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# THE EFFECT OF ONLINE ARGUMENTATION AND REFLECTIVE THINKING-BASED SCIENCE TEACHING ON SIXTH GRADERS' COGNITIVE ABILITIES

**Ömer Acar,**
**Zeynep Azaklı**

**Abstract.** *The effect of online argumentation and reflective thinking-based science teaching on sixth-grade students' epistemic cognition, metacognition, and logical thinking was explored in this study. The research was carried out in the 2020-2021 academic year when all teaching was online due to Covid-19. Students in the study sample were mostly from middle-class families. Students were divided into two groups for one semester; one received online argumentation and reflective thinking-based science teaching (experimental group) whereas the other received only online science teaching (control group). The exploratory factor analyses yielded two factors for epistemic cognition and metacognition questionnaires whereas the logical thinking test was found to be unidimensional. According to the results, experimental group students scored higher than control group students in post-test regulation of cognition and logical thinking. In addition, the experimental group developed knowledge of cognition, regulation of cognition, and logical thinking during the intervention. Although the experimental group scored higher than the control group on the set of post-test epistemic cognition factors, this significance did not appear amongst individual factors. As for the implications of this study, elements of distance learning that may have contributed to the development of students' cognitive abilities were discussed.*
**Keywords:** *argumentation-based teaching, distance learning, epistemic cognition, logical thinking, reflective thinking*

**Ömer Acar, Zeynep Azaklı**
*Kocaeli University, Türkiye*

## Introduction

The importance of constructing sound arguments for reaching evidence-based conclusions in informal contexts as well as in scientific disciplines has been stressed in informal logic (Toulmin, 1958). The reflection of this philosophy in science classes, as well as the poor reasoning of students (Jimenez-Aleixandre et al., 2000; Watson et al., 2004; Zeidler, 1997), led to the adoption of the argumentation teaching approach. Consequently, developing argumentation skills has become an important aim of science teaching (e.g., Milli Eğitim Bakanlığı, 2017; Next Generation Science Standards (NGSS) Lead States, 2013; Osborne et al., 2004). Constructing evidence-based arguments has even been included in the definitions of scientific literacy and scientific competency in student assessment programs (e.g., The Organisation for Economic Co-operation and Development, 2016).

Researchers have integrated the teaching of argumentation into wider science teaching and examined its effect on several student-level cognitive variables. Initially, encouraging results have been reported regarding the development of argumentation abilities (McNeill et al., 2006; Sandoval & Millwood, 2005), and scientific conceptual knowledge (e.g., McNeill et al., 2006; Zohar & Nemet, 2002). Later researchers explored the effect of teaching argumentation skills on other student-level cognitive variables, which are also important in science education, such as epistemic cognition, metacognition, and logical thinking. These studies have reported positive effects on epistemic cognition (Iordanou, 2016; Klopp & Stark, 2022; Ryu & Sandoval, 2012; Zeidler et al., 2009), metacognition (Iordanou, 2022), and logical thinking (Acar, 2014, 2015; Lavoie, 1999).

Although it can be inferred that argumentation processes automatically include the use of metacognitive strategies (see Leitão, 2007), Armstrong et al. (2008) found that few college students benefitted from using their metacognitive skills in writing reasoned arguments. In fact, Hoffmann (2016) stated that reflection was necessary for qualified argument and reasoning. In line with these findings, further studies have shown that reflective thinking aided argumentation teaching helped students develop more sophisticated arguments and achieve higher levels of metacognition (Felton, 2004; Hsu & Lin, 2017; Iordanou, 2022, Shi, 2019).



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*Relation of Argumentation-Based Teaching with Students' Epistemic Cognition, Metacognition, and Logical Thinking*

Since one should use sufficient and robust evidence to support a conclusion in a qualified argument (Sandoval & Millwood, 2005), epistemic cognition related to the justification of knowing may be fostered implicitly in argumentation-based learning environments (Osborne et al., 2013). Moreover, for a quality argumentation process, alternative explanations should be taken into account (Osborne et al, 2004). Consequently, epistemic cognition related to certainty of knowledge and justification and source dimensions of knowing may be enhanced implicitly in argumentation-based teaching. However equivocal results were found with regard to the influence of argumentation-based teaching on students' epistemic cognition. More clearly, several studies found a positive effect (Acar, 2016; Kuhn, 2010) while others found no effect of argumentation-based teaching (Osborne et al., 2013; Sandoval & Morrison, 2003) on students' epistemic cognition. These inconsistent results may be related to the nature of argumentation-based teaching and the duration of the intervention applied in these studies.

Although the argumentation process, in the form of supporting a point of view, considering other alternatives and responding to these alternatives, may place the arguer in a metacognitive framework implicitly (Leitão, 2007) and consequently one can expect the development of metacognitive skills during argumentation, research findings do not support this assumption. More clearly, it has been stressed that argumentation-based teaching should be supported by an explicit emphasis on students' metacognitive skills to develop both their metacognitive skills and argumentation (Armstrong et al., 2008; Iordanou, 2022). Indeed, integrating metacognitive guidance into argumentation-based teaching was found to be more effective in students' metacognition and argumentation (Felton, 2004; Hsu & Lin, 2017, Moshman, 1995).

Scientific reasoning, which was originally named logical thinking by Inhelder and Piaget (1958) and later scientific reasoning by Lawson (2000), can be developed through argumentation only if an elaborate effort to define evidence, justification, and conclusion is made explicitly (Garcia-Mila & Andersen, 2007). In fact, one constructs a hypothesis, generates evidence, and tests this hypothesis in scientific argumentation and these same processes are also common to scientific reasoning (Lawson, 2010). However, as Omarchevska et al. (2022) and Lawson (2003) stressed, one should self-regulate scientific reasoning for a qualified argumentation. Therefore, learning environments should incorporate metacognitive thinking about scientific reasoning for students to develop both their argumentation and scientific reasoning. Results of the studies that utilize competing theories teaching strategy, in which students are encouraged to think about which evidence and justifications they would use to support an argument, as well as being used to construct a rebuttal for alternative explanations, are encouraging for the enhancement of students' logical thinking skills (Acar, 2014, 2015; Lavoie, 1999).

*Argumentation-Based Science Teaching in Distance Education*

After a literature review, studies of argumentation-based teaching used in distance education were grouped into two categories. The first one was divided by the design of the study being naturalistic or interventional in nature. Thus, if the purpose of the research was to examine the argumentation quality of students during online argumentation-based teaching, it was categorized as a naturalistic study. In contrast, if a study examined the effect of online argumentation-based teaching on the cognitive characteristics of students, it was grouped as an interventional study. Studies were further categorized by the type of online argumentation-based teaching, whether it was synchronous or asynchronous.

A study by Puig et al. (2021), which was a naturalistic study, examined secondary students' arguments which they constructed for assessing information related to the news headlines about Covid-19. These authors found that participants were able to determine if a headline was true or false by applying several epistemic criteria. However, participants' assessments of headlines were found to be in the lower levels of the epistemic assessment hierarchy (Puig et al., 2021).

All the interventional studies found in the literature examined the effect of an online argumentation-based learning environment on students' arguments. However, only Yang et al. (2015) and Yeh and She (2010) also examined the effect of argumentation-based teaching on students' conceptual knowledge and inquiry skills. Furthermore, all student participants in these studies were eighth-grade students with the exception of a study by Lin et al. (2012) who used college students. Results of these studies showed that online synchronous or asynchronous argumentation-based


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learning environment had a positive effect on the quality of students' argumentation (Clark & Sampson, 2007; Lin et al., 2012; Tsai, 2015; Yang  et al., 2015; Yeh & She, 2010). In addition, Yeh and She (2010) reported a significant effect following online synchronous argumentation-based teaching on eighth-grade students' conceptual knowledge. Lin et al. (2012) examined the effect of reflective asynchronous online communication intervention on argumentation skills in comparison to asynchronous paper-pencil written argumentation intervention and found that students experiencing the former intervention outperformed their counterparts receiving the latter.

Yang et al. (2015) and Yeh and She (2010) performed studies which implemented online synchronous argumentation-based teaching.  In contrast, Clark and Sampson (2007) and Tsai (2015) utilized online asynchronous argumentation-based teaching. Finally, Lin et al. (2012) utilized both types of online argumentation-based teaching. Oral or written argumentation was fostered in these studies either synchronously or asynchronously. Furthermore, students' reflection on the argumentation process was encouraged in several studies (e.g., Lin et al., 2012; Tsai, 2015; Yang  et al., 2015). Despite these methodological differences, the results of these studies were consistent with the development of students' argumentation skills during instruction.

From these literature findings, the following inferences can be made. Interventional studies which sought the effect of online argumentation-based teaching did not include epistemic cognition, metacognition, and logical thinking as their dependent variables. In addition, there is a paucity of studies, which used both synchronous and asynchronous argumentation-based teaching and also integrated reflective thinking to foster students' oral and written argumentation.

*Problem Statement*

The effect of argumentation teaching on several cognitive variables, including epistemic cognition, metacognition, and logical thinking was explored in face-to-face learning environments (e.g., Acar, 2016; Iordanou, 2016, 2022; Lavoie, 1999). Positive results were found regarding the development of these skills. Although few studies aimed to examine the effect of online synchronous and asynchronous argumentation-based teaching on students' cognitive abilities, these studies mainly sought the effect of this kind of teaching on students' arguments and argumentation (e.g., Clark & Sampson, 2007; Lin et al., 2012; Tsai, 2015; Yang et al., 2015; Yeh & She, 2010). However, these studies did not examine specifically the relation of either synchronous or asynchronous online argumentation teaching with students' epistemic cognition, metacognition, and logical thinking. The occurrence of the Covid-19 pandemic, which has forced most teaching to go online and has made face-to-face instruction unusual, together with a general trend towards the use of online learning environments in recent years to supplement face-to-face learning, has made an exploration of the effect of online argumentation teaching on students' science learning important and would close an important gap in the literature. In addition, few studies integrated reflective thinking with argumentation intervention (e.g., Felton, 2004; Hsu & Lin, 2017; Iordanou, 2022; Shi, 2019), despite the fact that teaching that integrated reflective thinking helped students develop more sophisticated arguments (Hoffmann, 2016). Furthermore, earlier studies in this field did not include junior grade levels in middle school in their research samples. Needless to say, it is important to encourage reflective thinking and argumentation among students earlier in schooling so that these students will be able to form a more sound foundation of metacognitive thinking and argumentation in the future (Zohar & Barzilai, 2013). Therefore, the purpose of the present study was to explore the effect of online argumentation and reflective thinking-based science teaching on sixth graders' epistemic cognition, metacognition, and logical thinking. Accordingly, the following research question was explored:

Does online argumentation and reflective thinking-based science teaching, which has both synchronous and asynchronous components, have an effect on sixth graders' epistemic cognition, metacognition, and logical thinking?

## Research Methodology

*Research Design*

Since the aim of this study was to examine the effect of the intervention on students' cognitive abilities and random assignment of the study sample to control and experimental groups could not be done, a pre-test post-test non-equivalent control group research design was utilized (Wiersma, 1991).


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*Participants*

This research was conducted in a district of a metropolitan city in Turkey during the first semester of the 2020-2021 academic year when all lessons were taught online due to Covid-19. Participants were sixth graders attending a state school and students at this school were mostly from middle-class families. In addition, these students generally had a moderate science achievement level compared to the achievement level of students in other schools in the same district.

Two classes, which were taught by the second author with eight years of teaching experience, formed the experimental group. The control group consisted of two other classes, which were taught by two teachers. These teachers had teaching experience of 15 and 19 years. The teacher of the experimental group completed a graduate course on teaching argumentation, which consisted of three hours per week throughout a semester before the study started. Neither of the control group teachers had completed a course on argumentation pedagogy. As part of the intervention implemented in the experimental group, students performed argumentation activities outside of online lessons. Control group students also had science assignments which were not related to argumentation and had to be done outside of the online class period. Although there were a total of 78 students in the experimental and 77 students in the control group at the beginning of the semester, four students in the experimental and three students in the control group were excluded from the final sample since these students did not complete all the research instruments. Consequently, 74 students remained in each group in the final sample of which 35 girls and 39 boys were in the experimental, and 33 girls and 41 boys were in the control group.

Ethical approval of this research was obtained from a university's research ethics committee. Before the study took place, the research aim was explained to students. In addition, it was emphasized that participation in this research would be on a voluntary basis and that participation would not affect their grades. Finally, written consent forms from their parents were obtained.

*Intervention*

Three units were covered during the study period. These units were related to the solar system, systems in the human body, and force and motion. Twelve weeks were spent teaching these units. Toulmin's argument pattern (TAP) (Toulmin, 1958) was introduced to the experimental group in the first online lesson of the semester. In this lesson, the components of TAP and examples of a good and a bad argument according to TAP were introduced. In the following online lessons, students were fostered to use TAP for their reasoning in class discussions. In addition, 17 argumentation activities were constructed for these three units. Argumentation strategies, such as competing theories, table of statements, and predict-observe-explain (POE) were used in the construction phase of these activities (Osborne et al., 2004). In activities utilizing the competing theories strategy, two or more alternative explanations about a phenomenon were given to students. Fact cards were also given to students for them to use in their arguments. Then, students were asked to state their arguments along with their counterarguments and rebuttals. Several statements about a phenomenon were provided to students in the table of statements strategy. Then they were asked if these statements were true or false and indicated reasons for their responses. Students were given a phenomenon, several alternative explanations about this phenomenon, and an explanation of an experiment in POE strategy. First, students were asked which alternative explanation they agreed with and why (prediction) concerning the scientific mechanism underlying the example phenomenon. Then they made observations by doing experiments personally at home (observe). Finally, they were asked which claim fitted the observation best, state a counter-argument for the wrong alternative explanation, rebut the alternative explanation and make an explanation in which they compared their prediction with their observations (explanation). The Google Classroom learning platform was used to send the argumentation activities to students. Students also used this platform to return their assignments. After each activity was finished, a class discussion was held lasting about 10 minutes out of 30 minutes of a class period synchronously asking students to state their arguments, counter-arguments, and warrants. On the other hand, although control group students also had assignments which had to be done outside the online teaching, these assignments were not related to argumentation but included practices about the science content covered during each week. In addition, the control group did not receive any argumentation-based teaching during online classes.

Experimental group students were required to respond to reflective questions about their learning after each class. In contrast, the control group students did not make any activity related to reflective thinking during the study period. Reflective questions posed to experimental group students were about how they felt about their science


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learning in each class period, if they had any difficulty understanding the lesson content, and what learning strategies they would have used to overcome these difficulties. Again, the Google Classroom platform was used to send these questions. These questions were given as an assignment and students had to send their responses using the same medium at the end of each week during the study period.

### *Data Collection*

An epistemological beliefs questionnaire, a metacognitive awareness inventory, and a test of logical thinking were administered as pre- and post-tests by using Google Forms. Students were informed before about the time and duration of each administration. The teacher of the experimental group tracked the flow of students' submission of the instruments and closed access to the link when the duration of the instrument was finished. Each instrument was administered on a different day. This process was identical to the pre-and post-test administrations of instruments.

### *Study Variables*

#### *Epistemic cognition*

Students' epistemic cognition was assessed by a questionnaire, developed by Schommer-Aikins et al. (2005) which was then adapted to Turkish by Topcu and Yilmaz-Tuzun (2007). Although Schommer-Aikins et al. (2005) termed this psychological construct as epistemological beliefs, more recently researchers in this field have preferred the term epistemic cognition (e.g., Greene & Seung, 2014; Hofer, 2016). There were 30 items in this questionnaire having a 5-point Likert type scale. Schommer-Aikins et al. (2005) performed exploratory factor analysis (EFA) on middle school students' data from this questionnaire and found four factors. However, the authors stated that only two epistemic cognition factors reached minimal psychometric standards, defined as having a minimum of .55 for Cronbach's alpha and having at least three items.

In common with earlier research, 12 items that had a sophisticated epistemic meaning were reverse coded. Accordingly, receiving a higher score on the questionnaire meant having a more naïve belief. Reliability analyses of responses to post-test administration of this questionnaire resulted in a lower Cronbach's alpha value which was .48. Nine items were detected which did not contribute to this alpha level. When these items were removed, Cronbach's alpha was recalculated as .67. Before performing EFA, Bartlett's sphericity test and Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) were scrutinized. Statistics for Bartlett's test was 1072.16 ($p < .001$) and KMO was .80. These results provided justification for conducting EFA. Then, EFA was performed for the remaining 21 items. A Scree plot showed a sharp decrease between the Eigenvalues of the second and third factors. Therefore, a second EFA was performed for two factors. Varimax rotation was performed and factor loadings lower than .30 were omitted which has been used as a cut-off value for obtaining more reliable items within each factor (e.g., Andreu, 2022). As a result, 12 items were loaded on the first factor and 9 items were loaded on the second factor. Cronbach's alpha values of these factors were .86 and .79, respectively. When items loading to each factor were examined in detail, it was realized that items of the first factor were associated with the speed of one's learning and items of the second factor were associated with the variability of one's ability (see Schommer-Aikins et al., 2000). Similar to earlier studies, the first factor was named quick learning and the second factor was named fixed ability. Factor loadings obtained from EFA were used to compute the composite factor scores for pre-and post-test. Sample items loading to each factor are shown in Table 1.

**Table 1**
*Epistemic Cognition Factors and Sample Items*

| Factor name | Sample items |
|---|---|
| Quick learning | If I can't understand something right away, I will keep on trying. * |
| | If I find the time to re-read a textbook chapter, I get a lot more out of it the second time. * |
| Fixed ability | The really smart students don't have to work hard to do well in school. |
| | Working hard on a difficult problem only pays off for really smart students. |

* Items were reverse coded


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*Metacognition*

Students' metacognitive awareness was assessed by an inventory developed by Sperling et al. (2002). This inventory was specifically developed for assessing sixth to ninth-graders' metacognition and consisted of 18 items with a 5-point Likert scale. The Turkish adaptation of the instrument by Topçu and Yılmaz-Tüzün (2009) was administered. Both Sperling et al. (2002) and Topçu and Yılmaz-Tüzün (2009) identified two factors, namely knowledge of cognition and regulation of cognition, based on the results of EFA of the responses of middle school students to this inventory.

Initially, Bartlett's test and KMO were examined. Statistics for Bartlett's test was 838.48 ($p < .001$) and KMO was .88. These statistics provided justification for performing EFA. As a result of the first EFA, two factors were identified according to the Eigenvalues obtained from a scree plot of the factors. Consequently, a second EFA was run with two factors using varimax rotation and eliminating factor loadings lower than .30. The result of this analysis showed 10 items loading to the first factor and 8 items loading to the second. After examination of items of each factor and also inspired by previous research, these factors were named regulation of cognition and knowledge of cognition, respectively. Cronbach's alpha values of these factors were .85 and .73, respectively. Table 2 shows sample items for each factor that had higher loadings.

**Table 2**
*Metacognition Factors and Sample Items*

| Factor name | Sample items |
|---|---|
| Regulation of cognition | I ask myself if I have considered all options when solving a problem |
| | I ask myself if there was an easier way to do things after I finish a task |
| Knowledge of cognition | I learn best when I already know something about the topic |
| | I am a good judge of how well I understand something |

*Logical Thinking*

The logical thinking test, which was developed by Tobin and Capie (1983), was used for assessing students' logical thinking. The Turkish adaptation of this test, by Geban et al. (1992), was applied in the present study. There were eight two-tier and two open-ended test items in this instrument. Two-tier questions assessed reasoning skills related to controlling variables, proportion, correlation, and probability, while the open-ended items assessed combinatorial reasoning. In the two-tier questions, students first needed to select the right choice for reasoning that was in the question (first tier) and then select the reason for the selected response (second tier). In order for a student to obtain a full score on a two-tier question, he/she should have responded to both tiers correctly. Moreover, the student needed to have written complete combinations to get full credit on open-ended items which were about combinatorial reasoning. When students' responses were coded according to these criteria, Cronbach's alpha was .73 for the post-test.

## Research Results

### *Epistemic Cognition*

Descriptive statistics of control and experimental group students' epistemic cognition scores are shown in Table 3. Multivariate analysis of variance (MANOVA) was conducted both on student epistemic cognition pre-and post-test factor scores for examination of any difference between the groups. Results of the first MANOVA on pre-test scores showed no group difference ($F$ (2, 145) = 2.26, $p > .05$). In contrast, post-test MANOVA analysis showed that the two groups scores differed ($F$ (2, 145) = 4.52, $p < .05$, $\eta^2 = .06$). However, results of follow-up ANOVA showed that groups' post-test scores were not different for either quick learning ($F$ (1, 146) = 3.86, $p > .05$) or fixed ability ($F$ (1, 146) = 2.75, $p > .05$).


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To compare each group's epistemic cognition change during the intervention, pair-wise *t*-tests were run for the quick learning and fixed ability factors. Results showed that the control group's scores did not change significantly, for either quick learning ($t$ (73) = -0.55, $p > .05$) or fixed ability ($t$ (73) = -0.51, $p > .05$). Similarly, results for the experimental group showed no significant change for quick learning ($t$ (73) = -1.24, $p > .05$) and fixed ability ($t$ (73) = -0.72, $p > .05$).

**Table 3**
*Descriptive Statistics for Epistemic Cognition Factors*

| Factor Name | Group | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | *M* | *SD* | *M* | *SD* |
| Quick learning | Control | 18.28 | 5.26 | 17.92 | 5.74 |
| | Experimental | 17.17 | 5.16 | 16.13 | 5.32 |
| Fixed ability | Control | 15.68 | 3.91 | 15.42 | 4.12 |
| | Experimental | 14.76 | 4.31 | 14.24 | 4.49 |

*Metacognition*

The groups' mean and standard deviation scores for metacognition factors are shown in Table 4. MANOVA was conducted separately for pre-and post-test scores. Results of the first MANOVA demonstrated that metacognition factors' pre-test scores of the control and experimental groups did not differ ($F$ (2, 145) = 0.44, $p > .05$). In contrast, MANOVA performed on post-test scores identified a difference between the groups ($F$ (2, 145) = 2.90, $p < .05$, $\eta^2 = .04$). Follow-up ANOVA identified the difference to be present in regulation of cognition ($F$ (1, 146) = 4.92, $p < .05$, $\eta^2 = .03$) but not in knowledge of cognition ($F$ (1, 146) = 0.69, $p > .05$). The difference in scores obtained in post-test regulation of cognition factors favored the experimental group (see Table 4).

For comparing the change in metacognition scores during instruction, pair-wise *t*-test analysis was performed separately for control and experimental groups. Results of these analyses in the control group showed that neither regulation of cognition nor knowledge of cognition scores changed significantly during the study period ($t$ (73) = 0.81, $p > .05$; $t$ (73) = 1.65, $p > .05$, respectively). However, both the regulation of cognition and knowledge of cognition scores had increased in the experimental group during this period ($t$ (73) = 2.79, $p < .01$, $r^2 = .10$; $t$ (73) = 2.02; $p < .05$, $r^2 = .05$, respectively).

**Table 4**
*Descriptive Statistics for Metacognition Factors*

| Factor names | Group | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | *M* | *SD* | *M* | *SD* |
| Regulation of cognition | Control | 22.61 | 4.46 | 23.07 | 3.92 |
| | Experimental | 23.29 | 4.31 | 24.43 | 3.53 |
| Knowledge of cognition | Control | 17.30 | 2.54 | 17.85 | 1.75 |
| | Experimental | 17.63 | 2.75 | 18.11 | 2.07 |


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*Logical Thinking*

A separate ANOVA was performed both for the pre-and post-test scores. The first ANOVA showed no significant pre-test difference between the groups ($F$ (1, 146) = 2.38, $p$ > .05). However, the result of the second ANOVA showed a significant group difference for the post-test ($F$ (1, 146) = 4.15, $p$ < .05; $\eta^2$ = .03). This post-test difference was in favor of the experimental group (see Table 5).

The change in each group's logical thinking scores was examined by pair-wise $t$-test analysis. According to the results, control groups' logical thinking scores did not change significantly ($t$ (73) = 1.50, $p$ > .05). Similar analysis for the experimental group showed a significantly higher post-test score (see Table 5, $t$ (73) = 5.51; $p$ < .001, $r^2$ = .29).

**Table 5**
*Descriptive Statistics for Logical Thinking*

| Group | Pre-test | | Post-test | |
|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** |
| Control | 1.69 | 1.60 | 2.02 | 1.60 |
| Experimental | 1.29 | 1.59 | 2.72 | 2.46 |

## Discussion

The results of this study support the use of online argumentation and reflective thinking-based science teaching to develop students' cognitive abilities. More specifically, this study showed that experimental group students surpassed their control peers in terms of regulation of cognition and enhanced both metacognition factors during the intervention. In addition, the experimental group scored higher than the control group on logical thinking after the intervention. Moreover, the results demonstrated that students in the experimental group improved their logical thinking skills after the intervention while the control group students did not. Finally, although the result of the MANOVA on the set of post-test epistemic cognition scores showed a significant difference in favor of the experimental group, this significance was not identified by follow-up ANOVA of epistemic cognition factors. However, the null hypothesis for quick learning scores was accepted with only a small difference in the significance level ($p$ = .051).

Based on the results for epistemic cognition, it is possible that if the intervention had been longer than one semester, the post-test epistemological differences between the groups would have been more significant. Osborne et al. (2013) found no significant result regarding epistemic cognition in favor of the experimental group who had received two years of face-to-face argumentation intervention. The authors suggest that this may have been due to minimal support provided to the experimental group teachers during the professional development of argumentation pedagogy. In the present study, although science lessons were taught online and argumentation activities were done asynchronously by the experimental group, the results were encouraging for the development of students' epistemic cognition. In accordance with Osborne et al. (2013), this finding can be interpreted to be a result of the professional development of the experimental group teacher in argumentation pedagogy. This teacher had received a post-graduate course on argumentation pedagogy, which may have helped her to understand the techniques used to promote argumentation among students. A second possible reason for this promising result may be the integration of reflective thinking within science teaching. Students were required to write dairies in which they answered reflective questions about their science learning after each science lesson. Although previous research which integrated reflective thinking into argumentation-based teaching did not specifically investigate the effect of the intervention on students' epistemic cognition (e.g., Felton, 2004; Hsu & Lin, 2017, Moshman, 1995), they found the development of students' argumentation skills which may imply also the development of students' epistemic cognition. Finally, argumentation pedagogy, which encourages the construction of counter-argument and rebuttal, the use of sufficient evidence and proofs to


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support both written and oral arguments throughout this study may also have paved the way for the positive effect of the intervention.

Results regarding the metacognitive development evident in the experimental group are in alignment with the results of Iordanou (2022) who also reported the development of sixth graders' metacognitive skills and argumentation. However, Iordanou (2022) used a social issue (immigration) for developing argumentation during face-to-face instruction. Therefore, the present study adds to our knowledge base about argumentation-based teaching by suggesting that it is possible to enhance young learners' metacognitive skills for scientific issues in a distance-learning environment.

Another notable finding of the present study was related to the development of the experimental group's logical thinking skills. This group outperformed the control group in post-test logical thinking skills scores and had improved these scores from pre-to post-test. The development of logical thinking skills, especially in inquiry learning environments, is not new to the literature. Lavoie (1999) and Johnson and Lawson (1998) found improvement of students' reasoning skills in learning cycle learning environments where students construct hypotheses and test these hypotheses by making predictions, conducting experiments, making observations, and reaching conclusions. Although students in the experimental group in the current study undertook two POE activities in which they used hypothetico-predictive arguments, this small amount of activity is unlikely to have had such a major impact on logical thinking. In addition, improving the ability of students to construct counter-arguments and rebuttals using evidence in argumentation activities, through the use of competing theories strategy, may have also facilitated the development of logical thinking skills among students. Besides, as Omarchevska et al. (2022) emphasized, the inclusion of reflective thinking during the teaching of argumentation in the experimental group may have helped students self-regulate their scientific reasoning and promoted greater development. Therefore, our results suggest that it is possible to develop logical thinking skills among younger students (sixth graders) during distance education with the use of reflective thinking and encouragement of written and oral arguments during asynchronous argumentation activities and in synchronous class discussions.

## Conclusions and Implications

The purpose of the present study was to explore the effect of online argumentation and reflective thinking-based science teaching on sixth graders' cognitive abilities. Epistemic cognition, metacognition, and logical thinking of students in the control and experimental groups were assessed before and after the intervention. Results showed that intervention was effective, especially in developing experimental group students' metacognition and logical thinking. On the other hand, although it was found that intervention was also effective on the set of epistemic cognition factors, this effect was not observed among individual epistemic cognition factors.

Several important elements of this specific distance education were noteworthy which may have facilitated the development of these skills. First, students were encouraged to use evidence and proof in the construction of their arguments in online synchronous classes. Second, they were encouraged to perform argumentation activities in out-of-class periods during which they were required to construct sound arguments along with counter-arguments, and rebuttals. Finally, they were required to write diaries out of class time in which they were required to reflect on their science learning. Although these important teaching processes took place in this study, fostering students' reflective thinking in diaries may have been extended to an asynchronous discussion platform where students may have found chances to reflect on each other's arguments. Future studies can include this kind of online platform in their research design.

## Limitations

Experimental group students received both argumentation and reflective thinking-based science teaching. Therefore it is not possible to make a distinction between these two in producing the positive results reported. To make this distinction, a follow-up study would be required in which a second experimental group that would receive only argumentation-based teaching, would allow the investigation of this issue.

Although the MANOVA result suggested a significant effect in the set of post-test epistemic cognition factors in favor of the experimental group, this significance was not identified in follow-up ANOVAs. This may show that although the intervention was effective in making a difference in general epistemic cognition scores, more instructional time may be needed for the development of individual epistemological belief factors. It is


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suggested that a longer duration of online argumentation and reflective thinking-based science teaching may have resulted in an identifiable difference between control and experimental groups concerning individual epistemic cognition factors. This modification could also be included in any future research.

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**Declaration of Interest**

The authors declare no competing interest.

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| ***Ömer Acar*** *(Corresponding author)* | PhD, Associate Professor, Kocaeli University, College of Education, Umuttepe Campus, Kocaeli, Türkiye. E-mail: acarok@gmail.com ORCID: https://orcid.org/0000-0002-9369-5539 |
| ***Zeynep Azaklı*** | MSc, Science Teacher, Kartal İhsan Zakiroğlu Middle School, İstanbul, Türkiye. E-mail: zeyneppozgeldi@gmail.com ORCID: https://orcid.org/0000-0002-1156-320X |