Turkish Journal of Teacher Education

Volume 11, Issue 2, 2022 ISSN:2147-5156

The Effect of Argumentation-Based Socioscientific Teaching on the Academic Achievement of 7th-Grade Students in the Unit of Pure Substances and Mixtures**

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Keywords

Argumentation, Socioscientific Issues, Academic Achievement

Article History

Received
June 18, 2022
Revised
Dec 01, 2022
Accepted
Dec 20, 2022
Published
Dec 30, 2022

Abstract

The study investigated the effect of argumentation-based activities on middle school student's academic achievement. The research was conducted with 23 7th-grade students using argumentation-based activities for ten weeks. The "Particulate Structure of Matter Achievement Test," which includes the 7th Grade 4th Unit developed by Kizkapan and Bektas (2018), was used to measure academic achievement. The test consisted of 21 items and was administered as the pre-test before and the post-test after the intervention. Data were analyzed with the SPSS 24 package program. As a result of the research, it was seen that the scores the students got from the post-test were higher than the scores they got from the pre-test, and this difference was significant. In addition, since the activities applied throughout the intervention aimed to contribute to developing high-level thinking skills, it is noteworthy that the test also positively affected the development of problem-solving and critical thinking skills, which are taxonomic levels.

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** This paper was developed from the first researcher’s doctoral thesis and under the supervision of the second researcher

Introduction

New methods are being introduced to enrich science teaching and to promote scientific literacy. One of them is argumentation, which has been the subject of many studies in recent years. It is a process in which individuals put forward a claim and defend these claims by presenting evidence, and justifying them while trying to persuade people who have the opposite opinion. Therefore, argumentation process is a scientific discussion process in which individuals think like scientists and present their ideas both in writing and verbally (Aktami & Higde, 2017; Bas & Sevim, 2020). In science, the construction of knowledge is linked to the justification of knowledge, and claims must be linked to data and evidence, either through logical judgments or from different sources (or both) (Ayas et al., 2002). Therefore, argumentation on scientific issues can be defined as establishing a connection between claims and data through justification or evaluating information claims in the light of empirical or theoretical evidence. Scientific claims are thus separated from ideas (Jimenez-Aleixandre & Erduran, 2007). Argumentation is a social, intellectual, verbal activity that serves to justify or refute an opinion, consisting of statements aimed at gaining the approval of the listeners (Driver et al., 2000). Argumentation also has the potential to improve students' attitudes toward science, their enjoyment of science learning, and their reasoning skills (Trend, 2009; Bas & Sevim, 2020). It is one of the most effective tools to learn the nature of science (Kucuk & Bag, 2012; Kucuk & Cepni, 2015; Sevim, 2012).

The main components of argumentation were identified by Toulmin as data, claim, warrant, backing, qualifiers, and rebuttals (Toulmin, 2003). It can be limited to qualifiers to show the limits of the validity of the claim, and can also be refuted by contesting the data, reasons, or supports (Osborne et al., 2004). Driver et al. (2000) explained that the Toulmin model has some limitations besides its usefulness. These;

(i) The same expression may have a different meaning in a different context. Therefore, context must be taken into account when making sense of it;

(ii) Some elements of the argument (such as the rationale) are usually not made explicit in speech. Often these elements are implicit.

(iii) Speech need not proceed sequentially in its natural flow, and reference must be made to different and broad parts of the text to characterize the argument.

(iv) Not all points in argumentation are made through conversation. Sometimes can also be expressed via gestures, pointing at objects, nodding, etc. Moreover, pictures and graphics are no longer complementary but a central communicative feature of texts.

While written argumentation is used from time to time in the classroom environment, verbal argumentation is also used for students to explain their ideas to everyone. It is important to use the written argumentation method, especially in crowded classes, since not every student can always be given the right to speak. In this way, the teacher can learn the opinion of each student on the subject. In addition, a verbal argumentation process is needed so that students can defend their ideas or persuade someone who has an opposite opinion after they have created their arguments. In the verbal argumentation process, students collect data, make claims, justify their claims and defend them with backing. In the meantime, he learns to listen to opposing ideas, identify the missing or faulty parts of the ideas, and gain the skills to refute these ideas (Aktamis & Higde, 2017).

It can be said that argumentation has at least five potential contributions to science learning. These are (i) to Support access to cognitive and metacognitive processes that define expert performance and enable modeling for students, (ii) To support the development of communicative competencies and especially critical thinking, (iii) To support scientific literacy level and students' speaking and writing scientific language, (iv) to support acculturation within the practices of scientific culture and to develop epistemic criteria for the evaluation of knowledge, and (v) To support the development of reasoning, especially their selection of theories or situations based on rational criteria (Jiménez-Alexandre & Erduran, 2007).

It can be concluded from the items listed, argumentation is an important method for science education. Because students learn a lot of information at school and the argumentation process is considered very important because they can use this information through argumentation and have these scientific discussions in an environment where they can freely express the ideas they defend (Capkinoglu, 2015).

For an argument to be of good quality, it is not enough for the individual to just defend his/her claim and explain why this claim is true. To say that an individual has produced a strong and high-quality argument, he/she must be aware of the deficiencies of his/her claim, namely its rebuttals, and demonstrate with evidence why the counter-arguments are not true (Capkinoglu, 2015).

Socioscientific Issues and Teaching in Science Education

Socioscientific issues are controversial social issues that have conceptual and/or methodological connections to science (Sadler, 2004). They are open-ended problems with no definite solutions. They tend to have many reasonable solutions. These solutions can be informed by scientific principles, theories, and data, but solutions cannot be fully determined by scientific considerations. There are some problems and possible courses of action on socioscientific issues. It is influenced by various social factors such as politics, economics, and ethics. Socioscientific issues can be global in nature, such as climate change and the use of genetic technologies, or local, such as addressing a local environmental crisis or locating a new power plant (Sadler, 2011; Sevim, & Ayvaci, 2020).

Socioscientific issues are complex in nature and do not have a definitive solution. Even if they are based on science, they cannot be solved by simply referring to scientific knowledge. Rather, they involve various societal aspects and must be resolved by the integration of different, often competing, perspectives. Typically, socioscientific issues confront students with situations in which they must enter discussion or decision-making situations. They are considered real-world problems that can prepare students to become enlightened citizens (Eggert & Bogeholz, 2009). Socioscientific issues contribute to the development of students' decision-making skills due to the controversial nature of their dilemmas. For this reason, it can be said that argumentation is an appropriate method for teaching socioscientific issues (Topcu & Atabey, 2017).

On the other hand, there is not enough teaching which can be used for science teachers about teaching socioscientific issues (Topcu, 2017). Due to these shortcomings, there is a need for new research in which educational material and teaching environments are designed for the teaching of socioscientific issues (Topcu & Atabey, 2017). There is no common truth that everyone agrees on socio-scientific issues. By its very nature, it causes different opinions. Individuals form opinions by being influenced by their own lives, by reflecting their moral views, and by presenting scientific evidence at the same time. While moral values are a priority for some students, scientific evidence is at the forefront for some students. Therefore, the arguments created on a socioscientific issue can be very different from each other (Gulhan, 2012). Now, the important thing is not which claim the students are defending, but being able to justify their claim correctly, presenting data and backings about this claim, and being aware of the missing points of their argument.

Method

Research Design

This study used a One-Group Pretest-Posttest design. The one-group pretest-posttest design is a type of pre-experimental model in which the outcome of interest is measured two times (Karasar, 2014). In the design, the independent variable is applied to any group both before and after the intervention and the effect of the independent variable on the dependent variable are observed. In this study, the "Particulate Structure of Matter Achievement Test" (PSMAT) was applied to the same group as a pre-test and as a post-test before and after the intervention. The effect of argumentation-based activities on the academic achievement of 7th-grade students was measured and compared.

Sample

The research group consisted of 7th-grade students selected from a middle school in Istanbul, Turkey. A total of 29 students participated in the study. However, since the study required continuity, six students who were absent frequently and did not participate in all the activities were not included in the data analysis. While determining the research group, the criterion sampling method was used. The criteria of class selection are students having difficulty in making decisions on socioscientific issues, low academic achievement in science, and the teacher's command of the application method. The researchers took part in only two courses as participant observers.

A female teacher who had a master's degree in the field of argumentation and continued her doctorate studies during the activities was determined as a practitioner teacher and intervention was made in her class. The researchers followed the practitioner teacher through the videos recorded and directed the practitioner teacher at the points where the direction was required. By actively participating in the implementation of two activities, the researcher had the opportunity to get to know the students and helped the practitioner teacher with the points that should be emphasized.

The Intervention

In this study, a total of 15 activities based on argumentation and designed according to the 5E model were employed (see Karcili, 2022). In five of these, students were expected to construct an advanced argument containing argument elements and make a decision. While preparing the activities, the science unit was handled as a whole. During the activities, students should question what the sources of evidence are and the reliability of these sources, comprehend the argument elements such as claim, data, justification, supportive and rebuttal, listen to other people's ideas in the class discussion and change their mind when necessary, but defend their own opinion when necessary, simple argument in the first activities. In the following activities, it was expected that they would be able to create more advanced arguments and make a decision on a socio-scientific issue with a contradictory situation. The intervention process was completed in 11 weeks.

Data Collection Tools

In the study, the "Particulate Structure of Matter Achievement Test", which includes the 7th Grade 4th Unit developed by Kizkapan and Bektas (2018), was used. The test was developed to determine the students' levels at the end of the unit and consists of 21 items in total. Students get 1 point for each question they answered correctly and 0 points for each question they answered incorrectly. The maximum score that can be obtained from the test is 21 and the minimum score is 0. The Cronbach's Alfa reliability coefficient of the test was calculated as 0.87. Haladyna's Taxonomy was used while creating the items (Haladyna & Downing, 1989; Haladyna & Rodriguez, 2013). There are four steps in Haladyna's taxonomy. Comprehending, problem-solving, critical thinking, and creativity. Since it is difficult to reach the level of creativity in multiple choice questions, this test only includes items on comprehending, problem-solving and critical thinking. Table 1 includes the distribution of the questions in the test according to taxonomic levels.

Table 1

Distribution of Questions in PSMAT by Taxonomic Levels

Comprehending Level	Problem-Solving Level	Critical Thinking Level
1, 5, 9, 18	2, 3, 4, 6, 7, 8, 10, 12, 13, 15, 16, 17, 21	11, 14, 19, 20

Data Analysis

Data were analyzed by using SPSS 24 package program. To determine which analyzes will be used in the study, it was checked whether the distribution was normal or not and the number of samples. Since the sample was smaller than 30 is less likely to have a normal distribution (Can, 2020), measurements obtained from the small group may cause deviations from the normal distribution (Ravid, 1994). According to Buyukozturk (2007), the recommended normality tests are the Shapiro-Wilk test when n<50, and the Kolmogorov-Smirnov test when n>50. Since the sample of this study was 23 students, the Shapiro-Wilk test was used in the normality test. It was observed that the distributions were not normal. In cases where a normal distribution is not observed, non-parametric analyzes should be used. The paired sample t-test, which is a parametric test, is used to test the difference between two measurements (pretest-posttest) made at different times belonging to the same group. In this study, the Wilcoxon Signed Rank Test, the non-parametric equivalent of the paired sample t-test, was used.

Results

Pre-Test-Post-Test Analysis

Table 2 includes the results regarding the mean, standard deviation, maximum and minimum scores of the students in the pre and post-tests of PSMAT.

Table 2

Arithmetic Mean, Standard Deviation, Minimum and Maximum Values of PSMAT

	N	Minimum	Maximum	Mean	Standard Deviation
Pre-test	23	0	11	3,70	2,619
Post-test	23	6	15	8,96	2,345

It is seen from Table 2 that the scores of the students in the pre-test vary between 0-11, while they vary in the range of 6-15 points. The PSMAT. the average score of the students, who was 3.70 before the intervention, increased to 8.69 after the intervention. The normality test results are in Table 3.

Table 3

Normality Test Results of PSMAT Pre and Post-Test Scores

	Kolmogorov- Smirnov			Shapiro- Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	,280	23	,000	,858	23	,004
Post-test	,154	23	,165	,906	23	,033

Table 3 shows that both the pre and post-tests ($p<0.05$) do not show a normal distribution. The Wilcoxon Signed Rank Test results are in Table 4.

Table 4

Comparison of PSMAT Pre and Post-Tests Scores with Wilcoxon Signed Rank Test

Post-Test	Pre-Test		N	Mean Rank	Sum of Ranks	z	p
		Negative Ranks	1	1,00	1,00	-4,178	,000
		Positive Ranks	22	12,50	275,00		
		Ties	0				

Table 4 shows that there is a significant difference between the PSMAT pre and post-test average scores according to the Wilcoxon Signed Rank Test results ($p=0.00 < 0.05$). This difference is in favor of the post-test ($z=-4,178$). It means that the argumentation activities contributed positively to the student's learning of the particulate structure of matter unit.

Taxonomic Level of Particulate Structure of Matter Achievement Test

Table 5

Arithmetic Mean, Standard Deviation, Minimum and Maximum Values from PSMAT Taxonomy Levels

Taxonomy Level		N	Mean	Standard Deviation	Minimum	Maximum
Comprehending	Pre-Test	23	1,30	1,146	0	4
	Post-Test	23	1,57	1,080	0	4
Problem-Solving	Pre-Test	23	2,57	1,996	0	7
	Post-Test	23	5,74	1,573	2	9
Critical Thinking	Pre-Test	23	0,74	0,689	0	2
	Post-Test	23	1,57	0,896	0	3

Table 5 shows that the post-test average score (1.57) of the questions at the comprehension level increased. There is a higher increase in the post-test mean (5.74) than the pre-test mean (2.57) at the problem-solving level. It is seen that the critical thinking post-test mean (1.57) increased compared to the pre-test mean (0.74). Table 6 shows the variation of each question in the PSMAT.

Table 6

Pre-Test and Post-Test Scores of PSMAT

Question Number	Taxonomic Levels	Pre-Test Score Total	Post-Test Score Total
1	Comprehending	7	7
2	Problem-Solving	3	7
3	Problem-Solving	2	12
4	Problem-Solving	10	19
5	Comprehending	9	10
6	Problem-Solving	1	4
7	Problem-Solving	3	7
8	Problem-Solving	8	16
9	Comprehending	6	10
10	Problem-Solving	4	9
11	Critical Thinking	4	13
12	Problem-Solving	4	6
13	Problem-Solving	3	6
14	Critical Thinking	3	6
15	Problem-Solving	4	9
16	Problem-Solving	1	6
17	Problem-Solving	11	18
18	Comprehending	8	9
19	Critical Thinking	5	10
20	Critical Thinking	5	7
21	Problem-Solving	5	13

Table 6 shows how many students gave correct answers from the pre and post-tests. There has been an increase in the number of students answering questions at the problem-solving level. While the number of answers to the 3rd, 8th, and 21st questions at the problem-solving level was low in the pre-test, there was an increase in the number of answers in the post-test. For example, while two students answered the third question correctly in the pre-test, twelve students gave the correct answer in the post-test. At the critical thinking level, only four students answered the eleventh question correctly, while thirteen answered correctly in the post-test.

Comprehending Level

Table 7

Normality Test Results of Comprehending Level Total Scores

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	,257	23	,000	,877	23	,009
Post-test	,265	23	,000	,893	23	,018

Table 7 shows that both the pre and post-tests do not show normal distribution ($p<0.05$) at the level of comprehending. Wilcoxon Signed Rank Test was applied to compare them and the results are in Table 8.

Table 8

Comparison of Comprehending Level with Wilcoxon Signed Rank Test

	N	Mean Rank	Sum of Ranks	z	p
Negative Ranks	6	6,17	37,00	-,996	,319
Positive Ranks	8	8,50	68,00		
Ties	9				

*Based on Negative Ranks

Wilcoxon Signed Rank Test results show that no significant difference was observed between the pre and post-test results at the comprehending level ($z= -,996$, $p>0.05$).

Problem-Solving Level

Table 9

Normality Test Results of Problem-Solving Level Total Scores

	Kolmogorov- Smirnov			Shapiro- Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	,177	23	,061	,918	23	,062
Post-test	,246	23	,001	,881	23	,010

It is seen from table 9 that the pre-test shows a normal distribution ($p>0.05$), and the post-test does not show a normal distribution ($p<0.05$). Wilcoxon Signed Rank Test was applied to compare them and the results are in Table 10.

Table 10

Comparison of Problem-Solving Level with Wilcoxon Signed Rank Test

	N	Mean Rank	Sum of Ranks	z	p
Negative Ranks	3	6,00	18,00	-2,924	,003
Positive Ranks	20	12,90	258,00		
Ties	0				

*Based on Negative Ranks

It is seen from table 9 that a significant difference was observed between the pre and post-test results ($z= -2,924$, $p<0.05$). The fact that the difference scores are in favor of positive ranks (post-test) indicates that argumentation activities have a significant effect on problem-solving.

Critical Thinking Level

Table 11

Normality Test Results of Critical Thinking Level Total Scores

	Kolmogorov- Smirnov			Shapiro- Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	,256	23	,000	,790	23	,000
Post-test	,252	23	,001	,880	23	,010

Table 11 shows that both the pre and post-tests do not show normal distribution ($p<0.05$). Wilcoxon Signed Rank Test was applied to compare the critical thinking level and the results are in Table 12.

Table 12

Comparison of Critical Thinking Level with Wilcoxon Signed Rank Test

	N	Mean Rank	Sum of Ranks	z	p
Negative Ranks	4	7,50	30,00	-3,663	,000
Positive Ranks	16	11,25	180,00		
Ties	3				

*Based on Negative Ranks

Table 12 shows that a significant difference was observed between the pre and post-test results (z= -3,663, $p<0.05$). The fact that the difference scores are in favor of positive ranks (post-test) indicates that argumentation activities have a significant effect on critical thinking.

Discussions

The sample's lowest score on the PSMAT is 0, and the highest score is 21. It is seen that the pre-test mean was 3.70, and the post-test was 8.69. As a result of the Wilcoxon Signed Rank Test (z=-4,178), there was a statistically significant difference between them in favor of the post-test. Based on these results, it is clear that argumentation-based science teaching activities had a positive effect on the sample's academic achievement. There are some studies supporting that argumentation-based teaching increase academic achievement. For example, in a study conducted by Sekerci (2013) for ninth-grade chemistry, a significant difference was found in favor of the experimental group in the argument levels. In other studies, done by Ogreten (2014) with fourth-grade students, Yalcinkaya (2018) with sixth-grade students, and Uluay and Aydin (2018) with seventh-grade students, they found out that the argumentation method increased academic achievement. In addition, argumentation is a powerful tool for improving children's science learning, high-level of cognitive comprehending, practice, analysis, synthesis, and evaluation skills (Trend, 2009). The development of higher-order thinking skills will also contribute to meaningful learning.

Based on Haladyna's taxonomy, comprehension, critical thinking, and problem-solving were examined in three groups. As a result of the Wilcoxon Signed Rank Test, there was no significant difference (z= -,996, p>0.05) between the pre and post-test of comprehension level. However, there was a statistically significant difference in favor of the post-test at the level of critical thinking (z= -3.663, p<0.05) and problem-solving level (z= -2.924, p<0.05). The reason why there is no significant difference in the comprehending level questions may be that the students were able to answer the questions both in the pre and post-tests. However, it is noteworthy that while the students could not solve the questions at the level of critical thinking and problem-solving in the pre-test, they could solve them in the post-test. Accordingly, the activities contribute to developing problem-solving and critical-thinking skills. In the literature, there are studies supporting that argumentation-based teaching contributes to the development of critical thinking skills (Jiménez-Aleixandre & Erduran, 2007; Aktamis & Higde, 2017).

Conclusions

The study determined that argumentation-based science activities developed students' high-level thinking skills, such as critical thinking and problem-solving. Critical thinking focuses on evaluating the evidence supporting an argument, the evidence, and its evaluation. It enables individuals to think systematically and be inquisitive. However, it is necessary to confront students with real-life problems to enable thinking. In this case, it is recommended that teachers present real-life problems to students in learning environments by using argumentation elements, first create confusion and question their ideas, and support their critical thinking in this process. Thus, while students will improve their high-level thinking skills by using argument elements, they will increase the quality of their arguments and academic achievement by using their high-level thinking skills.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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