

Comparative Effects of Argumentation and Laboratory Experiments on Metacognition, Attitudes, and Science Process Skills of Primary School Children

Jale Kalemkuş^{1*}, Şule Bayraktar², Sabahattin Çiftçi³

¹Science Education, Kafkas University, Kars, Turkey

²Science Education, Giresun University, Giresun, Turkey

³Department of Basic Education, Necmettin Erbakan University, Konya, Turkey

*Corresponding author: jale.kalemkus@yahoo.com

ABSTRACT The purpose of this study is to investigate and compare the effects of laboratory experiments and argumentation-based science teaching on science process skills, metacognitive awareness levels, and attitudes towards the science of 4th-grade elementary school students. In this study conducted according to the quantitative research method, a pre-test and post-test quasi-experimental design was used with two experimental groups and a control group. Students from three classes of an elementary school participated in the study (N = 98). "Science Process Skills Test," "What Do I Really Think about Science Scale," and "Metacognitive Awareness Scale" were employed to collect data for the research. The study results showed that the science process skills of the 4th-grade students improved significantly in both experimental groups, which were taught by employing experiments and argumentation. Students' metacognitive awareness levels and attitudes towards science developed in all three groups. However, it was observed that the development was higher in the groups in which science teaching based on experiments and argumentation-based science teaching was performed, compared to the control group.

Keywords Argumentation, Experiments, Metacognition, Science Process Skills, Science Teaching

1. INTRODUCTION

Since the development of information technology facilitated access to information, today's schools aim to help students acquire higher-order skills rather than directly giving them the information. The 21st century requires individuals to have digital-age literacy, critical thinking, creative thinking, effective communication, and high efficiency (NCREL, 2003). Therefore, today's schools' primary goal is to equip students with these skills by making necessary arrangements in educational environments by utilizing teaching approaches considered useful in acquiring these skills. One of these approaches is argumentation-based teaching.

The importance of experiments is well known, and they are preferred by teachers in almost all levels of education in science education. However, although it has been shown to develop students' higher-order cognitive

skills, teachers are reluctant to practice argumentation (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Newton, Driver, & Osborne, 1999). Furthermore, argumentation is hardly utilized in primary grades. A review of research on argumentation shows that although a significant amount of research has been done at the middle and high school level, the number of studies conducted with primary school children is limited (Bağ & Çalık, 2017). More studies on the applicability of argumentation-based teaching in primary grades are needed. Furthermore, comparing the effectiveness of experiments and argumentation on particular cognitive and affective variables is valuable since the questions of

Received: 28 August 2020

Revised: 27 November 2020

Published: 27 January 2021

"Which is more effective?" or "Could one of them be an alternative to the other?" will be answered.

The purpose of this research is to investigate and compare the effects of laboratory experiments and argumentation-based science teaching on science process skills, metacognitive awareness level, and attitudes toward science of 4th-grade students.

1.1. Theoretical Framework

The argumentation process involves making claims, using data to support the claims, warranting the claims with scientific evidence, and further backing the warrants (Simon, Erduran, & Osborne, 2006). Accordingly, an argument is developed when a claim is made, providing evidence that supports this claim. (Simon et al., 2006; Van Eemeren & Grootendorst, 2004).

According to Toulmin (2003), an argument is an assertion and its accompanying justification. In a simple argument, there are three elements: data, claim and warrant. Toulmin also provides a more complex argument structure consisting of data, claim, backing, warrant, rebuttal, and qualifier, as seen in Figure 1.

Among these elements, data refer to evidence or specific information used to support the claim. A claim is an assertion that the individual would like to prove. Warrants explain the relationship of data with the claim. The backing is the generally widely accepted basic assumptions that justify strengthening the warrant. Qualifiers represent the special cases where the claims are correct and the limits of accuracy of the claim. On the other hand, Rebuttals represent special cases where the claim is not valid (Driver, Newton, & Osborne, 2000; Lazarou, 2010; Roberts & Gott, 2010; Simon et al., 2006;

Von Aufschnaiter, Erduran, Osborne, & Simon, 2008).

An example covering all Toulmin's argument model elements is given in Figure 2 (Kalemkus, Bayraktar, & Çiftçi, 2019).

As an element of scientific language, argumentation is essential both in the creation and transmission of scientific knowledge (Jimenez-Alexiandre et al., 2000). Considering that argumentation is one of the dimensions of acculturation in scientific discourse, it should be encouraged in science education (Jimenez-Alexiandre & Erduran, 2007). By developing arguments and evaluating others' arguments, students can build an understanding of how scientific knowledge is created (Driver et al., 2000).

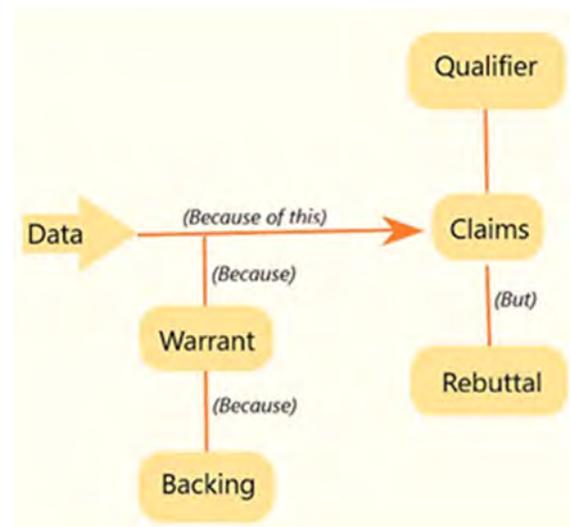


Figure 1 Toulmin's argument model (Toulmin, 2003: 97)

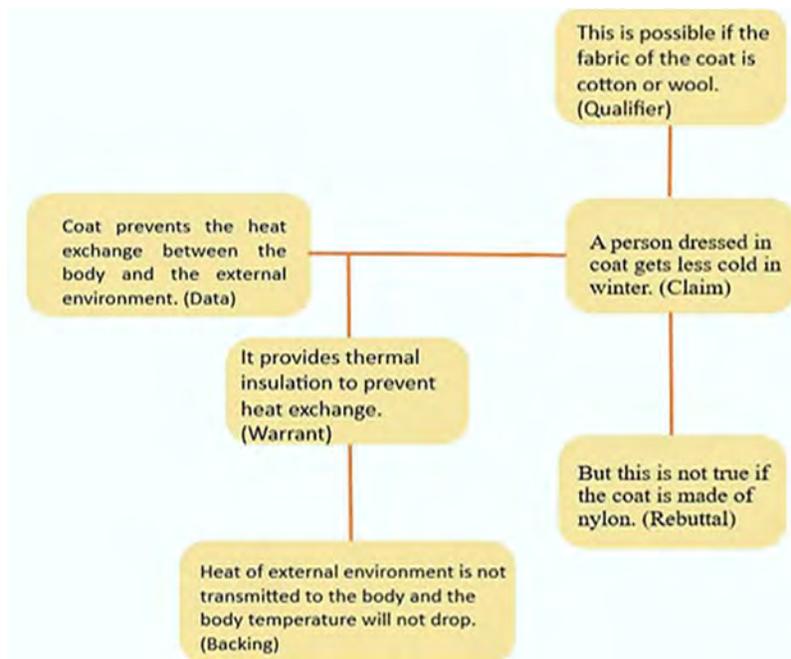


Figure 2 An example covering all the elements of Toulmin's argument model

Inclusion of argumentation in the teaching process supports students' critical thinking skills, improves their knowledge, thoughts, and judgment, and increases their ability to use scientific language (Osborne, Erduran, Simon, & Monk, 2001).

According to Driver et al. (2000), argumentation in science classes can help students understand the social dimension of science, improve their understanding of science's epistemology, and develop conceptual understanding and research skills. Students find a chance to compare their ideas and others' on a particular topic during the argumentation process. In a condition that their ideas contradict others, they evaluate the others' claims based on the supporting evidence. Suppose the supporting data, warrants, and backings are sufficient. In that case, students realize that their previous conceptions are not acceptable and reorganize their conceptual framework to accommodate the new knowledge, indicating that conceptual change occurs.

The fact that science generally includes abstract concepts, using teaching methods based on active learning seems to be mandatory. Laboratory experiments are essential in science education since they engage students with hands-on learning experiences (Özdener, 2005). Experiments could be defined as actions carried out in an appropriate environment with the necessary tools and equipment to demonstrate a known fact or test a hypothesis. In a learning environment based on laboratory experiments, students will have the opportunity of establishing a cause-effect relationship for the phenomena they encounter, identifying the problem and thinking about both causes and solutions of this problem, designing experiments to implement the solutions they thought of, and performing these experiments to draw conclusions based on the data they collected.

Using experiments, students would have a chance to know the world of scientists. Students, who observe their teacher or peers while constructing and testing a hypothesis, might develop a tendency to construct their hypotheses and test them. While testing the hypothesis, students think about variables that might affect the result, collect data, and reach the result by evaluating the data obtained. In this way, the students acquire higher-level cognitive skills by establishing a cause-effect relationship. If the students' hypothesis is not valid, they enter a different thinking process and feel a need to search for different solutions for the problem or reconsider their variables. When students need to construct a different hypothesis about the problem, they refer to social communication with peers and reach different solutions, thoughts, or ideas by interacting with them. Students' constructing and testing hypotheses enable them to discover the way the knowledge is constructed. In this process, where the student is active, learning by doing is supported. The students' psychomotor skills are also

supported by the experiments carried out as the students experience the process similar to that of scientists, their interest, curiosity, and motivation towards science increase. Experiments carried out both in the classroom and in the laboratory environment lead students to gain the ability to explain the events they encounter in daily life using scientific language. Also, through the experiences, the knowledge acquired by students becomes more concrete. Furthermore, students could relate the knowledge with their existing concepts, and meaningful learning takes place.

Science process skills have been defined as a set of practical skills for many scientific disciplines and reflect the skills scientists use in scientific research (Anagün & Yaşar, 2009; Padilla, 1990). Science process skills are grouped under two categories: necessary process skills and integrated process skills. Basic process skills are fundamental for scientific inquiry. Integrated skills, on the other hand, are grounded on the necessary skills and more complex (Padilla, 1990). Necessary process skills are recording data, classifying, measuring, communicating, observing, using space-time relationship between number and space, estimating (predicting), and drawing conclusions. Integrated process skills are: hypothesizing, determining/controlling variables, interpreting data, designing/conducting experiments, modeling, and defining operationally. Many reports on learning science emphasized that students should not only gain conceptual and quantitative information but also need to develop science process skills such as hypothesizing, designing experiments and making conclusions based on data and observations, and working with other people as a team to solve complex and open-ended problems (Etkina, Karelina, & Ruibal-Villasenor, 2008; Yang & Heh, 2007).

Metacognition is defined by Flavell (1976) as the information that a person has about their cognitive processes and products of these processes. For example; If I realize that I have more difficulty in learning A than B; If I think I should check again before I conclude that C is correct; If I think I should carefully examine each one before deciding which one is the best for a multi-choice job, this is a metacognitive process (Flavell, 1976).

Flavell (1979) believes that cognitive monitoring interventions occur through interactions between four concepts: metacognitive experience, goals/tasks, metacognitive knowledge, and strategies/actions. An individual acquires metacognitive knowledge as a cognitive creature related to humans and their various cognitive tasks, goals, actions, and experiences. A child who is aware that, unlike his friend, he is better in mathematics than essay writing can be given as an example of this knowledge. Metacognitive experiences are cognitive or affective experiences that accompany and relate to any cognitive intervention (Flavell, 1979). It is an example of a metacognitive experience to think of the

possibility of failure in some attempts to take place or to think that the previous attempt was performed very well (Flavell, 1979). Aims/tasks represent the goal of cognitive intervention. Actions/strategies, on the other hand, actions/strategies explain the cognition or behaviors used to achieve them (Flavell, 1979).

An individual's positive or negative emotional tendency towards objects, people, places, events, and ideas expresses the concept of attitude (İpek & Bayraktar, 2004). Having a positive attitude towards any lesson increases the student's motivation to learn that lesson. Thus, academic success can be expected to increase. Research by Downing and Filer (1999) and Zeidan and Jayosi (2015) reveal a significant positive relationship between attitudes and science process skills towards science.

1.2. Literature Review

A study by Asterhan and Schwarz (2007) examining the effect of argumentation on understanding concepts related to evolution determined that students participating in the argumentation process acquired more knowledge and retained the knowledge compared to the control group students. It was determined that the control group participants either lost their gains or failed to improve their conceptual understanding. Von Aufschnaiter et al. (2008) examined the argumentation processes and cognitive development of secondary school students in science and sociology courses. The research results determined that the students used their previous experiences and knowledge when they participated in the argumentation. Besides, students reinforced their existing knowledge and could elaborate on science concepts with such activities. Kınır (2011) investigated the effects of argumentation-based science learning approach on students' understanding of the concepts of chemistry and their academic achievement. The study results showed that this approach is more effective in understanding concepts related to chemical change and mixtures than traditional instruction.

Türkoguz and Cin (2014) concluded that argumentation-based teaching utilizing concept cartoons was more effective in increasing students' science process skills than traditional instruction. Similar results were found by Gültepe and Kılıç (2015) for chemistry class. Aslan (2016) showed that laboratory applications based on argumentation improved students' science process skills, found to be more effective, specifically in the students who have a low level of science process skills. Furthermore, the attitudes of the students in both groups towards the laboratory course increased positively. Karakuş and Yalçın (2016), in their meta-analysis study, concluded that argumentation-based science teaching has a positive and very large scale in terms of both academic achievement and science process skills.

Aydın and Kaptan (2014) determined that the students' metacognition and logical thinking skills in the group where the lessons were based on argumentation were positively affected. The inquiry laboratory's effect on the development of metacognitive skills among chemistry students was examined by Kipnis and Hofstein (2008). During the research activities, it was observed that the students used their metacognitive abilities at various stages of the research process. Based on these results, the researchers stated that inquiry laboratory applications could provide students with metacognitive skills opportunities.

Durmuş and Bayraktar (2010) found that both the experimental and conceptual change texts were more effective in overcoming the misconceptions than traditional instruction. Kanlı and Yağbasan (2008) investigated the deductive laboratory approach's effectiveness and the 7E model-based laboratory approach in developing science process skills. Results revealed that the science process skills of the students in both groups improved. Aydoğdu, Buldur, and Kartal (2013) examined the effect of open-ended and closed-ended experiments on acquiring science process skills. It was determined that there was a significant difference in the students' primary and integrated science process skills in both groups. The researchers stated that it could be said that open-ended science experiments based on scenarios are more effective in terms of developing primary and integrated science process skills than laboratory activities performed using closed-ended experiments.

In the study conducted by Celep and Bacanak (2013), it was carried out to get teachers' opinions about scientific process skills and acquire these skills. As a result of the interviews with the teachers; It was determined that they believe that the laboratory method, inventive path, 5E model, and Guess-Observe-Explain teaching methods are useful in gaining scientific process skills. It was also determined that teachers believed that question-answer technique, brainstorming, discussion, six-hat technique, demonstration experiment, open-ended experiment, deductive experiment, inductive experiment, project, and case study techniques were influential developing scientific process skills. In the study conducted by Freedman (2001), laboratory programs to increase scientific knowledge achievement and develop an attitude towards science were examined. As a result of the research, it was determined that the students who regularly conduct laboratory activities have higher scientific knowledge achievement levels than the students without laboratory experience. However, it was determined that there was no significant difference in attitude towards science between the two groups.

In the study conducted by Çetin and Şahin-Taşkın (2015), the effects of verbal feedback effectively given by

the teacher in the learning-teaching process on the metacognitive awareness, academic achievement, and attitudes of the primary school students were examined. At the end of the study, it was determined that the useful feedback of the teacher in the learning-teaching process significantly affected the students' academic achievement, attitudes towards the lesson, and metacognitive awareness.

This research examines the effects of science teaching with experiments and argumentation-based science teaching on the scientific process skills, metacognitive awareness levels, and attitudes toward science in 4th-grade primary school students. For this purpose, answers to the following questions were sought:

1. What is the effect of science teaching with experiments on primary school 4th-grade students' scientific process skills, metacognitive awareness, and attitudes towards science?

2. What is the effect of argumentation-based science teaching on primary school 4th-grade students' scientific process skills, metacognitive awareness, and attitudes towards science?

3. What is the effect of science teaching conducted with the current curriculum on primary school 4th-grade students' scientific process skills, metacognitive awareness, and attitudes towards science?

4. Do the effects of science teaching with experiments, argumentation-based science teaching, and science teaching carried out according to the current curriculum on the scientific process skills, metacognitive awareness, and attitudes towards the science of primary school 4th-grade students differ?

2. METHOD

2.1. Research Design

This study adopted a pre-test and post-test quasi-experimental design with two experimental groups and one control group. To separately evaluate the effects of argumentation-based science teaching and experimental science teaching on variables (metacognitive awareness,

scientific process skills, and attitude towards science) and to make a comparison between argumentation-based teaching and experimental teaching, research was conducted in two different experimental groups. The first experimental group (E1) was taught by utilizing experiments, the second experimental group (E2) was taught by utilizing argumentation activities, and the control group was taught by following the current curriculum.

2.2. Research Group

The research was carried out with 98 elementary school students studying 4th grade of a public school in Kars, Turkey. The first experimental group (E1) consisted of 29 students (15 girls, 14 boys), the second experimental group (E2) consisted of 34 students (17 girls, 17 boys), and the control group consisted of 35 students (12 girls, 23 boys).

2.3. Data Collection Instrument

"What I really think of science" Scale: "What I really think of science" Scale consisting of 21 Items, developed by Pell and Jarvis (2001) and adapted into Turkish by Kırıkkaya (2011), was used to determine students' attitudes towards science. Cronbach Alpha coefficient was calculated for this study as 0.794.

Metacognitive Awareness Inventory for Children: Metacognitive Awareness Inventory for Children (MAI-C), which was developed by Sperling, Howard, Miller, and Murphy (2002) to measure the metacognitive skills of 3rd–5th-grade students, and adapted into Turkish by Karakelle and Saraç (2007), was used to determine the metacognitive awareness levels of primary school 4th-grade students. In this study, the Cronbach Alpha coefficient was calculated as 0.89.

Science Process Skills Test: To determine the science process skills of 4th-grade students and to evaluate the developments in these skills, multiple-choice test items for measuring classification, measurement, observation, collecting data, space/time relation, prediction, determining variables, interpreting data, drawing a conclusion, hypothesis, modeling, and designing

Table 1 Pre-test scores on the data collection tools by participant groups (ANOVA)

The Data Collection Tools	Groups	Descriptive Statistical			ANOVA	
		N	X	Ss	F	p
"What I really think of science" Scale	Experiment 1	29	40.45	6.015	0.149	0.862
	Experiment 2	34	39.68	7.619		
	Control Group	35	39.63	5.976		
Metacognitive Awareness Inventory for Children	Experiment 1	29	22.97	6.62	0.521	0.596
	Experiment 2	34	24.38	5.609		
	Control Group	35	23.37	5.047		
Science Process Skills Test	Experiment 1	29	16.14	5.579	0.462	0.632
	Experiment 2	34	15.03	5.26		
	Control Group	35	16.17	5.737		

*significant at the level of $p < .05$

Table 2 Post-test scores on the data collection tools by participant groups (ANOVA)

The Data Collection Tools	Group	Descriptive Statistical			ANOVA	
		N	X	Ss	F	p
"What I really think of science" Scale	Experiment 1	29	57.14	4.462	39.158	0.000
	Experiment 2	34	54.59	5.411		
	Control	35	43.91	8.455		
Metacognitive Awareness Inventory for Children	Experiment 1	29	33.62	1.45	24.05	0.000
	Experiment 2	34	32.94	2.37		
	Control	35	27.57	5.95		
Science Process Skills Test	Experiment 1	29	24.48	2.68	19.972	0.000
	Experiment 2	34	23.09	4.18		
	Control	35	17.69	6.06		

*significant at the level of $p < .05$

experiment skills were developed by the researchers, based on the review of the relevant literature. There are 27 items in this multiple-choice test. Each item has four different options and one correct answer. Two faculty members working in science education, three science and technology teachers, and two classroom teachers were consulted for expert review of the test. After receiving expert opinions and making revisions in the test items in line with these opinions, the test was applied to 254 primary school 4th-grade students. At the end of the application, scoring was made by giving 1 point to each correct answer given by the students to the test items. Each wrong answer was given to the students' test items, and the items left blank or marked with more than one option were scored by giving 0 points. After scoring for each item, item difficulty indexes and item discrimination indices of the test items were calculated. The test items' discrimination indexes ranged between 0.34 and 0.77, and item difficulty indexes varied between 0.28 and 0.85. The KR-20 reliability coefficient of the test was calculated as 0.82.

2.4. Data Collection Process

The research was carried out during the instruction period of the "Let's Know the Matter" Unit of the science class for 4th-grade students and was completed in thirteen weeks, including pre-test and post-test studies. In the first experimental group (E1), closed-ended and open-ended experiments were carried out with group and demonstration experiments. The experiments were planned together with the first experimental group teacher, and the necessary tools and equipment were provided in advance (see Appendix A for a sample). In the second experimental group (E2), various argumentation activities such as competing theories with concept cartoons, expressions tables, and experiment reports were used for the instruction (see Appendix B for a sample). No intervention was made to the lessons in the control group, but it was carried out by following the current curriculum with approaches other than experiments and argumentation methods.

2.5. Data Analysis

One Way Analysis of Variance (ANOVA) was used to test whether there are significant differences among E1, E2, and Control group students, concerning Metacognitive Awareness Scale, Science Process Skills Test, and "What I really think of science" Scale for both pre-test and post-test.

3. RESULT

The ANOVA test results to determine whether statistically significant differences existed among the groups regarding the scores on the data collection instruments before the intervention are shown in Table 1.

As seen in Table 1, the ANOVA test results showed no statistically significant difference among the three different groups regarding attitudes, metacognitive awareness, and science process skills.

The post-test mean scores for the students in the E1, E2, and control group on the "What I really think of science" Scale, Metacognitive Awareness Inventory for Children, and Science Process Skills Test post-test are shown in Table 2. ANOVA test results revealed that there were statistically significant differences among the groups for all three tests. Scheffe test was used to determine which groups caused the difference.

According to the results of the Scheffe Test at Table 3 for "What I really think of science" Scale, "Metacognitive Awareness Inventory for Children Inventory", and "Science Process Skills Test" scores of the participant groups showed that the significant differences were between the students in both experimental groups and the control group ($p < .05$). There was not a significant difference between the scores of the two experimental groups.

4. DISCUSSION

This research was conducted to investigate the effects of laboratory experiments and argumentation-based science teaching on 4th-grade students' science process skills, meta-cognitive awareness levels, and attitudes

Table 3 Scheffe test

The Data Collection Tools	Group (I)	Group (J)	Variation in Average (I-J)	Standard Error	p
"What I really think of science" Scale	Experiment 1	Experiment 2	2.550	1.631	0.299
		Control	13.224*	1.620	0.000
	Experiment 2	Experiment 1	-2.550	1.631	0.299
		Control	10.674*	1.554	0.000
	Control	Experiment 1	-13.224*	1.620	0.000
		Experiment 2	-10.674*	1.554	0.000
Metacognitive Awareness Inventory for Children	Experiment 1	Experiment 2	0.680	0.987	0.790
		Control	6.049*	0.981	0.000
	Experiment 2	Experiment 1	-0.680	0.987	0.790
		Control	5.370*	0.941	0.000
	Control	Experiment 1	-6.049*	0.981	0.000
		Experiment 2	-5.370*	0.941	0.000
Scientific Process Skills Test	Experiment 1	Experiment 2	1.395	1.168	0.493
		Control	6.797*	1.160	0.000
	Experiment 2	Experiment 1	-1.395	1.168	0.493
		Control	5.403*	1.112	0.000
	Control	Experiment 1	-6.797*	1.160	0.000
		Experiment 2	-5.403*	1.112	0.000

*significant at the level of $p < .05$

towards science. Results of the study showed that both experiments and argumentation activities were more effective than traditional instruction. The studies conducted on the experimental method support the results obtained in this study. In the study conducted by Kanlı and Yağbasan (2008), the 7E model-based laboratory approach's effectiveness and the deductive laboratory approach in developing scientific process skills were examined. At the end of the study, it was determined that both the 7E model-centered laboratory approach and the deductive laboratory approach improved the students' scientific process skills. In the study conducted by Bilen and Aydoğdu (2012), the activities prepared based on the strategy of "Predict-Observation-Explain" in the general biology laboratory were examined by comparing it with the validation laboratory approach to the development of scientific process skills. For the research, while the proposed laboratory approach was carried out with the experimental group, the validation laboratory approach was applied to the control group. At the end of the research, it was observed that there was an improvement in the scientific process skills of both the experimental group students and the control group students. It was also determined that this improvement was more in the experimental group. In environments where laboratory experiments occur, students can experience science skills such as hypothesizing, designing an experiment to test their hypothesis, determining and controlling the experiment variables, conducting the experiment, observing, classifying, and recording data. When these opportunities are provided, it will be possible to expect

for the students to develop their science process skills over time.

When the literature is examined, it is seen that there is a study that examines the effect of the experimental method on metacognition. This study was conducted by Ulu and Bayram (2014). This study investigated whether the laboratory applications in the Science and Technology course with activities based on the science writing tool cause a difference in terms of metacognitive knowledge and skills. At the end of the research, there was a significant difference in favor of the experimental group in terms of explanatory knowledge, methodological knowledge, conditional knowledge, planning, and cognitive strategy dimensions of the students' metacognitive knowledge and skills. Still, there was no difference between the experimental and control groups in terms of self-control, self-assessment, and self-monitoring. Students may not feel a need to overthink their self-learning when they are passive receivers of information. However, they can follow their self-learning processes when they are given opportunities to be more active. Therefore, the development of metacognitive awareness is expectable in an environment that includes experimental activities.

Previous studies determined a positive relationship between attitude and science process skills. One of these studies was done by Downing and Filer (1999). In the study, the relationship between teacher candidates' scientific process skills and their attitudes towards science was examined. At the end of the study, it was determined that there is a significant positive relationship between primary school teacher candidates' science process skills

and their attitudes towards science. Another research was conducted by Zeidan and Jayosi (2015). In the study, the relationship between students' attitudes towards science and their scientific process skills was examined. At the end of the study, it was determined that there is a significant positive relationship between scientific process skills and attitude towards science. Based on this finding, it is possible to link the development of attitudes towards students' science to develop science process skills. Additionally, experiments in teaching environments lead students to a position where they could create knowledge by being physically and mentally active rather than passive receivers of information. When students become active in teaching environments, they feel the lesson is fun and develops positive attitudes.

Results of this study revealed that argumentation-based science teaching also has a positive effect on science process skills. Previous research results support this result. In the study conducted by Çınar and Bayraktar (2013), the effect of argumentation-based science teaching on students' scientific process skills was examined. It was determined that the students' scientific process skills in the group in which the argumentation-based science teaching was carried out were statistically significantly higher than the students in the group where the current teaching was applied. In the study conducted by Türkoguz and Cin (2014), the effect of argumentation based on concept cartoons activities on students' scientific process skills was examined. At the end of the study, it was determined that the students' scientific process skills in the experimental group in which argumentation-based teaching based on concept cartoons was carried out developed more than the control group students. In the study conducted by Gültepe and Kılıç (2015), the effect of scientific argumentation on students' scientific process skills in chemistry teaching was examined. As a result of the research, it was determined that both the traditional teaching approach and the argumentation-based teaching approach improved students' scientific process skills. Simultaneously, it was determined that argumentation-based teaching was more effective than the traditional teaching approach in developing students' scientific process skills. In the study conducted by Aslan (2016), the effect of argumentation-based laboratory applications on scientific process skills and attitude towards laboratory course was examined. At the end of the study, it was determined that argumentation-based laboratory applications improve students' scientific process skills and more effective in developing students' skills with lower scientific process skill levels. It was determined that the students' attitudes in both groups towards the laboratory course increased positively with the application. Through argumentation, students are involved in the process of making claims. To support a claim, they need to access some data, make observations, design and apply

experiments, record the data, and interpret it. Besides, students have to determine the variables that will affect their claims to determine their claims' limitations and refutations. Students feel the need to use these skills for their claims and evaluate others' claims. Through argumentation activities, students use science process skills in experimental teaching, which will improve these skills over time.

In the study conducted by Aydın and Kaptan (2014), argumentation on the metacognition and logical thinking skills in teacher candidates' education was examined. At the end of the research, it was determined that the students' metacognitive and logical thinking skills in the group where the lessons were conducted based on argumentation were positively affected. In the study conducted by Erenler (2017), the effect of argument-based inquiry research applications on pre-service teachers' metacognitive awareness was examined. At the end of the study, it was determined that the argument-based inquiry research method applications were statistically significant in all sub-dimensions of metacognitive awareness. In the study conducted by Ulu (2019), the argumentation-based science learning approach on students' metacognitive knowledge and skills was investigated. Laboratory activities were carried out in the control group based on the traditional approach, in the experiment-1 group based on the open inquiry-based argumentation-based science learning approach, in the experiment-2 group, based on the guided inquiry-based argumentation-based science learning approach. At the end of the study, two results were obtained. The first of these is that argumentation-based science learning-based laboratory applications are more successful than traditional-based laboratory applications in increasing students' metacognitive knowledge and skills. The other result is that the guided inquiry-based Argumentation-based science learning laboratory applications in increasing students' metacognitive knowledge and skills are more successful than the open inquiry-based argumentation-based science learning laboratory applications. Argumentation practices might lead students to evaluate their self-learning. It is possible for the student to question his or her learning, claiming "I learned" or "I did not learn" and evaluate the argument in the light of the supporting evidence similar to the questioning process of evaluating whether a claim is true or false in the context of the subjects they learn. Individuals' ideas or evaluations of their learning are related to meta-cognition. Therefore, it is possible to conclude that argumentation activities will increase students' metacognitive awareness levels.

It was determined that argumentation positively affected students' attitudes, and this result was supported by previous research. In the study conducted by Yalçın Çelik and Kılıç (2014), the effect of argumentation-based

instruction on students' conceptual understanding, attitude towards chemistry, and argumentation tendencies was examined. At the end of the study, it was determined that the students studying with argumentation had significantly higher levels of conceptual understanding, attitude towards chemistry, and argumentation tendency than the students studying with the traditional teaching method. Through argumentation activities, students enter making and strengthening their claims and assessing the contradictory claims. A learning environment in which the student is active is expected to positively affect the lesson's attitude towards the lesson. Therefore, argumentation activities will also have a positive effect on attitudes.

Control group students' scores on "What I really think of science Scale" and "Meta-cognitive Awareness Inventory for Children" and "Science Process Skills Test" were also increased during this study; however, this increase was low in science process skills. This result suggests that the current curriculum also positively affects metacognitive awareness levels and attitudes towards science. The low increase in science process skills might result from their not engaged with experiments during the study period.

5. CONCLUSION

This study showed that laboratory experiments and argumentation were useful in developing metacognitive awareness, science process skills, and attitudes. Considering the positive effects of argumentation on students, teachers might be encouraged to teach science classes based on argumentation when the experiments cannot be used. In other words, argumentation-based teaching can be preferred as an alternative to the experimental method. For teachers to utilize argumentation-based teaching, they should be familiar with argumentation-based teaching activities and then be able to create their argumentation activities. Teachers also need to gain awareness regarding the effects of metacognition on the learning process. This way, they can motivate their students to think about their self-learning, leading to improved learning outcomes.

Teachers' awareness of the positive effects of experiments and argumentation should be developed considering the results of this study and the previous studies on the subject. Laboratory conditions in schools should be improved to comply with today's technological developments, and the use of these laboratories should be encouraged. Especially in elementary school science lessons, students should be actively involved in the thinking process by including experimental practices and simple equipment types. In this process, students should be given time for making observations, thinking about a situation, offering solutions, evaluating the offered

solutions, and, if needed, developing or changing these solutions, and they should be motivated for this.

ACKNOWLEDGMENT

This study is a part of the first author's doctoral thesis.

REFERENCES

- Anagün, Ş. S., & Yaşar, Ş. (2009). İlköğretim beşinci sınıf fen ve teknoloji dersinde bilimsel süreç becerilerinin geliştirilmesi [Developing scientific process skills at science and technology course in fifth grade students]. *İlköğretim Online*, 8(3), 843-865.
- Aslan, S. (2016). Argümantasyona dayalı laboratuvar uygulamaları: Bilimsel süreç becerilerine ve laboratuvar dersine yönelik tutuma etkisi [Argumentation based activities in the laboratory: Effects on science process skills and attitudes towards laboratory course]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 31(4), 762-777.
- Asterhan, C. S., & Schwarz, B. B. (2007). The effects of monological and dialogical argumentation on concept learning in evolutionary theory. *Journal of educational psychology*, 99(3), 626.
- Aydın, Ö., & Kaptan, F. (2014). Fen ve teknoloji öğretmen adaylarının eğitiminde argümantasyonun biliş üstü ve mantıksal düşünme becerilerine etkisi ve argümantasyona ilişkin görüşler [Effect of argumentation on metacognition and logical thinking abilities in science and technology teacher education and opinions about argumentation]. *Eğitim Bilimleri Araştırma Dergisi*, 4(2), 163- 188.
- Aydoğdu, B., Buldur, S., & Kartal, S. (2013). The effect of open-ended science experiments based on scenarios on the science process skills of the pre-service teachers. *Procedia- Social and Behavioral Sciences*, 93, 1162-1168.
- Bağ, H., & Çalık, M. (2017). A thematic review of argumentation studies at the K-8 level. *Education and Science*, 42(190), 281-303.
- Bilen, K., & Aydoğdu, M. (2012). Tahmin et- gözle- açıkla (TGA) stratejisine dayalı laboratuvar uygulamalarının öğrencilerin bilimsel süreç becerileri ve bilimin doğası hakkındaki düşünceleri üzerine etkisi [A study on the efficiency of predict-observe-explain strategy on general biology laboratory applications]. *Gaziantep Üniversitesi Sosyal Bilimler Dergisi*, 11(1), 49-69.
- Kırkkaya, E. B. (2011). Grade 4 to 8 primary school students' attitudes towards science: Science enthusiasm. *Educational Research and Reviews*, 6(4), 374-382.
- Celep, A., & Bacanak, A. (2013). Yüksek lisans yapan öğretmenlerin bilimsel süreç becerileri ve kazandırılması hakkındaki görüşleri [Perceptions of teachers who are attending on their master's degree regarding the science process skills and their attainment]. *Türk Fen Eğitimi Dergisi*, 10(1), 56-78.
- Çetin, M. F., & Şahin-Taşkın, Ç. (2015). Sözlü dönütün ilkököl öğrencilerinin akademik başarı, derse yönelik tutum ve üstbilişsel farkındalığına etkisi [The effect of verbal feedback on primary school students' academic achievement, attitude towards the lesson and metacognitive awareness]. *Sakarya Üniversitesi Eğitim Fakültesi Dergisi*, 29, 39-67.
- Çınar, D., & Bayraktar, Ş. (2013). Argümantasyon temelli fen öğretiminin 5. Sınıf öğrencilerinin öğrenme ürünlerine etkisi [The effect of argumentation based science instruction on 5th grade students' learning outcomes] (Doctoral dissertation, Necmettin Erbakan University, Turkey). Retrieved from <https://acikerisim.konya.edu.tr/xmlui/handle/20.500.12452/782>
- Downing, J. E., & Filer, J. D. (1999). Science process skills and attitudes of pre-service elementary teachers. *Journal of Elementary Science Education*, 11(2), 57-64.
- Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84(3), 287-312.
- Durmuş, J., & Bayraktar, Ş. (2010). Effects of conceptual change texts and laboratory experiments on fourth grade students'

- understanding of matter and change concepts. *Journal of Science Education and Technology*, 19(5), 498-504.
- Erenler, S. (2017). *Argüman temelli sorgulayıcı araştırma uygulamalarının fen bilgisi öğretmen adaylarının üstbilişsel farkındalık düzeyine ve yazma becerilerine olan etkilerinin incelenmesi* [The effect of Argument Driven Inquiry (ADI) method on pre-service science teachers' metacognitive awareness and scientific writing skills] (Master's thesis, Abant İzzet Baysal University, Turkey).
- Etkina, E., Karelina, A., & Ruibal-Villasenor, M. (2008). How long does it take? A study of student acquisition of scientific abilities. *Physical Review Special Topics-Physics Education Research*, 4(2), 1-15.
- Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. Resnick (Eds.), *The nature of intelligence* (pp. 231-236). Hillsdale, NJ: Erlbaum.
- Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, 34(10), 906-911.
- Freedman, M. P. (2001). *The influence of laboratory instruction on science achievement and attitude toward science among ninth-grade students across gender differences*. Retrieved from ERIC database (ED454070).
- Gültepe, N., & Kilic, Z. (2015). Effect of scientific argumentation on the development of scientific process skills in the context of teaching chemistry. *International Journal of Environmental & Science Education*, 10(1), 111-132.
- İpek, C., & Bayraktar, Ş. (2004). Aday öğretmenlerin fen bilimleri ve sosyal bilimlere bakışları [Prospective teachers' views on science and social sciences]. *Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi*, 1(1).
- Jimenez-Aleixandre, M. P., Rodriguez, A. B., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, 84(6), 757-792.
- Jimenez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: an overview. In S. Erduran, & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: perspectives from classroom-based research* (pp. 3-27). Dordrecht, The Netherlands: Springer.
- Kalemkus, J., Bayraktar, Ş., & Çiftçi, S. (2019). Eğitimde sosyal, zihinsel ve sözlü-yazılı bir aktivite: Argümantasyon [A social, mental and verbal-written activity in education: Argumentation]. *Electronic Turkish Studies*, 14(4).
- Kanlı, U., & Yağbasan, R. (2008). 7E modeli merkezli laboratuvar yaklaşımının öğrencilerin bilimsel süreç becerilerini geliştirmedeki yeterliliği [The efficacy of the 7E learning cycle model based on laboratory approach on development of students' science process skills]. *Gazi Üniversitesi, Gazi Eğitim Fakültesi Dergisi*, 28(1), 91-125.
- Karakelle, S., & Saraç, S. (2007). Çocuklar için üst bilişsel farkındalık ölçeği (ÜBFÖ-Ç) A ve B formları: Geçerlik ve güvenilirlik çalışması [Validity and factor structure of Turkish versions of the Metacognitive Awareness Inventory for Children (Jr. MAI) - A and B Forms]. *Türk Psikoloji Yazıları*, 10(20), 87-103.
- Karakuş, M., & Yalçın, O. (2016). Fen eğitiminde argümantasyon temelli öğrenmenin akademik başarıya ve bilimsel süreç becerilerine etkisi: Bir meta-analiz çalışması [The effect of the argumentation-based learning in science education to the academic achievement and scientific process skills: A meta-analysis study]. *Anadolu Üniversitesi Sosyal Bilimler Dergisi*, 16(2), 1-20.
- Kingir, S. (2011). *Using the science writing heuristic approach to promote students understanding in chemical change and mixtures* (Doctoral dissertation, Middle East Technical University, Turkey). Retrieved from <https://open.metu.edu.tr/handle/11511/21489>
- Kipnis, M., & Hofstein, A. (2008). The inquiry laboratory as a source for the development of metacognitive skills. *International Journal of Science and Mathematics Education*, 6, 601- 627.
- Lazarou, D. (2010). Learning to TAP: An Effort to Scaffold Students' Argumentation in Science. In G. Çakmakçı, & M. F. Taşar (Eds.), *Contemporary Science Education Research: Scientific Literacy and Social Aspects of Science* (pp. 43-50). Ankara: Pegem Akademi.
- NCREL (2003). *enGauge 21st Century Skills for 21st Century Learners*. Retrieved from http://www.cwasd.k12.wi.us/highschl/newsfile1062_1.pdf
- Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, 21(5), 553-576.
- Osborne, J., Erduran, S., Simon, S., & Monk, M. (2001). Enhancing the quality of argument in school science. *School Science Review*, 82(301), 63-70.
- Özdener, N. (2005). Deneysel öğretim yöntemlerinde benzetişim (simulation) kullanımı [Use of simulations in experimental teaching methods]. *The Turkish Online Journal of Educational Technology (TOJET)*, 4(4), 93-98.
- Padilla, M. J. (1990). *The science process skills. Research matters...to the science teacher*. Retrieved from ERIC database (ED266961).
- Pell, T., & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education*, 23(8), 847-862.
- Roberts, R., & Gott, R. (2010). A framework for practical work, argumentation and scientific literacy. In G. Çakmakçı, & M. F. Taşar (Eds.), *Contemporary science education research: Scientific literacy and social aspects of science* (pp. 99-105). Ankara: Pegem Akademi.
- Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, 28(2-3), 235-260.
- Sperling, R. A., Howard, B. C., Miller, L. A., & Murphy, C. (2002). Measures of children's knowledge and regulation of cognition. *Contemporary educational psychology*, 27(1), 51-79.
- Toulmin, S. (2003). *The uses of argument* (3rd Ed.). New York: Cambridge University Press.
- Türkoguz, S., & Cin, M. (2014). Effects of argumentation-based concept cartoon activities on students' scientific process skills. *Mersin University Journal of the Faculty of Education*, 10(2), 142-156.
- Ulu, C., & Bayram, H. (2014). Araştırma sorgulamaya dayalı bilim yazma aracı kullanımının üstbilişsel bilgi ve becerilere etkisi [Effects of implementing inquiry based approach known as science writing heuristic on metacognitive awareness and skills]. *Turkish International Journal of Special Education and Guidance & Counseling*, 3(1), 68-80.
- Ulu, C. (2019). Argümantasyon Tabanlı Bilim Öğrenme Yaklaşımına Dayalı Laboratuvar Uygulamalarının Üstbilişsel Bilgi ve Becerilere Etkisi [The Effects of Argumentation-Based Science Learning Approach Based Laboratory Applications on Metacognitive Knowledge and Skills]. *Uluslararası Bilim ve Eğitim Dergisi*, 2(1), 11-23.
- Van Eemeren, F. H., & Grootendorst, R. (2004). *A systematic theory of argumentation*. New York: Cambridge University Press.
- Von Aufschnaiter, C., Erduran, S., Osborne, J., & Simon, S. (2008). Arguing to learn and learning to argue: case studies of how students' argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching*, 45(1), 101-131.
- Yalçın Çelik, A., & Kılıç, Z. (2014). The impact of argumentation on high school chemistry students' conceptual understanding, attitude towards chemistry and argumentativeness. *Eurasian Journal of Physics and Chemistry Education*, 6(1), 58-75.
- Yang, K. Y., & Heh, J. S. (2007). The impact of internet virtual physics laboratory instruction on the achievement in physics, science process skills and computer attitudes of 10th-grade students. *Journal of Science Education and Technology*, 16(4), 451-461.
- Zeidan, A. H., & Jayosi, M. R. (2015). Science process skills and attitudes toward science among Palestinian secondary school students. *World Journal of Education*, 5(1), 13- 24.