (Long & Marson, 2003) and stimulating creative thinking (Keogh, Naylor, de Boo, & Feasey, 2001). They can also be used as assessment tools (Keogh, Naylor, de Boo & Feasey, 1999). Concept cartoons are commonly created as posters and prominently displayed in areas accessible to all students, allowing easy visibility and engagement. The teacher provides explanations to the students, clarifying the roles and viewpoints of the characters portrayed in the cartoon. The teacher then asks them which opinion they agree with and why. This method facilitates an environment where students can freely express their thoughts and the reasoning behind them while also attentively listening to their classmates' perspectives. This is the first stage of constructivist science teaching. By encouraging students to critically examine the ideas presented in the concept cartoons, this method fosters an investigative mindset. Through this process, students can identify and correct any misconceptions they may have about the topic at hand (Keogh & Naylor, 1999). This approach also empowers them to actively engage with the content and strengthens their ability to think critically and analytically (Keogh & Naylor, 1999).

The greatest challenge in teaching the NoS is to rectify the misconceptions acquired by students in their prior learning. The efficacy of using concept cartoons is evident in their capacity to dispel students' misconceptions through discussions and visual teaching materials. Concept cartoons can concretize the NoS teaching processes and create learning environments that captivate students with their humorous appeal. Most researchers have focused on the effect of concept cartoons on teachers and preservice teachers. It is vital for teachers to be well-versed in the NoS, but the primary goal of these efforts should be to help students develop perspectives on science. Relying solely on teaching the NoS to teachers and expecting students to infer from their teachers' discourse is not a scientific approach. Instead, the primary focus should be on directly educating the students about the NoS, ensuring that they have a clear understanding of its fundamental concepts and principles. This approach empowers students to engage with scientific thinking independently and develop a solid foundation in understanding the NoS. This study investigated the effect of concept cartoon activities on eighth graders' understanding of NoS. The sub-goals of the research are;

1. To convey to students that the concepts of observation and inference are different from each other in the nature of science by using the concept cartoon method.
2. To teach the principle that scientific knowledge is subjective, which is inherent in science, through the concept cartoon method.
3. To make students understand that creativity and imagination lead in the acquisition and advancement of scientific knowledge through the concept cartoon method.
4. In teaching the nature of science, it is to explain that scientific knowledge can change using the concept cartoon method.

Method

Research design

This study adopted a quasi-experimental unequal-group pretest-posttest design. A quasi-experimental design is employed when random selection is not feasible or practical. Researchers utilize existing groups or classrooms to form comparison groups. In this design, participants are not randomly assigned to groups, making it distinct from a true experimental design. Instead, the groups are formed based on pre-existing characteristics or conditions. In this design, the experimental and control groups are compared without random assignment (Fraenkel & Wallen, 2000; McMillan & Schumacher, 2010).

Study group

The study population consisted of all eighth graders in Arsuz/Hatay, Türkiye. Participants were recruited from a middle school with four classrooms of eighth graders. The study groups were selected using the convinience sampling method as the groups were already formed in four branches in the school. Convenience sampling involves taking sample members that are easily accessible to the researcher (Özen, & Gül.,2007). The sample consisted of 100 participants divided into experimental (n=50; two classrooms) and control (n=50; two classrooms) groups.

Data Collection Tools

The researcher developed measurement tools to assess the impact of the NoS-related concept cartoons on 8th graders' understanding of the NoS. The researcher consulted three experts (a professor, an associate professor, and an assistant professor) from the Faculty of Education of Mustafa Kemal University to develop the measurement tools addressing the components of the NoS (observation and inference, subjectivity, creativity and imagination, and the mutability of scientific knowledge). The researcher also prepared checklists to ensure the validity and reliability of the measurement tools, which consisted of concept cartoons and open-ended questions on the NoS. The measurement tools were used as a pretest and posttest.

The researcher developed a rubric for each principle in order to quantitatively evaluate the questions in the measurement tools. The researcher consulted experts to develop a draft rubric. The experts recommended including fewer items with precise statements for ease of scoring. They also suggested that the items should be formulated as positive statements. The researcher revised the draft based on expert feedback and consulted the experts again. The researcher revised the draft based on expert feedback again and used the final version.

Procedure

The intervention focused on four components of the NoS: (1) observation and inference, (2) subjectivity, (3) creativity and imagination, and (4) the mutability of scientific knowledge. The measurement tools were used as a pretest to assess all participants' understanding of the four components before the intervention. The experimental group received the intervention, while the control group attended classes based on the MoNE curriculum. All participants took the posttest after the intervention. The data were analyzed to determine whether the intervention was better than the MoNE curriculum.

MoNE Curriculum

The control group attended classes based on the MoNE curriculum. At the beginning of the lesson, all participants were asked questions about science, such as, "What is science?," "What kind of character would you like to see in a scientist?," and "Can science answer every question?". The teacher listened to their responses without comment, providing a supportive environment that allowed them to express themselves freely. Then, the teacher delivered a comprehensive presentation and lecture on the NoS, explaining the four selected elements for the research. Students were given the opportunity to ask questions at the end of the presentation. Their questions were answered by both the teacher and other students. The lesson concluded with a class discussion to further explore the topics covered.

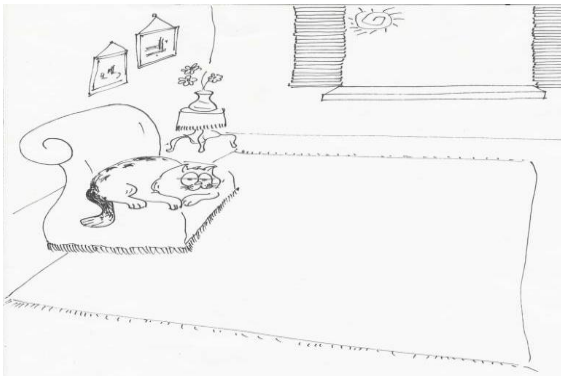
Intervention

The experimental group attended lectures about the NoS based on conceptual cartoons. The following are the details of the process.

Observation and Inference

To illustrate the distinction between observation and inference to the participants in the experimental group, the researcher crafted a concept cartoon and developed a comprehensive lesson plan presented through visual presentations. During the lesson, the participants in the experimental group were prompted to recall their experiences from the science and technology course. The researcher also posed questions like "What did you observe?" to direct their focus toward the concept of "observation" in the scientific process. Afterward, the researcher organized the experimental group participants into groups of 4-5 individuals and presented the four conceptual cartoons through multiple sessions. Within their respective groups, participants engaged in discussions about what they perceived in the images and shared their observations with the entire class. In the tables, the symbol "O" denoted observation sentences, while "I" represented inference sentences.

Figure 1.
Observation – Inference



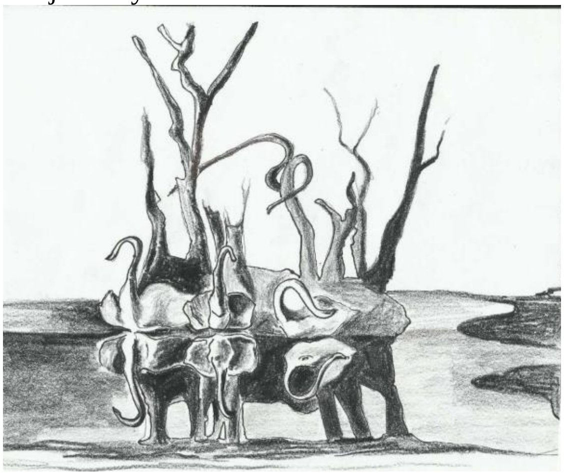
Observation and Inference 1	
O	There is a cat lying on the couch.
O	There are pictures on the wall.
O	There is a vase on the coffee table.
I	It is hot, the sun is out.
I	The cat is sweltering from the heat.
O	There's a carpet and a sofa.
O	The curtain is open; the sun is shining.

The researcher made adjustments to the first presentation and subsequently presented the second and third presentations to the experimental group participants. After showing the cartoons, the researcher inquired about their impressions and opinions regarding the content. Subsequently, the participants were asked a series of questions to further engage them in the learning process.

Lastly, the researcher showcased the fourth presentation and shared the thoughts of the characters depicted in the image about the situation. Following the presentation, the researcher requested the group spokespersons to engage in discussions with their respective group members, encouraging them to express whether they found the thoughts of the characters in the picture to be accurate or not. The process concluded with a review of the sentences formulated by the students during the presentation, where the researcher questioned whether they were observation sentences or inference sentences, reinforcing the meanings of the concepts of observation and inference.

Subjectivity
To introduce the concept of subjectivity to the participants, the researcher developed a concept cartoon and a comprehensive lesson plan, organizing it into visual presentations. First, the researcher presented the first visual in Figure 2.

Figure 2.
Subjectivity



The researcher divided the students into groups of five and instructed them to select a spokesperson. The participants were shown the presentation, and the researcher asked each group's spokesperson to share what they observed. To stimulate discussion, the researcher encouraged the groups to explore the possibility of different answers. Subsequently, the researcher presented another version of the cartoon, revealing the opinions of the characters and fostering a discussion about how scientists can interpret data differently, highlighting the subjectivity inherent in scientific knowledge.

Creativity and Imagination
To convey the principles of creativity and imagination to the experimental group participants, the researcher developed a concept cartoon and created a comprehensive lesson plan structured around visual presentations. At the outset of the lesson, the researcher evaluated the participants' prior knowledge about fossils and paleontology. Following this, the participants were divided into groups of 4-5 individuals and encouraged to envision themselves as a team of paleontologists

involved in an excavation site. The researcher displayed their discovery through multiple presentations (Figure 3). Next, the participants were asked to examine the fossil from the perspective of a paleontologist and speculate which limb of which creature it could belong to.

Figure 3.
Creativity

The participants were instructed by the researcher to sketch the limb on blank pieces of paper. After completing their drawings, the researcher presented them with an image of the actual bone fragment, as determined by the scientists. The participants were then prompted to reflect on the accuracy of their drawings in comparison to the real fossil fragment. Subsequently, they were encouraged to engage in a discussion to explore the reasons behind any disparities between their predictions and the actual fossil fragment.

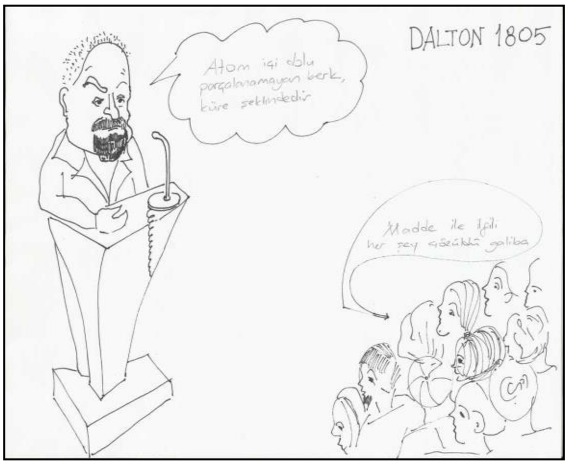
Lastly, the researcher presented the cartoon with the perspectives of the characters and posed the question: "Do you think scientists have used their imagination when studying a fossil, as you did?" The participants engaged in a discussion, exploring whether scientists might be influenced by their imagination in their work, drawing on the characters in the picture. Guided by the teacher and the input provided by the group spokespersons, the discussion was concluded, and the study came to a close.

The mutability of scientific knowledge

To educate the experimental group participants about the principle of the mutability of scientific knowledge, the researcher designed a concept cartoon and developed a comprehensive lesson plan, transforming this cartoon into visual presentations.

The researcher commenced the lesson by posing warm-up questions to engage the participants, assess their prior knowledge about the concept of the atom, and draw their focus toward the subject. Following this, the participants were divided into groups of 4-5 students and presented with a visual presentation (Figure 4) discussing the first theory of the atom and Dalton, the scientist who proposed it. The researcher then prompted the participants to discuss and exchange views with their classmates regarding the aspects of this atomic model that differ from the presently accepted model.

Figure 4.
The theory of the atom



Following that, the researcher presented visuals of the atomic theories proposed by Thomson and Rutherford and encouraged the groups to engage in discussions about the similarities and differences between these models and the previous atomic theories. After receiving responses from the spokespersons, the researcher prompted them to deliberate on the reasons behind the changes in atomic models over time.

Lastly, the researcher showcased visuals of the Modern Atomic Model and, following a recapitulation of all atomic theories through presentations, asked the question: "Is the Modern Atomic Model the ultimate theory about the atom, or could this perspective be replaced by a new one, just like previous theories, due to the advancement of time and technology?" Subsequently, the researcher presented the cartoon characters' views and prompted the participants to discuss their perspectives. The discussion was concluded with the researcher informing them that there is no absolute certainty in the NoS as scientific knowledge remains subject to change.

Data Analysis

A rubric was used to assess the data. The rubric was rated on a scale of 1 (lowest) to 3 (highest). The researcher also used Miles and Huberman's (1994) formula: [Reliability = (number of agreements) / (number of agreements + number of disagreements)*100] to calculate intercoder reliability, which should be at least 80% (Miles & Huberman, 1994; Patton, 2002). Reliability coefficients were calculated for each sub-dimension (observation and inference, subjectivity, creativity and imagination, and the mutability of scientific knowledge). The reliability coefficients were 80% for observation and inference, 95% for subjectivity, 80% for creativity and imagination, and 86% for the mutability of scientific knowledge.

As an initial step, a normality test should be conducted to determine whether parametric or non-parametric methods are applicable. According to Kalaycı (2016), the Kolmogorov-Smirnov test is recommended for cases with 29 or more samples, whereas the Shapiro-Wilk test should be used for situations with fewer than 29 samples. In the present study, the sample consisted of 50 participants. Therefore, the Kolmogorov-Smirnov test was conducted to determine the assumption of normality. The observation-inference, subjectivity, mutability, creativity, and total pre-test and post-test scores demonstrated a significance level of $p<0.05$, indicating that the data were not normally distributed. Therefore, non-parametric tests were performed to analyze the data. The Mann-Whitney U Test was utilized to compare the NoS understandings of the experimental and control groups. This test was used to compare the pretest and posttest scores of the experimental and control groups. The Wilcoxon signed ranks test was used to compare the pretest and posttest scores of the experimental group within itself and the pretest and posttest scores of the control group within itself.

The effect size for significant differences was also calculated to standardize the results, as statistical significance can be influenced by the number of samples. This ensures a more meaningful and comparable assessment of the impact of the variables under consideration. By computing effect sizes, the influence of the number of samples on the results was mitigated, resulting in an objective and standardized measure of significance. This approach enhances the meaningful interpretation and comparison of the research findings.

Standardization allows researchers to compare different variables or different scales in different studies. The equation for converting z-scores to effect sizes used in this study is as follows. The evaluation criteria proposed by Cohen (1988) is that $r= \pm .1$ is a small effect, $r= \pm .3$ is a medium effect, and $r= \pm .5$ is a large effect.

$$r = \frac{z}{\sqrt{N}}$$

r: Effect size
z: z-score (SPSS)
N: sample size

Findings

The Kolmogorov-Smirnov test was utilized because both the experimental and control groups consisted of 50 participants (Kalaycı, 2016). Table 5 shows the test results.
This section addressed the Kolmogorov-Smirnov test results regarding observation-inference, subjectivity, mutability, and creativity.

Table 5.
Observation-inference, subjectivity, mutability, creativity, and total scores

	Statistics	df	p
Experimental group pretest observation-inference	.514	50	.000
Control group pretest observation-inference	.506	50	.000
Experimental group posttest observation-inference	.523	50	.000
Control group posttest observation-inference	.280	50	.000
Experimental group pretest subjectivity	.302	50	.000
Control group pretest subjectivity	.312	50	.000
Experimental group posttest subjectivity	.490	50	.000
Control group posttest subjectivity	.359	50	.000
Experimental group pretest mutability	.317	50	.000
Control group pretest mutability	.348	50	.000
Experimental group posttest mutability	.454	50	.000
Control group posttest mutability	.395	50	.000
Experimental group pretest creativity	.431	50	.000
Control group pretest creativity	.400	50	.000
Experimental group posttest creativity	.424	50	.000
Control group posttest creativity	.404	50	.000
Experimental group pretest total	.203	50	.000
Control group pretest total	.219	50	.000
Experimental group posttest total	.237	50	.000
Control group posttest total	.210	50	.000

The results indicated that the data were non-normally distributed ($p<0.05$). Consequently, non-parametric tests were employed (Table 5). The Mann-Whitney U test was conducted to determine whether there was a significant difference in pretest scores between the experimental and control groups. Table 6 shows the results.

Pretest Scores

This section presented the Mann-Whitney U test results regarding the difference in pretest scale scores between the experimental and control groups.

Table 6.
Pretest results

	Group	n	X	Mean Rank	Sum of Ranks	U-Score	Z	p
Observation-inference	Experimental	50	1.16	49.96	2498.00	1223.00	-.319	.750
	Control	50	1.20	51.04	2552.00			
Subjectivity	Experimental	50	1.64	50.68	2534.00	1241.00	-.068	.946
	Control	50	1.64	50.32	2516.00			
Mutability	Experimental	50	1.66	53.66	2683.00	1092.00	-1.215	.224

	Control	50	1.54	47.34	2367.00			
Creativity	Experimental	50	1.92	48.70	2435.00	1160.00	-.890	.373
	Control	50	2.00	52.30	2615.00			
Total	Experimental	50	6.32	51.35	2567.50	1207.50	-.305	.760
	Control	50	6.38	49.65	2482.52			

There was no significant difference in the pretest scores for "creativity," "subjectivity," "observation-inference," and "mutability" between the experimental and control groups. The test results indicated that most participants had limited opinions about the NoS, which was expected since they had not received any education on the topic. Overall, the results demonstrated that almost all participants had similar views about the NoS before receiving any instruction. Regarding participants' prior knowledge of the difference between observation and inference, their understanding was lower compared to their knowledge of other principles (experimental group x=1.16, control group x=1.20). Two main reasons contributed to this. First, they believed that experimentation and observation were the sole methods utilized to acquire scientific knowledge. Second, they lacked a clear understanding of the terms "observation" and "inference." This finding is in line with Çelik's (2016) study, which also revealed that students had limited knowledge about inference in science, as they struggled to acknowledge that "scientists make inferences from experimental data." Çelik (2016) reported that only one in five students mentioned inference, while the majority stated that "the results are what scientists observe in their experiments

All participants exhibited moderate scores regarding subjectivity, suggesting that they had limited awareness of the notion that scientific knowledge can be subjective and subject to change. There was no significant difference in scale scores between the experimental and control groups. Only a few participants were aware that scientific knowledge is not fixed. Conversely, a majority of the participants perceived scientific knowledge as absolute, considering that there would be no science if it were not finalized. This misconception is common due to the tendency of teachers to convey knowledge with a sense of certainty to their students. Additionally, phrases such as "the law of conservation of mass" can reinforce the perception that knowledge is immutable and unchanging.

The long-standing notion that science is entirely objective has become deeply ingrained in the teaching system. As a result, both teachers and students may develop the belief that scientists should be completely free from subjectivity. Unfortunately, this traditional perspective on the NoS can lead to misconceptions being perpetuated in the classroom. Teachers who are not acquainted with the evolving understanding of the NoS may unknowingly pass on these misconceptions to their students.

There was no significant difference in the pretest "creativity" scores between the experimental and control groups (Table 6). However, it is noteworthy that participants had a relatively higher mean pretest "creativity" score compared to the other components. Interestingly, participants expressed that creativity was indeed important in scientific endeavors, but they perceived imagination to play a role primarily in inspiring the initial stages of scientific exploration. This finding aligns with Köseoğlu, Tümay, and Üstün's (2010) observations, wherein students believed that scientists were creative individuals who utilized their creativity mainly for designing experiments and collecting data. They also emphasized the importance of scientists being objective in other stages of scientific pursuits.

Posttest results

This section presented the Mann-Whitney U test results regarding the difference in posttest scale scores between the experimental and control groups.

Table 7.
Posttest results

	Group	n	X	Mean Rank	Sum of Ranks	U Score	z	p	Effect size
Observation-Inference	Experimental	50	2.88	61.86	3093.00	682.00	-4.713	.000	0.47
	Control	50	2.32	39.14	1957.00				
Subjectivity	Experimental	50	2.80	61.70	3085.00	690.00	-4.485	.000	0.45
	Control	50	2.32	39.30	1965.00				
Mutability	Experimental	50	2.72	63.01	3150.50	624.50	-4.887	.000	0.49
	Control	50	2.18	37.99	1899.50				
Creativity	Experimental	50	2.66	59.32	2966.00	809.00	-3.477	.001	0.35
	Control	50	2.30	41.68	2084.00				
Total	Experimental	50	11.06	70.08	3504.00	271.00	-6.901	.000	0.69
	Control	50	9.14	30.92	1546.00				

The experimental group exhibited a significantly higher mean posttest "observation-inference" score than the control group ($z= -4.713$, $p<0.05$, $r = -.47$). The effect size, indicated by the R-value, was found to be in the medium to large range, suggesting a substantial impact of the intervention. Interestingly, Çil (2010) utilized a direct reflective approach but was unable to effectively teach students the principle of "observation-inference." The lack of significant change in students' posttest scores was attributed to their resistance in letting go of their pre-existing misconceptions. In contrast, our results suggest that concept cartoons proved to be more successful in helping students dispel their misconceptions compared to the direct reflective approach. This demonstrates the effectiveness of concept cartoons as an instructional method in promoting better understanding and addressing misconceptions related to the NoS.

The experimental group displayed a significantly higher mean posttest "subjectivity" score than the control group ($z= -4.485$, $p<0.05$, $r = -.45$). The effect size, falling in the medium to large range, indicates a substantial impact of the intervention on the participants' understanding of subjectivity. Concept cartoons proved instrumental in encouraging the experimental group participants to evaluate data in a manner similar to scientists. Moreover, these cartoons helped them realize that their classmates might interpret the same data differently. As a result, we can confidently suggest that the intervention promoted meaningful learning by actively engaging the experimental group participants in the learning process. The utilization of concept cartoons effectively facilitated the grasp of subjectivity in the NoS, fostering a deeper and more nuanced understanding among the students in the experimental group.

The experimental group demonstrated a significantly higher mean posttest "mutability" score than the control group ($z= -4.887$, $p<0.05$, $r = -.49$). The intervention proved to be instrumental in helping the experimental group participants comprehend and acknowledge that scientific knowledge can change over time. In contrast, the control group participants exhibited resistance to modifying their misconceptions regarding the changeability of scientific knowledge. The concept cartoons, based on the constructivist approach, effectively facilitated the learning process by empowering the students to explore and access information on their own. This empowering approach encouraged the experimental group to recognize the dynamic nature of scientific knowledge. Çelik (2016) also reported similar findings, where only a minority of students (one in ten) believed that scientific knowledge was subject to change over time. This highlights the significance of implementing constructivist-based methods, such as concept cartoons, to effectively address and dispel common misconceptions related to the mutable nature of scientific knowledge.

The experimental group demonstrated a significantly higher mean posttest "creativity" score than the control group (z= -3.477, p<0.05, r = -.35). Although the effect size was in the medium to large range, it was closer to the low value. The reason for this observation is that students often tend to characterize scientists as inherently creative. The difference in posttest scores after the intervention may be attributed to the fact that the experimental group participants recognized the importance of creativity and imagination not only at the initial stage of generating ideas but throughout the entire scientific process. This insight suggests that the concept cartoons used in the intervention effectively enabled the experimental group to grasp the essential role of creativity and imagination in all facets of scientific endeavors, which contributed to the improvement in their posttest "creativity" scores. While the effect size might not be as substantial as in other areas, it still reflects the meaningful impact of the intervention on students' perceptions and understanding of creativity in the context of scientific practices.

The total test scores revealed that the intervention was highly effective in educating the experimental group participants about the components of the NoS (z= -6.901, p<0.05, r = -.69). The substantial effect size indicates a significant impact on the experimental group's understanding of the NoS. The success of the intervention can be attributed to the utilization of concept cartoons, which actively engaged the experimental group participants in every stage of the learning process. By involving the students in discussions, reflections, and critical thinking through the use of concept cartoons, the intervention fostered a deeper understanding of the NoS and its fundamental principles. The constructivist approach employed with concept cartoons proved to be an effective and engaging method for enhancing the participants' grasp of the NoS, resulting in a notable improvement in their total test scores

Pretest and posttest scores: Experimental group

This section addressed the Wilcoxon signed ranks test results regarding the difference between pretest and posttest scores in the experimental group.

Table 8.

Wilcoxon signed ranks test results: Experimental group

	Posttest-pretest	n	Mean Rank	Sum of Ranks	z	p	Effect size
Observation-inference	Negative ranks	0	.00	.00	-6.437	.000	0.65
	Positive ranks	48	24.50	1176.00			
	Ties	2					
Subjectivity	Negative ranks	0	.00	.00	-5.855	.000	0.59
	Positive ranks	42	21.50	903.00			
	Ties	8					
Mutability	Negative ranks	1	14.00	14.00	-5.622	.000	0.56
	Positive ranks	40	21.18	2688.00			
	Ties	9					
Creativity	Negative ranks	1	17.00	17.00	-5.498	.000	0.55
	Positive ranks	35	18.54	649.00			
	Ties	14					
Total	Negative ranks	0	.00	.00	-6.198	.000	0.62
	Positive ranks	50	25.50	1275.00			
	Ties	0					

The experimental group exhibited significantly higher mean posttest scores in "observation-inference," "subjectivity," "mutability," and "creativity" compared to their pretest scores ($p<0.05$). All effect sizes were greater than 0.50, indicating a large effect size for each component. These findings strongly suggest that the intervention was highly effective in educating the experimental group participants about the various components of the NoS and in helping them dispel their misconceptions related to it. The substantial effect sizes imply that the concept cartoons and constructivist approach employed in the intervention played a crucial role in enhancing the participants' understanding of the NoS. By actively engaging the students in the learning process and encouraging critical thinking, reflection, and discussions, the intervention effectively promoted significant improvements in their knowledge and comprehension of the key principles and components of the NoS. Overall, these results affirm the success of using concept cartoons as an instructional tool in fostering a deeper and more accurate understanding of NoS among the experimental group participants. Research also shows that concept cartoons help students dispel their misconceptions related to the NoS (Atasoy &Akdeniz, 2007; Baysarı, 2007; Burhan, 2008; Demir, 2008; Ekici et al., 2007; Kabapınar, 2005; Kuşakçı, 2007; İngeç, 2008; Özsevgeç et al., 2020; Sancar, & Koparan, 2019; Say, 2011; Yıldız, 2008; Yürekli, 2020).

Pretest and posttest scores: Control group

This section addressed the Wilcoxon signed ranks test results regarding the difference between pretest and posttest scores in the control group

Table 9.
Wilcoxon signed ranks test results: Control group

	Posttest-pretest	**n**	**Mean Rank**	**Sum of Ranks**	**Z**	**p**	**Effect size**
Observation-inference	Negative ranks	0	0.00	0.00	-5.706	.000	0.57
	Positive ranks	40	20.50	820.00			
	Ties	10					
Subjectivity	Negative ranks	0	0.00	0.00	-4.919	.000	0.49
	Positive ranks	28	14.50	406.00			
	Ties	22					
Mutability	Negative ranks	2	15.50	31.00	-4.922	.000	0.49
	Positive ranks	31	17.10	530.00			
	Ties	17					
Creativity	Negative ranks	2	9.00	18.00	-3.273	.000	0.33
	Positive ranks	16	9.56	153.00			
	Ties	32					
Total	Negative ranks	0	0.00	0.00	-5.991	.000	0.60
	Positive ranks	46	23.50	1081.00			
	Ties	4					

The control group demonstrated significantly higher mean posttest scores in "observation-inference," "subjectivity," "mutability," and "creativity" compared to their pretest scores ($p<0.05$). The effect sizes were as follows: subjectivity ($r = 0.49$), creativity ($r = 0.33$), and mutability ($r = 0.49$), indicating medium to high effect sizes. For "observation-inference," the effect size was high (r = 0.57), and for the total test, it was also high (r = 0.60). These results suggest that even without the intervention, the control group participants exhibited notable improvements in their understanding of the components of the NoS. This result is an expected result due to the teaching done before the post-test. The effect sizes indicate that these improvements were not merely marginal but had a meaningful impact on the control group's knowledge and perceptions regarding the NoS. Although the effect sizes were generally lower than those of the experimental group, they still demonstrate that the control group's exposure to the regular science teaching process contributed to enhancing their understanding of the NoS.

Both the experimental and control groups demonstrated significant improvements in their understanding of the components of the NoS. However, the results indicate that the use of concept cartoons in the experimental group was more effective than the curriculum-based teaching in the control group. The ability of the experimental group participants to express their views through cartoon characters fostered active participation in the lessons without hesitation. This active engagement in the learning process motivated the students and created a comfortable classroom environment, leading to more effective and meaningful learning experiences. Research supports the idea that concept cartoons are fun and motivating tools in education. Several studies (Özüredi, 2009; Özalp, 2006; Durmaz, 2007; Keogh & Naylor, 1999; Kılıç, 2010; Özşahin, 2009; İnel et al., 2009) have highlighted the positive impact of conceptual cartoons on students' motivation and learning outcomes. By using concept cartoons, educators can create an engaging and enjoyable learning environment that encourages active participation and helps students to retain the learned concepts effectively. The study's findings underscore the effectiveness and potential of concept cartoons as a valuable teaching tool in science education.

Discussion and Conclusion

This section discussed the results under the headings of the components of the NoS.

Results Regarding the Component of Observation-Inference

There was no significant difference in the pretest "observation-inference" scores between the experimental and control groups, indicating that both groups had a similar level of knowledge about this component of the NoS before the intervention (See. Table 6).

The experimental group participants exhibited a significantly higher mean posttest "observation-inference" score than their pretest score, indicating that the intervention was effective in helping them differentiate between these two concepts of the NoS. Similarly, the control group participants showed a significantly higher mean posttest "observation-inference" score than their pretest score, suggesting that the regular curriculum-based teaching also contributed to their improved understanding and differentiation between observation and inference in the scientific process.

The experimental group demonstrated a significantly higher mean posttest "observation-inference" score compared to the control group, indicating that the intervention using conceptual cartoons was more effective in teaching the experimental group participants about the two concepts of the NoS than the regular curriculum-based teaching received by the control group. The higher posttest scores in the experimental group suggest that the use of concept cartoons facilitated a deeper understanding and differentiation between observation and inference in the NoS compared to the traditional curriculum-based teaching method employed with the control group.

Results regarding the component of subjectivity

Before the intervention, a common belief among most participants was that scientists were inherently objective in their research and tended to arrive at a single, definitive conclusion. This perception highlights a common misconception about the NoS, which often portrays scientific knowledge as rigid and unchanging, with scientists following an entirely objective and uniform path to reach their conclusions. Doğanay, Demircioğlu and Yeşilpınar (2014) reported that most students believed that objectivity was the most salient characteristic of scientists.

There was no significant difference in the pretest "subjectivity" scores between the experimental and control groups, indicating that both groups had a similar level of knowledge about this component of the NoS before the intervention.

Both the experimental and control groups exhibited significantly higher mean posttest "subjectivity" scores compared to their pretest scores, indicating that both teaching methods had a positive impact on improving the participants' understanding of subjectivity in the NoS. However, the greater difference between the pretest and posttest scores in the experimental group suggests that concept cartoons were more effective than curriculum-based teaching in fostering a deeper and more significant improvement in the participants' comprehension of subjectivity.

The experimental group had a significantly higher mean posttest "subjectivity" score compared to the control group (Table 7). This result suggests that the intervention using concept cartoons was more effective in teaching the concept of subjectivity in the NoS to the experimental group participants compared to the curriculum-based teaching employed with the control group. The difference in mean scores between the two groups further supports the notion that concept cartoons can play a valuable role in enhancing students' understanding of subjectivity in the context of scientific knowledge.

Results Regarding the Component of Creativity

Before the intervention, the majority of participants held the belief that scientists primarily utilized their creativity and imagination only during the initial stages of their scientific endeavors, such as when designing experiments. While acknowledging that scientists are indeed creative individuals, they tend to perceive creativity as limited to the experimental design phase and not as relevant or significant in the data collection and interpretation stages of scientific inquiry. Both the experimental and control groups had significantly higher mean posttest “creativity” scores compared to their pretest scores. However, the difference was greater in the experimental group (See. Table 7). Moreover, the experimental group had a significantly higher mean posttest “creativity” score than the control group, suggesting that the intervention effectively challenged this misconception among the experimental group participants. Through active discussions and engagement with the cartoons, the participants came to realize that creativity and imagination are integral to the entire scientific process, from conceiving research questions to data analysis and interpretation. This newfound understanding expanded their perception of the role of creativity in science beyond just experimental design, helping them recognize its significance throughout the scientific journey. This shift in perspective is an essential step toward fostering a more accurate understanding of the principles of creativity and imagination in the context of scientific knowledge.

Results Regarding the Component of the Mutability of Scientific Knowledge

Both the experimental and control groups demonstrated a significant increase in their mean posttest "mutability" scores compared to their pretest scores, as indicated in Tables 8 and 9. In the experimental group, the effect size was large, indicating a substantial impact of the intervention using concept cartoons on enhancing the participants' understanding of the concept of mutability in the NoS. On the other hand, in the control group, the effect size was medium to large, suggesting that the regular curriculum-based teaching also had a positive effect on improving the participants' comprehension of mutability. However, the experimental group still had a significantly higher mean posttest "mutability" score than the control group, indicating that the intervention with concept cartoons was more effective than the curriculum-based teaching in enhancing the participants' understanding of the concept of mutability. The larger effect size in the experimental group underscores the added value of using concept cartoons as a powerful and engaging teaching tool to promote a deeper understanding of the NoS and its changeability.

Recommendations

This study investigated how successful concept cartoons were in teaching 8th graders the four components of the NoS. The findings demonstrate that concept cartoons were highly successful in teaching eighth graders the four components of the NoS. The use of conceptual cartoons as a teaching tool significantly contributed to the participants' comprehension of the observation-inference, subjectivity, mutability, and creativity aspects of scientific knowledge. The engagement and active participation fostered by concept cartoons created a more appealing and interesting learning environment for the eighth graders. This enhanced level of involvement led to improved understanding and retention of the concepts related to the NoS. The visual and interactive nature of concept cartoons allowed students to relate to the content, encouraging them to question their prior knowledge and dispel misconceptions. Overall, the study highlights the effectiveness of concept cartoons as a valuable instructional tool, particularly in the context of teaching complex scientific concepts to middle-grade students. The findings underscore the importance of utilizing engaging and interactive methods to promote meaningful learning experiences and foster a deeper understanding of the NoS among students.

Examining the effect of concept cartoons on primary school students' comprehension of the four components of the NoS would be a valuable research direction. Primary school is a critical period in a student's education, and introducing engaging and interactive methods, such as concept cartoons, could significantly impact their understanding of fundamental scientific concepts. Research in this area could provide insights into the age-appropriate use of concept cartoons and their effectiveness in teaching complex scientific ideas to young learners. It could also shed light on the potential benefits of introducing concepts related to the NoS at an early age, laying the foundation for a more accurate and nuanced understanding of scientific principles in later years. By investigating the impact of concept cartoons on primary school students' comprehension of the NoS, educators and policymakers can gain valuable information to design more effective and engaging science education curricula that foster a deeper appreciation for scientific inquiry and critical thinking from an early age.
Exploring the impact of concept cartoons on students' comprehension of other components of the NoS beyond observation-inference, subjectivity, mutability, and creativity would be a valuable avenue for research. The NoS is a multifaceted concept that encompasses various principles. Therefore, investigating the effectiveness of concept cartoons in teaching additional components can provide a more comprehensive understanding of their potential in science education.

Conducting longitudinal studies that employ validated scales and administer them over an extended period of time would be crucial in determining the long-lasting effects of concept cartoons on students' comprehension of the components of the NoS. Longitudinal research designs allow researchers to track changes in participants' understanding and attitudes over time, providing valuable insights into the lasting impact of educational interventions.

Developing concept cartoon guiding materials can provide an innovative and effective alternative to traditional the NOS activities in science courses. While activity-based the NOS teaching materials have their benefits, concept cartoons offer a unique approach that combines visual appeal, engagement, and critical thinking.

Researchers should consider involving students in the process of designing concept cartoons, either by seeking their opinions or actively engaging them in the preparation process. By doing so, the cartoons can be tailored to better resonate with the students' interests, experiences, and perspectives, making the learning experience more engaging and meaningful for them. Teachers can also encourage students to create their own concept cartoons as part of the learning process. By involving students in the creation of these educational materials, teachers can promote creativity, critical thinking, and a deeper understanding of the subject matter. The products designed by students can then be utilized as supplementary course materials, enriching the learning environment and providing diverse perspectives on the NoS.

Ethical Statement
This article was produced from the first author's master's thesis.

Data Availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest
None

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