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# Enhancing Cognitive Abilities in Elementary School Students: Exploring the Impact of Teaching Socioscientific Issues through Argumentation Method in Science Education[1]

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**Abstract**

In this study, we investigated the impact of teaching socioscientific issue-based science activities using the argumentation method on the cognitive abilities of elementary school students. The study comprised a total of 63 eighth-grade students, with 32 in the experimental group and 31 in the control group, all attending a state school under the Ministry of National Education. Employing a quasi-experimental design with a pre-test and post-test control group, participants were selected through convenient sampling. In the experimental group, students engaged in activities centered around argumentation scenarios, while the control group received traditional lectures and in-class activities. The activities for the experimental group were designed in accordance with the Toulmin argumentation model. Data collection relied on three scales: attitudes towards socioscientific issues scale developed by Topçu (2010), the reflective thinking scale created by Yıldırım (2012), and the critical thinking scale by Görücü (2014). The study's findings indicated that the control group students' attitudes towards socioscientific issues demonstrated positive changes, although there was no significant enhancement in their critical thinking and reflective thinking skills. In contrast, the experimental group students exhibited significant improvements in their attitudes towards socioscientific issues, reflective thinking abilities, and critical thinking skills. These results underscore the potential benefits of incorporating socioscientific issue-based science activities more extensively in the classroom, offering students a more comprehensive educational experience.

**Keywords:** Science Education, Discussion, Socioscientific Issues, Critical Thinking, Reflective Thinking

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## Introduction

The rapid advancement of science and technology exerts a profound influence not only on social, cultural, and economic spheres but also on the field of education (Uşun, 2000). Particularly in the early 21st century, the surge in globalization, the rapid pace of economic, technological, political, and cultural transformations, and the ubiquitous use of communication tools have made educational reform an unavoidable necessity (Bala, 2013). One of the foremost objectives of national education systems is to nurture individuals who are attuned to the demands of their era. This entails cultivating individuals capable of interpreting events, identifying problems, generating solutions, conceiving original ideas, engaging in critical thinking, fostering collaboration, and nurturing creativity (Geisinger, 2016; Griffin et al., 2012; Karakaş, 2015; Kozikoğlu & Altunova, 2018; Larson & Miller, 2011). Nevertheless, instilling these

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competencies poses a significant challenge for educators (Soylu, 2004). Consequently, effective schooling should inspire students to acquire these proficiencies, enabling them to select and apply pertinent information in their daily lives (Sevgi, 2016). This underscores the importance of science education as a key component in equipping individuals with these competencies (Soylu, 2004).

Science education holds sway over every facet of our existence and is intertwined with every dimension of our lives. Therefore, science education and the realm of science occupy pivotal roles in shaping human existence. Science is defined as a discipline that scrutinizes the natural world and its phenomena, endeavoring to anticipate occurrences that have yet to transpire (Kaptan & Korkmaz, 1999). Those who possess a deep understanding of science are individuals versed in comprehending the environment they inhabit, displaying sensitivity to societal occurrences, assuming responsibility, inquisitively questioning their surroundings, and demonstrating analytical and contemplative thinking abilities (Gülhan, 2012). When we delve into the objectives of science, it becomes evident that this discipline is a cornerstone for nurturing individuals who are adept at grasping the intricacies of the world around them.

Hence, science should empower individuals with the capacity to not only understand and grasp information but also apply and generate it when needed. It should enable individuals to translate the knowledge they acquire into practical use in their everyday lives, fostering sensitivity to societal events and the environment in which they reside (Duran, 2016; Özcan, 2019). The intricate interplay between science, society, and the environment is a dynamic one, with these three elements continually influencing each other. The demands and needs of society act as catalysts for the emergence and advancement of science. However, the reception of scientific developments varies among different segments of society, leading to diverse viewpoints and even societal divisions. Consequently, the concept of "socioscientific issues" assumes a pivotal role in elucidating and comprehending societal dilemmas (Sadler, 2004; Sadler & Zaidler, 2004). Integrating socioscientific issues into the science learning process aids students in gaining a better understanding of the challenges they confront in their daily lives, encourages them to contemplate these issues critically, devise solutions, and link this knowledge to their academic learning (Sevgi, 2016).

Socioscientific issues are characterized as matters encompassing both scientific and social dimensions, lacking a single definitive answer, open to various perspectives, and fraught with ethical and moral considerations (Sadler & Zaidler, 2005; Sadler & Fowler, 2006; Zaidler & Nichols, 2009; Topçu, 2015). Examples of such issues include cloning, GMOs (Genetically Modified Organisms), chemical drugs, global warming, flu vaccines, stem cell research, alternative fuels, and nuclear energy (Levinson, 2006; Topçu, 2015). The incorporation of activities rooted in socioscientific issues into the science curriculum makes substantial contributions to students' cognitive, affective, and social development (Topçu, 2017). A learning environment centered on socioscientific issues fosters the development of scientific thinking, analytical reasoning, critical thinking, reflective contemplation, logical analysis, as well as skills in analysis, interpretation, evaluation, questioning, ethics, and morality (Evren & Kaptan, 2014). Moreover, socioscientific-based classroom activities contribute to students' character development, instilling values such as honesty, compassion, and respect (Zaidler & Nichols, 2009). Thanks to this form of education, students are better equipped to make informed and ethical decisions when confronted with complex societal issues (Albe, 2008). Therefore, nurturing students' interest in socioscientific issues not only advances their acquisition of high-level skills but also enhances the overall quality of education.

Given that socioscientific issues inherently involve contradictions and room for discussion, it becomes exceptionally important for students to foster a healthy discussion environment when addressing these complex matters. To facilitate this, the adoption of the "argumentation method" (Soysal, 2012) is crucial, as it empowers students to engage in open and constructive discussions (Means & Voss, 1996). Argumentation is a process in which individuals articulate their viewpoints in a coherent and logical manner (Patronis et al., 1999). In this method, individuals propose solutions to real-life problems, and during the course of argumentation, their ideas may evolve, allowing them to consider opposing perspectives. Argumentation is frequently employed to cultivate high-level and enduring thinking skills, particularly in the context of science education. Argumentation-based science learning classes often introduce contemporary and science-based topics into the classroom environment, using these subjects as focal points for classroom discussions (Altun, 2010; Cüneyt & Bayram, 2015; Demirel, 2016; Hasançebi & Günel, 2013; Sampson & Clark, 2008). Moreover, these classes also frequently incorporate socioscientific issues, which involve ethical and moral discussions on the societal implications of science and technology (Atabey, 2016; Karışan, 2011; Karışan, 2014; Karışan et al., 2017; Yapıcıoğlu & Kaptan, 2018).

Critical thinking represents a high-level cognitive process that involves questioning information and issues, substantiating information with evidence, refining and developing thoughts, and striving to reach reasonable conclusions (Gündoğdu, 2009). This skill empowers individuals to question information critically and arrive at more accurate insights (Görücü, 2014). Critical thinking is not an innate trait but is cultivated through education, encouraging students to scrutinize and analyze the knowledge they acquire (Semerci, 2003). Consequently, creating a comfortable learning environment is crucial for nurturing critical thinking skills. Reflective thinking, another form of higher-order thinking, has garnered increasing attention in recent years, leading to extensive research in this area. The term "reflective thinking" is derived from the concept of 'reflecting' (Köksal, 2006). This mode of thinking, initially proposed by John Dewey, has been referred to by various terms in the literature, such as deep thinking (Vural & Kutlu, 2004) and careful thinking [Ministry of National Education,(MoNE), 2007]. Reflective thinking encompasses the ability to gain a deeper understanding of oneself, engage in profound contemplation about life, question, solve problems, remain open to diverse perspectives, express thoughts clearly, comprehend effective learning methods, approach learning and teaching processes from a critical standpoint, anticipate the future, and apply what has been learned in real-life scenarios (Ersözlü, 2008). Individuals who approach situations with a degree of skepticism tend to develop critical thinking skills, leading to a more precise identification of problems. Such individuals can then generate solutions through a systematic problem-solving approach, ultimately giving rise to creative ideas (Tican, 2013). Consequently, the active utilization of reflective thinking within educational processes holds paramount importance.

the This research focuses on the cultivation of higher-order thinking skills, particularly critical thinking and reflective thinking, within the context of science education, with a specific emphasis on socioscientific issues. Critical thinking equips students with the ability to question and assess information critically, while reflective thinking nurtures deep thinking, problem-solving aptitude, and the application of acquired knowledge in daily life. In our fast-paced and intricately interconnected world, these two skills are indispensable for endowing students with critical thinking acumen, analytical prowess, and effective problem-solving abilities. Integrating socioscientific issues into science activities offers students a unique opportunity to comprehend and critically appraise the interplay between science and technology in their societal context. This research endeavors to provide a fresh perspective on science education practices by examining how this pedagogical approach can enhance the thinking skills of secondary school students. Consequently, this study holds the potential to serve as a valuable resource for educators and curriculum developers, contributing to the formulation of more effective strategies for nurturing 21st-century skills among students.

The overarching aim of this study is to investigate the impact of argumentation-based practices on the perspectives and cognitive abilities of students in the context of socioscientific issues. Specifically, the research seeks to address the following subproblems:

1) Is there is a significant difference between the pre-test and post-test scores of the experimental group students on the 'Views on Socioscientific Issues Scale' after engaging in argumentation-based practices.

2) Is there a significant difference between the pre-test and post-test scores of the control group students on the 'Views on Socioscientific Issues Scale'?

3) Is there a significant difference in the pretest and posttest scores of the experimental group students on the 'Reflective Thinking Scale' following argumentation-based practices.

4) Is there a significant difference between the pre-test and post-test scores of the control group students on the 'Reflective Thinking Scale'?

5) Is there a significant difference between the pre-test and post-test scores of the experimental group students on the 'Critical Thinking Scale' subsequent to argumentation-based practices.

6) Is there a significant difference between the pre-test and post-test scores of the control group students on the 'Critical Thinking Scale'?

By addressing these subproblems, the study aims to provide a comprehensive understanding of the effects of argumentation-based practices on students' views on socioscientific issues, reflective thinking, and critical thinking skills."?

## Method

### Research Model

In this study, we employed a quasi-experimental design method featuring a pre-test - post-test control group, which is a quantitative research approach. The primary objective of quasi-experimental designs is to assess whether there is a discernible alteration in the behavior of the group subjected to an intervention, as well as to gauge whether there exists a significant divergence between the experimental and control groups in terms of this behavior change (Maxim, 1999). The selection of which group serves as the experimental group and which as the control group is determined through an impartial and unbiased process, often involving random assignment (Karasar, 2007).

### Participants

The study was carried out during the 2020-2021 academic year, involving a total of 63 eighth-grade students in a public school located in Aydın province. The participants were divided into an experimental group comprising 32 students and a control group comprising 31 students. These two groups were selected from one randomly chosen class out of five classes in the school. The selection process was based on the principle of random selection, ensuring that the sampling units from each class were chosen in a fair and independent manner (Fraenkel et al., 2006). Given the researcher's presence in the region, a convenience sampling method was employed. This method aims to optimize time, cost, and labor resources while enabling the researcher to make the most efficient use of available resources (Büyüköztürk et al., 2018). The distribution of the study group is detailed in Table 1.

**Table 1**

*Distribution of Participants According to Gender*

| Group | Girl | Boy | Total |
|---|---|---|---|
| **Control** | 18 | 13 | 31 |
| **Experimental** | 15 | 17 | 32 |
| **Total** | 33 | 30 | 63 |

### Implementation

To track the evolution of students' argumentation skills throughout the research, the initial step was to choose suitable activities. The researchers meticulously selected and identified these activities. In the selection process, certain criteria were taken into account, including the socioscientific nature of the topics, their relevance to prior classroom experiences, their capacity to engage and motivate students, and their potential to spark lively discussions without becoming tedious. The researchers developed four distinct activities to facilitate the investigation's outcomes. Detailed information about the grade level of each activity is provided in Table 2.

**Table 2**

*Subjects and Grade Levels of Student Worksheets*

| Activity | Subject | Grade Level |
|---|---|---|
| 1 | Geothermal Energy | 6 |
| 2 | Nuclear Energy | 6 |
| 3 | Base Stations | 7 |
| 4 | Agricultural Pesticides | 7 |

Once the research subjects had been established, a selection of pertinent online news articles, videos, printed newspaper reports, and cartoons linked to the socioscientific issues in question was gathered. From this collection of data, the most suitable materials, tailored to the students' comprehension levels, were carefully chosen for inclusion in the research. An example activity plan can bee seen in Appendix 1.

**Control Group Activities**

At the outset of the study, the control group was subjected to the administration of scales designed to evaluate their perspective on socioscientific issues. Subsequently, socioscientific activities were introduced to the control group students. These activities comprised watching videos, utilizing PowerPoint presentations, and receiving traditional lectures. Following these presentations, a question-answer approach was employed, involving teacher-student interactions with the students. However, it's worth noting that argumentation activities were not integrated into the control group's curriculum. Given that the activities in the control group had a shorter duration compared to those in the experimental group, supplementary sessions were conducted to ensure that the subjects in the control group received equivalent exposure to the topics. The entire study spanned twelve class hours, spread across six weeks, with two class hours dedicated to the study each week. At the conclusion of the research, post-tests for the Socioscientific Issues Scale, Critical Thinking Scale, and Reflective Thinking Scale were administered to the students following the initial pre-tests conducted at the study's outset.

**Experimental Group Activities**

At the commencement of the study, the experimental group underwent pre-test assessments using the attitudes towards Socioscientific Issues Scale, Critical Thinking Scale, and Reflective Thinking Scale. Subsequently, the argumentation method was introduced to the students, along with instructions on how to engage in scientific discussions. The students were familiarized with Toulmin's argumentation model, and sample activities were conducted in alignment with this model. Once it was confirmed that the students had grasped this method, then predetermined argumentation activities were initiated.

Prior to launching into discussions, it was ensured that the students had been exposed to these topics beforehand, with a recap conducted in the form of question-and-answer sessions to prevent them from fading into obscurity. Subsequently, students were presented with engaging and concise introductions, such as short videos, cartoon films, newspaper articles, etc., before launching into discussions on the respective topics.

During these discussions, students were granted ample time and space to articulate their own viewpoints and were encouraged to persuade their peers while countering opposing perspectives. Students were prompted to incorporate Toulmin's elements (Claim, data, warrant, backing, qualifier, rebuttal) of scientific discussion into their arguments. Each week, a new activity was discussed, and the discussions held during these sessions were meticulously recorded.

At the culmination of this approximately six-week endeavor, the students underwent post-test assessments utilizing the "Attitudes Towards Socioscientific Issues," "Critical Thinking Scale," and "Reflective Thinking Scale." Following the completion of these assessments, the study was brought to a close.

**Data Collection Tools**

**Attitudes towards Socioscientific Issues Scale**

The study utilized the "Attitudes Towards Socioscientific Issues Scale" to assess the participants' perspectives on socioscientific issues. This scale, developed by Topçu in 2010, comprises three sub-dimensions and a total of 30 items. It employs a Likert-type format with five response options, including "1. Strongly Disagree," "2. Disagree," "3. Undecided," "4. Agree," and "5. Strongly Agree." Notably, nine items within the scale carry negative connotations, and thus, their coding was reversed, with "1" indicating "Strongly Agree" and "5" indicating "Strongly Disagree." The table below presents the sub-dimensions of the scale, along with the internal consistency reliability coefficient (Cronbach α) values, as well as the pre-test and post-test internal consistency reliability coefficient (Cronbach α) values acquired in the course of this study (Table 3).

**Table 3**

*Sub-dimensions and Internal Consistency Reliability Coefficient (Cronbach α) Values of the Scale of Attitudes towards socioscientific issues*

| Subdimension | Name of the subdimension | Cronbach α | Pretest Cronbach α | Post test Cronbach α |
|---|---|---|---|---|
| 1. Dimension | Benefits of SSI | 0,90 | 0,79 | 0,81 |
| 2. Dimension | Enjoying SSI | 0,81 | 0, 73 | 0,76 |
| 3. Dimension | Anxiety about SSI | 0,70 | 0,68 | 0,72 |

In this study, the internal reliability coefficients were assessed using Cronbach's alpha, with a pre-test value of 0.80 and a post-test value of 0.85 for the overall scale. When examining the sub-dimensions of the scale, the pre-test Cronbach alpha coefficient for the first sub-dimension (Benefits of SSI) was 0.79, the second sub-dimension (Enjoying SSI) was 0.73, and the third sub-dimension (Anxiety about SSI) was 0.68. Notably, the pre-test Cronbach alpha coefficient for the third sub-dimension, which pertains to anxiety towards socioscientific issues, fell slightly below the recommended threshold of 0.70, as suggested by Büyüköztürk (2015). It's important to consider that the confidence interval of a study is influenced by factors such as the sample size (Şencan, 2005). Thus, the lower pre-test coefficient for the third sub-dimension may be attributed to the relatively small sample size and the limited number of items included. In contrast, the post-test internal reliability coefficients showed improvement, with values of 0.81 for the first sub-dimension, 0.76 for the second sub-dimension, and 0.72 for the third sub-dimension, suggesting enhanced measurement consistency after the intervention.

### Reflective Thinking Scale

The participants' reflective thinking was assessed using the "Reflective Thinking Scale," which was developed by Yıldırım in 2012. This Likert-type scale employs a 5-point rating system with 17 items, offering response options that include "1. Strongly Disagree," "2. Disagree," "3. Undecided," "4. Agree," and "5. Strongly Agree." The scale is unifactorial, measuring a single factor. The highest attainable score on this scale is 85, while the lowest possible score is 17. In Yıldırım's (2012) original work, the Cronbach's α internal reliability coefficient for the scale was determined to be 0.86. For the pre-test in this study, the Cronbach's α internal reliability coefficient for the Reflective Thinking Scale was calculated as 0.79, and for the post-test, it was found to be 0.77. These coefficients indicate the degree of internal consistency for the scale in measuring reflective thinking among the participants in both the pre-test and post-test phases of the study.

### Critical Thinking Scale

The participants' critical thinking was evaluated using the "Critical Thinking Scale," which was developed by Görücü in 2014. This scale encompasses four sub-dimensions: communication, truth-seeking, self-confidence, and prejudice. It employs a 5-point Likert-type rating system with response options including "1. Strongly Disagree," "2. Disagree," "3. Undecided," "4. Agree," and "5. Strongly Agree." The highest achievable score on this scale is 85, while the lowest possible score is 17, with a midpoint score of 51. Görücü (2014) categorized scores as follows: 17-34 as very low, 35-50 as low, 51-68 as medium, and 69-85 as high. Notably, certain items (2, 4, 9, 11, and 12) in the scale are reverse or negative items, and their scores were reversed through recoding (1-5, 2-4, 4-2, and 5-1). In the original work by Görücü (2014), the

Cronbach's α internal reliability coefficient for the scale was reported as 0.70. In this study, the Cronbach's α internal consistency coefficient for the pre-test was calculated as 0.72, and for the post-test, it was determined to be 0.71. Here are the sub-dimensions of the Critical Thinking Scale along with the internal consistency reliability coefficient (Cronbach α) values for both pre-test and post-test measurements, as detailed in Table 4:

**Table 4**

*Sub-dimensions of Critical Thinking Scale and Internal Consistency Reliability Coefficient (Cronbach α) Values*

| Subdimension | Name of the subdimension | Cronbach α | Pretest Cronbach α | Post test Cronbach α |
|---|---|---|---|---|
| 1. Dimension | Communication | 0,46 | 0,65 | 0,63 |
| 2. Dimension | Seeking the truth | 0,58 | 0,68 | 0,66 |
| 3. Dimension | Self Confidence | 0,67 | 0,71 | 0,70 |
| 4. Dimension | Bias | 0,63 | 0,70 | 0,67 |

**Data analysis**

The data collected in this study were subjected to statistical analysis using specialized software. The predetermined significance level for the analysis was set at 0.05. As a preliminary step in the analysis, the normality of the test results was checked, taking into account the specified significance level. In this study, which had an experimental group consisting of 32 participants and a control group consisting of 31 participants, the Shapiro-Wilk test was employed to assess the normality of the data. The results of these tests indicated that the data obtained from the research followed a normal distribution. Consequently, parametric tests were deemed appropriate for this study. To compare the pre-test and post-test data obtained from both the experimental and control groups on three scales, the independent samples t-test was utilized. When examining the pre-test and post-test data within each group, the dependent samples t-test was applied. Additionally, effect size calculations were performed to quantify the magnitude of the differences between the groups. Effect size is a statistical measure that indicates the size of the expected differences between groups (Cohen, 1988).

**Validity and Reliability**

Validity and reliability are crucial considerations in a quantitative study, especially when employing a pretest-posttest experimental and control group design. To ensure the integrity of the scores, we took specific measures. For internal validity, we minimized confounding variables, employed random assignment to control extraneous variables, and addressed potential threats like history, maturation, or testing effects. To ensure construct validity we precisely defined and operationalized key variables. We explicitly detailed the measures for both pretest and posttest assessments, ensuring clarity. Additionally, we rigorously selected measurement tools, affirming their capacity to accurately capture intended constructs. These steps collectively enhance the construct validity of our study, affirming a robust alignment between our conceptualizations and the implemented measurements. We used transparent reporting by clearly describing the methods used to establish validity and reliability in the study to enhance transparency and replicability.

## Findings

The study aimed to investigate the impact of argumentation-based practices on thinking skills of 8th-grade students regarding socioscientific issues and their attitudes towards SSI. The findings obtained in the study were organized as sub-problems, and the analysis methodology was determined as follows.

**Findings Related to the First Sub-Problem:** Is there is a significant difference between the pre-test and post-test scores of the experimental group students on the 'Views on Socioscientific Issues Scale' after engaging in argumentation-based practices. The results obtained from the dependent sample t-test are presented in Table 5.

**Table 5**

*Experimental group students' pretest and posttest scores of views on Socioscientific Issues*

| | n | $\bar{x}$ | SD. | t | p |
|---|---|---|---|---|---|
| **Experimental Posttest** | 32 | 127.22 | 6.25 | 11.75 | .000 |
| **Experimental Pretest** | 32 | 100.66 | 11.53 | | |

The post-test (X=127.22, SD=6.25) and pre-test (X=100.66, SD=11.53) scores of the experimental group can be seen in Table 5, resulting in $t_{62}$= 11.75, p=.000. The calculated p-value being less than 0.05 led to the rejection of the null hypothesis, indicating a statistically significant difference between the experimental group's post-test and pre-test scores. The effect size, as measured by the difference between the means, was substantial, with a magnitude of 26.56. This difference in means was considered to have a large effect, as evidenced by an eta squared ($\eta^2$) value of 0.82.

**Findings Related to the Second Sub-Problem:** Is there a significant difference between the pre-test and post-test scores of the control group students on the 'Views on Socioscientific Issues Scale' ? The results obtained from the dependent t-test are presented in Table 6.

**Table 6**

*Control gorup students' pretest posttest scores of views on Socioscientific Issues*

| | n | $\bar{x}$ | SD | t | p |
|---|---|---|---|---|---|
| **Control Posttest** | 31 | 111.03 | 3.87 | 4.99 | .000 |
| **Control Pretest** | 31 | 100.32 | 11.88 | | |

The posttest (X=111.03, SD=3.87) and pre-test (X=100.32, SD=11.88) scores of the control group can be seen in Table 6, resulting in $t_{60}$= 4.99, p=.000. The calculated p-value being less than 0.05 led to the rejection of the null hypothesis, indicating a statistically significant difference between the control group's post-test and pre-test scores. The magnitude of the difference between the means was 10.71, signifying a substantial effect. This difference in means was considered to have a large effect, as reflected in the eta squared ($\eta^2$) value of 0.45.

**Findings Related to the Third Sub-Problem:** Is there a significant difference in the pretest and posttest scores of the experimental group students on the 'Reflective Thinking Scale' following argumentation-based practices. The results obtained from the dependent samples t-test for the scores of the experimental group students on the Reflective Thinking Scale before and after the experiment are presented in Table 7.

**Table 7**

*Experimental group students' pretest posttest scores of reflective thinking scale*

| | n | $\bar{x}$ | SD. | t | p |
|---|---|---|---|---|---|
| **Experimental Posttest** | 32 | 66.78 | 4.19 | 8.601 | .000 |
| **Experimental Pretest** | 32 | 54.81 | 6.05 | | |

The post-test (X=66.78, SD=4.19) and pre-test (X=54.81, SD=6.05) scores of the experimental group can be seen in Table 7, resulting in $t_{62}$= 8.601, p=.000. With the calculated p-value being less than 0.05, the null hypothesis was rejected, indicating a statistically significant difference between the experimental group's post-test and pre-test scores. The magnitude of the difference between the means was substantial, with a value of 11.97. This difference in means was considered to have a large effect, as evidenced by an eta squared ($\eta^2$) value of 0.70.

**Findings Related to the Fourth Sub-Problem:** Is there a significant difference between the pre-test and post-test scores of the control group students on the 'Reflective Thinking Scale'?

The dependent sample t-test results of the scores obtained by the control group students from the reflective thinking scale before and after the study are presented in Table 8.

**Table 8**

*Control group students' pretest posttest scores of reflective thinking scale*

| | n | $\bar{x}$ | SD. | t | p |
|---|---|---|---|---|---|
| **Control Posttest** | 31 | 59.98 | 3.81 | 1.351 | .672 |
| **Control Pretest** | 31 | 58.68 | 4.52 | | |

The post-test (X=59.98, SD=3.81) and pre-test (X=58.68, SD=4.52) scores of the control group can be seen in Table 8, resulting in $t_{60}$= -.292, p=.672. The calculated p-value, being greater than 0.05, led to the acceptance of the null hypothesis. Therefore, it was observed that there was no significant difference between the control group's post-test and pre-test data.

**Findings Related to the Fifth Sub-Problem:** Is there a significant difference between the pre-test and post-test scores of the experimental group students on the 'Critical Thinking Scale' subsequent to argumentation-based practices.

The dependent t-test results of the scores obtained by the experimental group students who engaged in argumentation-based socioscientific activities from the critical thinking scale before and after the experiment are presented in Table 9.

**Table 9**

*Experimental group students' pretest posttest scores of critical thinking scale*

| | n | $\bar{x}$ | SD. | t | p |
|---|---|---|---|---|---|
| **Experimental Posttest** | 32 | 60.63 | 5.14 | -2.755 | .010 |
| **Experimental Pretest** | 32 | 56.50 | 6.72 | | |

The post-test (X=60.63, SD=5.14) and pre-test (X=56.50, SD=6.72) scores of experimental group can be seen in Table 9 resulting in $t_{62}$= -2.755, p=.010. With the calculated p-value being less than 0.05, the null hypothesis was rejected, indicating a statistically significant difference between the experimental group's post-test and pre-test scores. The magnitude of the difference between the means was substantial, with a value of 4.13 in favor of the experimental group. This difference in means was considered to have a large effect, as evidenced by an eta squared ($\eta^2$) value of 0.20

**Findings Related to the Sixth Sub-Problem:** Is there a significant difference between the pre-test and post-test scores of the control group students on the 'Critical Thinking Scale' ? The results of the dependent sample t-test regarding the significance of the difference between the pre-test and post-test scores of the 8th-grade students in the control group in terms of their critical thinking awareness are presented in Table 10.

**Table 10**

*Control group students' pretest posttest scores of critical thinking scale*

| | n | $\bar{x}$ | SD. | t | p |
|---|---|---|---|---|---|
| **Control Pretest** | 31 | 58.48 | 6.06 | -.911 | .369 |
| **Control Posttest** | 31 | 56.94 | 6.19 | | |

The post-test (X=56.94, SD=6.19) and pre-test (X=58.48, SD=6.06) scores of control group can be seen in Table 10, resulting in $t_{60}$= -0.911 and p=0.369. As the calculated p-value was greater than 0.05, the null hypothesis was accepted. Therefore, it was concluded that there was no statistically significant difference between the control group's post-test and pre-test data.

## Discussion

This study aimed to investigate the impact of teaching socioscientific issue-based science activities using the argumentation method on the cognitive abilities of elementary school students. To achieve this goal, the research assessed students' attitudes towards socioscientific issues, reflective thinking skills, and critical thinking skills before and after the intervention, and compared the mean scores between the experimental and control groups. The findings regarding the first research question indicate that students in the experimental group developed a more positive attitudes towards socioscientific issues following the intervention. Argumentation-based practices, which encourage open discussion and critical thinking, are particularly effective in addressing socioscientific issues in the classroom (Topçu & Atabey, 2017). These practices provide students with opportunities to engage in meaningful discussions about real-world issues, making science education more relevant and engaging (Sadler, 2004). The literature also emphasizes the use of socioscientific scenarios in argumentation practices, as they relate to everyday life and can enhance students' interest, moral values, and motivation in the subject (Topçu, Atabey, & Çiftçi, 2018). Consequently, the present study expectedly observed a positive change in the post-test results of students in the experimental group who engaged in socioscientific scenarios using the argumentation method. Overall, integrating socioscientific argumentation into science education contributes to the development of scientifically literate individuals.

Regarding the second research question, the analysis revealed that students in the control group also developed a more positive attitudes towards socioscientific issues after the intervention. Discussing socioscientific issues in the classroom environment tends to increase students' motivation and interest in the subject (Albe, 2008). Previous research by Gülhan (2012) and Kaya (2019) also demonstrated that teaching socioscientific issues in the classroom enhances students' interest in these topics. Additionally, addressing socioscientific issues that are closely related to students' daily lives and frequently encountered in society can further boost their interest in these topics (Khishfe, 2012). In this study, the choice of socioscientific issues that students regularly encounter in their daily lives contributed to the control group students' increased interest. Furthermore, the fact that these topics are subjects of ongoing public discourse and debate likely heightened the students' engagement. These results support the notion that systematic integration of socioscientific issues into the learning environment can lead to positive attitudes and greater incorporation of these issues into students' lives.

It was observed that the increase in the interest of control group students towards socioscientific issues was not as pronounced as that of the experimental group students. This discrepancy can be attributed to the fact that control group students did not have the opportunity to engage in argumentation-based practices. It is natural that students in the control group, lacking experience in argumentation, did not experience the same level of development in their perspectives on socioscientific issues as their counterparts in the experimental group. Therefore, these findings suggest that addressing socioscientific issues in the classroom environment alone may have limitations in terms of its impact.

The analysis conducted to address the third research question revealed a significant improvement in the reflective thinking skills of the experimental group students after the application. This suggests that addressing socioscientific issues in the classroom environment using the argumentation method had a positive impact on students' reflective thinking skills.

Reflective thinking can be understood as a problem-solving approach where ideas are systematically organized, connecting each new idea to prior knowledge in order to find solutions (Alp & Taşkın, 2008). Students engaged in reflective thinking actively participate in the learning process through argument development. They critically evaluate information, support their ideas with evidence, engage in rebuttals, and effectively apply their learning to real-life situations (Erduran & Jimenez Aleixandre, 2007). The argumentation method encourages students to question, accept, and challenge information actively, facilitating meaningful learning experiences (Aslan, 2009). Discussing socioscientific issues in the classroom, particularly through scenarios that connect to students' daily lives, brings real-world relevance into the learning environment, enhancing students' experiential learning (Güngörmez, Akgün, & Duruk, 2016).

In this study, students' reflective thinking skills notably improved through discussions of socioscientific issues like global warming, pesticides, and base stations—topics relevant to their daily lives. Güngörmez et al. (2016) similarly found that scenario-based learning enhanced students' reflective thinking skills. However, it's worth noting that Karaca (2018), in a study on the effects of science education based on socioscientific issues using a constructivist approach with 7th-grade students, did not observe significant improvements in reflective thinking skills. Consequently, this research is significant in demonstrating the positive impact of socioscientific argumentation on students' reflective thinking abilities.

The analysis conducted to address the fourth research question reveals that there was only a minimal increase in reflective thinking among the control group students after the application, and their mean scores exhibited slight differentiation, albeit not statistically significant. This finding aligns with the study conducted by Öz (2019) on the application of an argumentation-based learning approach in the context of triangles, which also found no significant difference between the pre-test and post-test results of control group students' reflective thinking.

Reflective thinking involves the process of recalling experienced information, engaging in critical thinking about this information, evaluating it, and applying it to real-life situations (Atay, 2003). As this definition suggests, it is crucial for students to encounter real-life problems to develop reflective thinking skills effectively. Socioscientific issues, being dilemmatic topics with multiple perspectives and no single answer, frequently arise in daily life (Sadler & Zeidler, 2005). Discussing such issues in the classroom environment plays a pivotal role in fostering reflective thinking skills. Through these discussions, students actively engage in the learning process and cultivate their ability to approach problems from various angles (Yalçın, 2018).

The analysis conducted for the fifth research question reveals that the application of socioscientific argumentation significantly improved the critical thinking skills of the experimental group students. This finding is supported by Şahin (2016), who investigated the impact of an argumentation-based science learning approach on the academic achievement, metacognition, and critical thinking skills of gifted students, concluding that critical thinking skills notably increased among the experimental group. Similarly, Karakaş (2018) reported similar outcomes in his study, which explored the effects of argumentation-based teaching on the critical thinking, academic achievement, and argumentation skills of pre-service primary school teachers.

Critical thinking, as defined by Ennis (1993), involves individuals making informed decisions using logic and reflective thinking skills. To foster these skills, students need to experience uncertainty and engage in activities that require them to make claims, provide evidence, justify their positions, challenge opposing views, and analyze contrary ideas (Snyder & Snyder, 2008; Akbıyık, 2002). Therefore, teaching socioscientific issues characterized by their complex, dilemmatic nature and inherent uncertainty through argumentation methods—where students present claims, offer evidence, engage in reasoned discourse, and question ideas—is expected to enhance critical thinking skills. In this study, socioscientific scenarios were explored using argumentation methods in the experimental group. During these discussions, students sought evidence to support their positions, shared their viewpoints with peers, analyzed opposing perspectives, and attempted to counter opposing arguments. As a result, it is not surprising that the socioscientific argumentation approach led to a significant improvement in the critical thinking skills of the experimental group students.

The analysis conducted for the sixth research question revealed that there was no significant difference between the pre-test and post-test scores of the control group students on the critical thinking scale. Additionally, it was observed that the post-test scores for critical thinking were slightly lower than the pre-test scores, although this decrease was not statistically significant. This finding aligns with numerous studies in the literature. For example, Sevgi (2016), in her master's thesis study investigating the impact of discussing socioscientific issues featured in newspaper articles using the argumentation method on the critical thinking skills of seventh-grade students, found that there was no significant difference between the pre-test and post-test data of the control group students' critical thinking skills. Koçak (2014) obtained similar results in his study, which investigated the effects of an argumentation-based science learning approach on critical thinking disposition.

## Suggestions

- Research Design: This study employed a quantitative research design for a one-semester application. Future research endeavors should consider a more holistic approach and delve deeper into the subject matter by incorporating qualitative methodologies. This approach can provide a different perspective and yield more comprehensive findings.
- Duration of Study: The research was conducted over a total of 12 lesson hours, with 2 hours per week over a 6-week period. It is worth considering that this duration may not be sufficient for students to fully embrace the argumentation model. Future studies should explore longer-term implementations to better assess the effectiveness of this approach.
- Selection of Socioscientific issues: The study revealed that students displayed more interest in socioscientific issues relevant to their daily lives. It is advisable that future studies focus on socioscientific issues that students can readily relate to within their own environments.
- Teacher Training: Effective implementation of the argumentation method relies on well-prepared teachers. Future research should include teacher training programs to enhance their ability to successfully apply this method in the classroom setting.
- Sustainability: To gain a more comprehensive understanding of the enduring effects of argumentation-based socioscientific education, it is recommended that long-term follow-up studies be conducted. These studies can shed light on the sustainability of the observed effects on students over time.

## Limitations

- Sampling and Generalization: The research was confined to a specific school, which restricts the generalizability of the findings to students in other educational institutions. The sample comprised students from a singular school, and thus, it did not encompass a diverse range of regions or school types.
- Time Constraints: Due to the study's limited timeframe of 6 weeks, the assessment of the effects of a more extended educational program was unattainable. Future research conducted over a more extended period could provide deeper insights into how results evolve over time.
- Voluntary Participation: The study relied on the voluntary participation of students, potentially introducing limitations regarding the applicability of the results to the broader student population. The unique interests and motivations of the participants may have influenced the outcomes.

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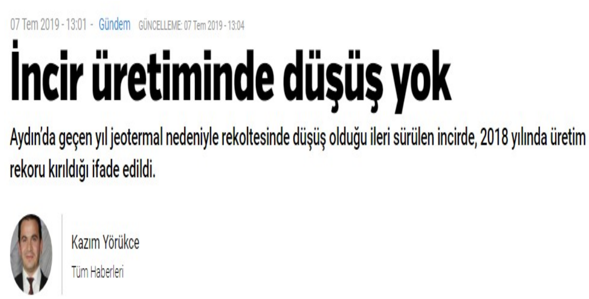
**Appendix 1**
**Geothermal Energy**


Aydın; The city where oil flows from its mountains and honey from its plains. Famous for its history, tourism, agriculture and high temperatures, Aydın, the land of efes, has recently been making a name for itself with debates in the media instead of these unique features. In addition to the high temperatures of the underground waters and the hot summer sun on the earth, Aydın has recently been scorched by the heated debates of its citizens. The province, which has many geothermal plants due to its abundant hot

water resources, wants to establish more geothermal power plants. While some of the people support these plants, others oppose them. Now let's watch together why people are discussing the establishment of geothermal power plants. (Two videos about GEPPs in Aydın, two in favor of GEPPs and two against GEPPs are shown.)
You are also citizens living in Aydın. The establishment of geothermal power plants in the region where you live is being discussed and your fellow citizens have different reactions to the establishment of geothermal energy. How would you react to the establishment of geothermal energy?
Claims:
Data:
Warrant:
Backing:
Rebuttals: