COMPUTER-AIDED ARGUMENT MAPPING: EFFECT OF INDIVIDUAL AND COLLABORATIVE PRACTICES ON REASONING SKILLS

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ABSTRACT

This study mainly examines the effects of computer-aided individual and collaborative argument mapping practices on pre-service science teachers' reasoning abilities by adopting an experimental research method, i.e., pre-test post-test control group pattern. Fifty senior pre-service science teachers participated in this study. The science writing heuristic tool and individual argument mapping practices were used within the scope of the subject of optics for eight weeks in the experimental and control groups. In addition, students in the experimental group participated in collaborative argument mapping practices. The logical thinking ability test was used as a data collection tool. Results of the quantitative analysis showed that the pre-service teachers who participated in collaborative argument mapping practices were more successful in developing their reasoning skills. In this regard, computer-assisted collaborative argument mapping is an effective method for improving reasoning skills. These findings can be attributed to the fact that collaborative argument mapping gives students more room for group discussion in the context of the subject. It is possible to say that collaborative argument mapping includes social and cognitive activities required for the development of reasoning skills. In other words, in collaborative argument mapping, the pre-service teachers with different views in the same group had the opportunity to develop their reasoning skills by critically questioning their own ideas and those of their group mates. In general, it is normal for collaborative pre-service teachers who have more social and cognitive argumentation experiences to perform better in terms of reasoning than the individual argument mapping group.

Keywords: *Argument-based Inquiry (ABI), Individual Argument Mapping, Collaborative Argument Mapping, Logical Thinking Ability*

INTRODUCTION

The importance of reasoning ability is being increasingly recognized in the education domain in the 21st century. Science education, in particular, emphasizes high-level cognitive skills such as reasoning rather than low-level cognitive skills such as recalling and understanding information. In science standards, science programs are prepared with a significant emphasis on the need to teach students high-level reasoning (National Research Council, 2012). Another important aspect is the addition of reasoning dimensions to the science assessment frameworks of exams such as PISA and TIMSS. While 30% of the TIMSS assessment is devoted to measuring reasoning in science as one of the dimensions of the cognitive domain (Mullis et al., 2009), PISA has been measuring not only the content knowledge of students but also their skills for implementing scientific knowledge in their daily lives since 2015 (OECD, 2012). In this regard, it is clear that students should carry out activities that support their reasoning skills such as explaining scientific events, interpreting data and evidence, designing scientific research, and making evaluations.

According to the argumentative reasoning theory, reasoning is a social ability that develops based on the design and evaluation of arguments (Mercier & Sperber, 2011). According to this view, reasoning develops best in the presence of an argument-based context. Such context arises naturally within a group that is willing to collaborate but is not like-minded. People get better results when they discuss a topic as a group rather than by themselves (Mercier & Sperber, 2017). The nature of argumentation, which requires individual and social activities (Erduran & Jiménez-Aleixandre, 2008) to develop a dialogical discourse with scientific knowledge to reach a group decision or consensus on a topic (Osborne et al., 2004), supports this theory. Therefore, it can be said that argumentation practices in collaborative learning environments enable students to improve their reasoning.

In science education research, the argument-based inquiry (ABI) approach is frequently reported as an effective tool to strengthen students' reasoning and metacognitive skills (Yore, 2000; Burke et al., 2005; Bybee, 2008). This approach consists of a series of activities wherein students formulate questions, assert claims through practice, present evidence for these claims, and construct arguments based on valid reasoning (Keys et al., 1999). In this process, it is common for students to construct erroneous arguments and face difficulties in resolving complex argument structures. This is because the process involves activities that require intense cognitive efforts such as defining argument elements as well as identifying and evaluating deficiencies and errors. In fact, these activities are likely to produce an excessive cognitive load significant enough to interfere with the attention, memory, performance, and learning of students (Harrell, 2007; van Bruggen et al., 2002). To overcome these difficulties, tools such as argument mapping wherein individuals can present the hierarchical relationships between their arguments and sub-components (Braak et al., 2008) were developed. Argument mapping is a visual technique used to map arguments using simple box and arrow diagrams (ter Berg et al., 2013).

Due to technological advances and increased interest in visualization techniques such as mapping and argument mapping has been extensively applied in software (Harrison, 2011). Individual and collaborative arguments can be created according to the features offered by the software. These features allow students to create counter-arguments and evaluate them. Creating counter-arguments necessitates students to engage in a higher level of reasoning (Jonassen & Carr, 2000). In short, creating a computer-aided argument map makes it easy to present complex reasoning clearly and explicitly (van Gelder, 2003).

Research indicates that computer-aided argument mapping positively affects students' reading comprehension levels (Chiang et al., 2016; Eftekhari & Sotoudehnama, 2018), ability to recall information on the subject and permanent learning (Eftekhari & Sotoudehnama, 2018), critical thinking skills (van Gelder, 2001; Donohue et al., 2002; Twardy, 2004; Darhany, 2020; Esfandiari et al., 2020; Grant, 2021), and argumentation skills (Uçar & Çelik, 2020). In literature, the argumentation process is reported to clearly encourage reasoning. However, notably, there are few studies on computer-aided argument mapping. In this context, this study examines the effects of computer-aided argument mapping on reasoning based on individual and collaborative uses. The research question is as follows:

1. Is there a significant difference between collaborative argument mapping intervention and individual argument mapping intervention in terms of reasoning skills?

METHODOLOGY

Research Design

Within the scope of this study, an experimental research method, i.e., pre-test post-test control group design, was used. In this pattern, after participants are assigned randomly to the intervention conditions, a pre-test is applied, and after they are subjected to the intervention conditions, a post-test is applied. In addition, it is stated that it is a pattern with high internal validity since the experimental and control groups are assigned randomly (Christensen et al., 2015). The research pattern of this study is given in Figure 1:

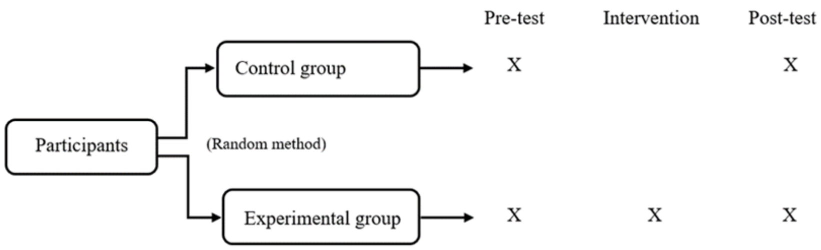

Figure 1. *Research pattern*

Study Group

The sample of this study comprised 50 senior pre-service science teachers studying at Kastamonu University in the 2017–2018 academic year. The pre-service teachers attended two different classes. Before the study, one of these classes was randomly assigned either as the control group or as the experimental group. The control and experimental groups comprised 19 and 31 pre-service teachers, respectively. The lectures were conducted for both groups using the ABI approach. To conduct ABI activities, the pre-service teachers were divided into groups of four to five people. While the control group created individual argument maps after the ABI activities every week, the experimental group created collaborative argument maps for four weeks in addition to what the control group did (ABI activities and individual argument maps).

Implementation Process

In the control and experimental groups, the lectures were conducted for eight weeks within the scope of the subject of "optics," including the preparation activity. The experimental and control groups participated in individual argument mapping activities every week after the ABI applications, adhering to the basic idea of the experiment activity. Unlike the control group, the experimental group created collaborative argument maps in addition to individual argument maps. To minimize the effects that may arise from the ABI approach and the individual argument mapping between the experimental and control groups, these activities were applied to both groups. In addition, the implementation process of this study comprised two pillars: ABI practices and argument mapping practices. The implementation process of this study is detailed below.

ABI Practices: In this study, eight ABI activities, including topics of light and shadow, mirrors, mirror systems, lenses, lens systems, refraction, and preparatory activities within the scope of the subject of "optics," were jointly carried out in the control and experimental groups. First, the students were informed about the practices to be carried out during the study and that they would be responsible for how the experiments were designed, how they collected data, and how these data were analyzed during the implementation process. During the activity process, the researchers took on the role of guides (for intense exploration of pre-instructional understanding, questioning, making attention big idea, give a clue…) due to the nature of the argumentation practices.

Before proceeding with the ABI experimental activities, the students were asked to form small groups of five to six people each and give a name to their group to increase their sense of belonging to the group work. Next, a preparatory activity was conducted before moving to the ABI activities as part of the subject of "optics." During the preparatory activity, the students were given a text containing a mysterious event and asked to solve the mystery, put forward a claim for this event, state the evidence supporting their claim, and write a script about the plot. Following this, each group went through the process of convincing other groups by sharing their claims, evidence, and scenarios with them. The preparatory activity introduced this process to the students who had not experienced the ABI process before and helped them make the process of creating arguments more efficient by realizing the structure between argument and evidence. Subsequently, the students were asked to make preparations within the scope of the topic of each week and attend class with initial questions. The students held discussions in small groups and sought answers to their questions. For this, the pre-service teachers designed an experiment in their groups with their peers and sought answers to their questions. Meanwhile, the researchers visited all groups and asked various questions to the students. These questions enabled students to think more intensely, be mentally active, and think at a higher level without losing sight of their target. In addition to the guidance provided by the researcher in small group discussions, peer interaction was experienced intensely. The students tried to complete the process by communicating with their group mates during the design and implementation phase of the experiments. In small group discussions, the pre-service teachers established a relationship between the research questions and their experiments due to the nature of the ABI approach and formulated their claims based on this relationship.

Following the small group discussions, the students shared the questions they researched, the data they obtained, the claims that were the result of their observations, and the evidence supporting these claims with the entire class. During the large group discussion, the researcher asked questions to the class designed to include other groups in the discussion, such as "Do you think so?" "Do you agree with your friends' opinions?" and "Is there anything you want to add?" In line with the answers given during these discussions, why- or how-questions were asked to the students to help them express themselves better and engage in a questioning process. Following the ABI practices, the experiment and control groups completed their experiment reports in line with the ABI approach at the end of each course.

Individual and Collaborative Argument Mapping Practices: An introductory lecture on creating an argument map was given to both groups before starting the experiment activities. In this course, the students were familiarized with an argument map, its purpose, and its usage. In addition, the online computer program (rationale-argument mapping) that they would use to create an argument map was introduced and sample practices were carried out on different subjects. Both groups were first tasked with creating an individual argument map for the preparatory activity. In this way, the students formulated their claims, supported them with evidence, explained their thoughts with logical justifications, and practiced formulating their arguments by establishing connections among claims, rationales, and evidence. Later, at the end of each ABI activity, the groups were tasked with creating seven individual argument maps on the topic that reflects the main idea of that activity. Feedback was given to the students by evaluating the individual argument maps created to help them create better argument maps.

Unlike the control group, the experimental group created collaborative argument maps in addition to the individual argument maps. While creating collaborative argument maps, the students formed 16 small groups of two people. These practices were conducted in a computer laboratory where the students could use computers in groups of two. In collaborative mapping, the students started to create an argument map within the framework of a claim formulated by the researchers before the practice. Each small group had another small group to create an argument map together. A small group could discuss and evaluate the claims, rationales, and evidence developed through collaborative argument mapping with other small groups using an online discussion environment created using the software program. In line with their claims, the students tried to convince the other group by referring to the data they chose and different resources (information they learned, books, pictures, or online resources) and sharing their visuals. The researchers, too, were involved online in the interaction process of two small different groups. The researchers asked guiding questions and added supporting or refuting expressions to enable students to question the claims, rationales, and evidence they put forward. In other words, the researchers were involved in the collaborative mapping process as guides as in the ABI activities.

Data Collection Tools

The logical thinking ability test (LTAT), originally developed by Tobin and Caple (1981) and translated into Turkish by Geban, Aşkar, and Özkan (1992), was used as a data collection tool in the study. This test is important in terms of showing how much students can use cause-effect relationships and problem-solving strategies in problems they may encounter, especially in the fields of science and mathematics. The questions in this test are designed to determine and control the variables that require not only scientific thinking but also logical thinking. The test also includes answers that measure the knowledge of ratio, knowledge of probability, and synthesis ability of the student. The test has eight two-steps multiple-choice and two open-ended questions. As a result of the reliability studies of the test, the correlation value was found to be 0.81.

Data Analysis

In this study, the effect of individual and collaborative argument mapping on pre-service teachers' logical thinking skills was examined. For this purpose, the pre-test and post-test scores of the pre-service teachers were considered. To analyze the quantitative data obtained, the SPSS Statistics software was used, the pre-test was taken as a covariate, and analysis of covariance (ANCOVA) was performed on the post-test scores.

RESULTS

The pre-test LTAT was used to determine whether there was a meaningful difference between the logical thinking ability test of the two groups. The t-test and ANCOVA were applied since the data provided assumptions of normal distribution (Kolmogorov–Smirnov: $p > 0.05$), homogeneity (Levene's Test: $p > 0.05$), and linearity and homogeneity of regression trends ($p > 0.05$). An analysis of the t-test results for independent samples revealed that there was no statistically significant difference between the groups. The pre-test LTAT results showed that there were small differences between the total test scores of the groups; however, these differences were not statistically significant. The pre-test LTAT score was used as a covariate to reduce the error variance, to get a sounder statistical test and to statistically compensate for the primary differences between the control and experiment groups. The logical thinking ability test post-test mean scores of the students in the control and experiment groups as corrected according to the logical thinking ability pre-test scores are shown in Table 1. The findings of the ANCOVA analysis on the post-test LTAT are provided in Table 2.

The findings of the ANCOVA analysis of post-LTAT in Table 2 showed a significant difference between the logical thinking ability post-test scores corrected according to the groups' pre-test LTAT scores ($F_{(1,47)} = 11.095$, $p = 0.002$). The eta square value (η_p^2) derived from the ANCOVA analysis shows that the experiment group, unlike the control group, accounts for 19.1% difference in the post-test LTAT scores regardless of the pre-test LTAT total scores. The mean post-test LTAT scores in the experiment group are higher than the mean scores of the control group students.

Table 1
Post LTAT Findings

Test	Group	Average	Corrected Average
Post LTAT	Control	11.895	11.211
	Experiment	14.290	14.709

Table 2
Findings of Post LTAT ANCOVA Analysis

Source of variance	Sum of squares	sd	Average of squares	F	PA	η_p^2
Pre CT	234.752	1	234.752	19.174	0.000	0.290
Group	135.837	1	135.837	11.095	0.002	0.191

Error	575.425	47	12.243
Total	9829.000	50	

DISCUSSION AND CONCLUSION

Reasoning is an important educational goal at all levels for students to develop their high-level cognitive skills. Many factors affect the development of students' reasoning skills in the classroom environment, and teachers' pedagogical approach is highly important in this regard. Research indicates that teachers' behaviors such as revealing students' ideas, giving feedback on their work, and engaging the details of their thoughts support students' reasoning (Franke et al., 2009). In addition, teachers who experienced argumentation practices as students use this method in their classes (Zeidler, 1997). Therefore, it is important for pre-service teachers to participate in argumentation-based practices to improve their reasoning skills and gain pedagogical competence in the practices that support this development.

Argument maps are the tools used for the visualisation of an argument structure. Organizing an argument structure in a hierarchical manner and in the form of pyramid is important so that a mental picture is created for the whole argument and answers are sought for the questions aiming to reveal the relation between the claims (van Gelder, 2002). Argument maps serve visual presentation of the arguments having deductive structures through graphic techniques. An argument map allows for transforming the abstract structure of reasoning into a concrete conceptual structure (ter Berg & van der Brugge, 2013). As a conclusion, an argument map is a visual structure where elements of an argument are represented in a transparent and effective manner (van Gelder, 2005). Computer-aided argument mapping is a technology-based pedagogical tool that provides a suitable learning environment for developing complex learning outcomes such as critical thinking (Davies, 2011).

In this direction, this study focused on researching the effect of computer-aided argument mapping practices in individual and collaborative modes on pre-service teachers' reasoning skills. The students in the study group created individual argument maps as part of the subject of optics, while those in the experimental group participated in collaborative argument mapping practices in addition to individual argument mapping. Quantitative analysis was conducted to understand how these conditions affect reasoning skills. Results showed that collaborative argument mapping was more successful in improving the reasoning skills of pre-service teachers.

The findings of this study are consistent with those of previous studies demonstrating that collaborative argument mapping had a positive effect on improving reasoning skills (Jonassen & Carr, 2000; Osborne et al., 2004; Burke et al., 2005; Akyol et al., 2009; Mercier & Sperber, 2011; Darabi et al., 2013; Ioannou et al., 2014). These findings can be attributed to the fact that collaborative argument mapping gives students more room for group discussion in the context of the subject. The steps necessary to create an argument include various skills of students such as having a conceptual understanding of the subject; collecting evidence and analyzing data; justifying, sharing, and defending claims; trying to persuade peers and reconciliation at the end of the discussion (Voss & Means, 1991). In this regard, it is possible to say that collaborative argument mapping includes social and cognitive activities required for the development of reasoning skills. In particular, as Mercier and Sperber (2011) stated, the development of reasoning in the analysis, evaluation, and construction of arguments depends on the collaboration skills used in this process. Collaborative argument maps, for example, make it much easier to assess a student's reasoning skills. This is because students clearly understand what is in their friends' mind without confusing variables involved in verbal or text-based discussions (Davies, 2009). In addition, students refraining from challenging others' claims may cause them to display poor quality dialogue and argument (Weinberger et al., 2010). Moreover, although students are involved in the argumentation process, they have difficulty recognizing others' opposite argument structures (Sadler, 2004; Noroozi et al., 2012). Therefore, tools that can reflect and improve the quality of group processes through external representations such as collaborative argument maps have a strong potential to support reasoning in the argumentation process (Janssen & Bodemer, 2013; Streng et al., 2010). As Sönmez, Çakan Akkaş, and Kabataş Memiş (2020) said, educational value of creating an argument map comes from allowing students to explore different views in the process to support the validity and logic of their reasoning.

The argumentation process requires students to develop cognitive and social activities, such as forming arguments, realizing erroneous arguments, and analyzing and evaluating complex argument structures (Erduran & Jiménez-Aleixandre, 2008). When students create collaborative argument maps in addition to the argumentation process, this enables them to increase their social and cognitive interaction. In this way, students have to use their reasoning skills and develop their high-level cognitive skills (Akyol et al., 2009; Darabi et al., 2013; Ioannou et al., 2014). In addition, argument mapping helps students avoid getting into the complex structure of arguments and identify reasoning problems in the arguments (ter Berg & van der Brugge, 2013). In this study, the pre-service teachers who performed collaborative argument mapping were able to intervene in the points they wanted to change or improve in their arguments in a short time; they did this by reviewing the arguments they formulated as a group and the arguments of other groups using the features provided by the software used. In this process, the pre-service teachers had the opportunity to see their own logic errors and those of their friends by having small and large group discussions. As emphasized by Twardy (2004), this is in line with the view that it is necessary to define and evaluate argument elements to develop reasoning skills. Similarly, the argumentative reasoning theory acknowledges that reasoning develops through finding arguments and evaluating activities in the context of dialogue (Mercier & Sperber, 2011). In other words, in collaborative argument mapping, the pre-service teachers with different views in the same group had the opportunity to develop their reasoning skills by critically questioning their own ideas and those of their group mates. In this case, it is normal for collaborative pre-service teachers who have more social and cognitive argumentation experiences to perform better in terms of reasoning than the individual argument mapping group.

RECOMMENDATIONS

In light of these findings, computer-assisted collaborative argument mapping is considered a useful method for improving reasoning skills. Based on the many benefits of computer-assisted collaborative argument mapping, it is recommended to implement argument mapping practices to develop reasoning skills at appropriate educational levels. For subsequent research, suggestions can be made to evaluate the argument maps produced using collaborative and individual modes and share the results for the quality of arguments. In addition, determining the problems encountered during computer-aided collaborative and individual argument mapping practices is recommended as it will provide evidence for the argumentation process.

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