PERR
PSYCHO-EDUCATIONAL RESEARCH REVIEWS

Psycho-Educational Research Reviews
11(*1*), 2022, 324-340
www.perrjournal.com

Impact of Different Types of Argument Maps on Critical Thinking: A Quantitative Study with the Pre-Service Science Teachers in Turkey

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Keywords

Argument based inquiry
Argument map
Critical thinking skills
Critical thinking disposition

Article Info:
Received : 07-06-2021
Accepted : 23-11-2021
Published : 11-04-2022

DOI: 10.52963/PERR_Biruni_V11.N1.21

Abstract

The aim of the study was to examine the impact of the use of argument maps by final year students of the science-teaching program on critical thinking. In the research, out of experimental research models, quasi-experimental pre-test-post-test control group design was used. Sample of the study consisted of 84 final year pre-service science teacher studying in three different classes in the fall semester of 2017-2018 academic year. While one of these classes was identified as control group, the other two classes were determined to be experimental groups at the beginning of the study. In the control and experimental groups, lectures on the subject of "Optics" were held with the Argument Based Inquiry (ABI) approach for 8 weeks in total. Different from control groups, experimental groups created eight individual argument maps in total within the framework of weekly subjects. In addition to the individual argument maps, one of the experimental groups created collaboratively argument maps for 4 weeks. collaboratively argument map practices were performed with 17 small groups consisting of two persons. Researchers were involved in the collaboratively map creation process as guides. Critical Thinking Test was used as measurement tool at the beginning and end of the practices. Data were analysed through one-way ANOVA via the SPSS program. At the end of the analysis, it was concluded that individual and collaboratively argument mapping practices were effective in the development of critical thinking skills of the pre-service teachers.

To cite this article: Kabataş Memiş, E., Çakan Akkaş, B. N., & Sönmez, E. (2022). Impact of different types of argument maps on critical thinking: a quantitative study with the pre-service science teachers in Turkey. *Psycho-Educational Research Reviews, 11*(1), 324-340. doi: 10.52963/PERR_Biruni_V11.N1.21

INTRODUCTION

It is stated that one of the fundamental aims of education is to make the students acquire the general thinking skills and critical thinking skills, in particular (National Science Education Standards 1996; van Gelder 2005; MNE 2013; MNE 2018). It can be said that the main goal of higher education institutions is to develop critical thinking of university students who constitute the potential workforce of the future in the 21st century (Halpern, 2014). Moreover, the World Economic Forum declared that critical thinking is the third most demanded skill. Critical thinking is frequently emphasised as a key '21st century skill' that all students need in order to prepare for higher education and the workplace (Kuhn, 2015). It is important to develop thinking skills that include critical thinking elements as it will help individuals make critical and smart decisions in their work lives (Zulkifli, Abd Halim, & Yahya, 2016). At this point, it is even more important to improve the critical thinking skills of the pre-service teachers as the teachers of the future. However, despite the emphasis on critical thinking as a basic skill, the current evidence suggests that this skill is not taught commensurately in universities (Davies & Barnett 2015; Davies 2011; Huber & Kuncel, 2016). A recent study revealed that US employers believe that graduates do not have the critical thinking ability required for success in business life, and only 39% are competent (Association of American Colleges and Universities, AACU, 2021). Considering these findings, the focus should be on what are effective instructional practices to improve students' critical thinking levels. Emphasizing that critical thinking is a learned skill requiring education and practice, Synder and Synder (2008) stated that the students should be actively involved in learning for the development of this skill. One of the environments supporting critical thinking is argumentation practices, which contain research and inquiry based processes. Andrews (2015) points out that both critical thinking and argumentation overlap in certain regions and that both have various pedagogical implications for teaching and learning in higher education. Therefore, it can be concluded that it is important to focus more on argumentation, which is one of the ways to encourage critical thinking. In this respect, it is important for students to reflect on what they have learned, try to apply new ideas, compare their own ideas with the information in the books and actively discuss what they have learned in small groups (Paul, Binker, Jensen, & Kreklau, 1990). In fact, it can be said that these practices reflect the argumentation process.

Richard Paul (2011) emphasises the importance of specifying and evaluating arguments in critical thinking, and, as such, highlights the relationship between two concepts (critical thinking and argumentation). Similarly, the argumentation process reflects a discussion process that takes shape based on written and oral arguments. Social negotiation is considered the main activity of argumentation, as it addresses uncertainty between different or controversial arguments and emphasises a collaborative discussion process (Chen, Benus, & Hernandes, 2019). Throughout this social negotiation, attention is drawn to the use of language elements such as discussion and writing in the formation of arguments and scientific knowledge (Cavagnetto & Hand 2012; Chen, Hand, & Park 2016).

In this study, individuals mostly use the speaking dimension of the language during the negotiations in the argumentation process, whereas argument mapping, which is a writing activity, also supports the writing dimension of the language. As Rivard and Straw (2000) stated, speaking in this process makes it possible to create, share, explain and distribute scientific ideas, while writing ensures the creation and reinforcement of new knowledge related to prior knowledge. In addition, it is thought that if individuals go through these processes cyclically, it will help raise their awareness of their own reasoning. Therefore, in this study, it was aimed to support the scientific negotiation process by using argument maps in addition to the argumentation process. It is stated that criticism entails the ability not only to identify the elements of an argument, but also to assess the validity of data and supports for competing alternatives (Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013). In addition, an argument map contains important argumentative information, such

as how an argument was constructed, including evidence, reasons and objections; what was concluded and what was not supported within the framework of simple rules (van der Brugge, 2018). In particular, it is stated that an argument map ensures that critical thinking skills such as interpretation, analysis, evaluation, explanation, self-evaluation and self-regulation are used significantly (Toulmin, 2003). For this reason, in the present study, argumentation and argument mapping applications were used simultaneously, as it was thought that this would support various skills such as identifying, evaluating and analysing arguments which have an important place in critical thinking. In addition, due to the emphasis on the social negotiation process in argumentation, collaborative argument mapping activities which could provide such an environment were included in the creation of argument maps. Therefore, argumentation and argument mapping activities ensure that social negotiation is conducted in the form of oral and written discussions. Considering these situations, argument mapping, in particular, has significant potential to improve critical thinking. However, it has been observed that still there are limited studies on this subject (Kabataş Memiş & Çakan Akkaş, 2020; Butchart et al. 2009; Dwyer, Hogan, & Stewart 2012; Kunsch, Schnarr, & van Tyle 2014; Uçar & Demirarslan Cevik 2020; van Gelder 2002). In the light of this data, this study aims to examine the effect of argument mapping on the critical thinking skills and tendencies of pre-service teachers.

CONCEPTUAL FRAMEWORK

CRITICAL THINKING

Human beings are distinguished from the other living creatures with the ability to think and can make sense of what is going around thanks to this ability. Thinking is an important skill, which ensures systematic linguistic, mental and social development in the individuals, help them learn information and shape the plans for the future (Güneş, 2012). However, in today's conditions where standard thinking is not adequate, individuals need to have quality thinking skills. Thus, Paul (2012) emphasizes the importance of the formation of evidence-based and justified ideas for quality thinking instead of simply suggesting ideas. The word "critical" is derived from "kritikos", which means judgment, distinction and assessment in Greek, and evolved into "criticus" in Latin and was incorporated into the other languages, as well. "Critical thinking", which has referred to thinking in an objective and detailed manner, in depth and away from the fixed ideas ever since the era of Socrates, is accepted as the most advanced and developed mode of thinking (Fettahlıoğlu & Kaleci, 2018). Owing to these features, it can be argued that critical thinking is a quality thinking.

When the literature is examined, it is seen that there are different definitions for critical thinking. Critical thinking refers to the identification of a problem encountered, detection of assumptions concerning the problem and testing of the reliability and validity of the assumptions through the use of induction, deduction and other logical processes along with the existing information and data sources (Kennedy et al., 1991). Critical thinking is reflective and logical thinking performed by a person while deciding on what to do or what to believe (Ennis, 1993). According to Paul and Elder (2008), critical thinking is a way of thinking where a person guides, disciplines, monitors and confirms oneself. In fact, it is stated that many definitions of critical thinking agree on the value and importance of recognising and forming arguments as reasoning skills (Davies & Barnet, 2015).

According to the definitions of critical thinking in the literature, there are two subdimensions of critical thinking as cognitive (skill) and affective (disposition). It can be stated that the basic skills emphasized in critical thinking are analysis, assessment, deduction, explanation and self-regulation (Facione, 2015). As for the disposition dimension of critical thinking, it is expressed as the characteristics that the individuals possess while deciding on what to believe (Ennis, 2011). Facione et al. (2000) stated that dispositions related to critical thinking are cognitive maturity, being analytical, open-mindedness, curiosity, self-confidence, seeking for the truth and being systematic. When the individuals having the critical thinking skills lack the adequate critical thinking dispositions, they will get difficulty in using these skills (Seferoğlu & Akbıyık, 2006). Therefore, development of the skill and

disposition dimensions of critical thinking in a coordinated manner is of great importance for the development of critical thinking.

ARGUMENT MAPPING

In addition to the positive impact of the ABI approach on critical thinking, it has recently been stated that creating argument maps, which allow for examining and analysing the argument structures in an effective manner, is effective, as well (van Gelder, 2015). Argument maps are the tools used for the visualisation of an argument structure. At this point, knowing what an "argument" is and what are the components that the concept of argument includes is important. While argument includes a claim, data, reason and supporting elements, the process of discussion endowed with these elements is called as "argumentation" (Osborne, Erduran, & Simon, 2004). As for an argument map, it refers to the visual presentation of an argument structure and discussion in a systematic manner. An argument map, which is the two-dimensional representation of an argument structure, is a tree-shaped diagram of boxes and arrows (Twardy, 2004). The direction of the boxes and arrows changes depending on the roles of reasons and objections in the argumentation structure (ter Berg & van der Brugge, 2013). Argument map is created by considering the reasons supporting the main claim as well as the relation between the main claim and the other claims (Davies, 2010). At one end of the argument map, there is a claim expected to be supported while reasons supporting the claim or objections to the claim are located at the other ends (Twardy, 2004).

Organizing an argument structure in an 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.

Creating an argument map enables the analysis of the hierarchical relationships between components and the evaluation of the validity and quality of the argument (Kim, 2015). An argument map organized in this manner 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).

THE USE OF ARGUMENT MAPPING TO ENHANCE CRITICAL THINKING

As in all phases of education, developing basic skills of the students at the level of higher education as well as their critical thinking skills is important. For training individuals able to think critically, contents of the courses taken during the university education need to be reorganized to serve this purpose and problem solving and critical thinking practices related to the areas of interest should be included in the courses (Kökdemir, 2012). Pointing out that critical thinking is a teachable skill, van Gelder (2015) stated that reasoning and discussion are key for critical thinking. Davies and Barnet (2015) stated that critical thinking in higher education consists of six dimensions that are different from, but are integrated with, each other: (1) basic skills in critical argumentation (reasoning and inference), (2) critical judgements, (3) critical thinking dispositions and attitudes, (4) critical entities and actions, (5) social and ideology criticism and (6) critical creativity or critical openness. Thus, the importance of including the ABI approach containing reasoning and discussion activities and argument map creation activities into the learning process has increased.

Argumentation based inquiry (ABI) activities allow for problem solving, decision making and critical thinking developments of the individuals and motivate them for high level thinking (Hand, 2008). Scientific discussions held within the scope of the ABI approach, which includes above-mentioned activities and a research-inquiry based learning process, play a key role in the development

of both critical thinking skills and dispositions of the students (Kabataş Memiş, 2016). In particular, students can use many critical thinking skills such as those related to analysing, evaluating and interpreting thanks to the discussions they participate in this process (Sönmez, Kabataş Memiş & Yerlikaya, 2021; Sönmez, Çakan Akkaş & Kabataş Memiş, 2020). This shows the necessity of integrating the activities based on the ABI approach into the classroom environments for the development of critical thinking. Effective ABI practices may allow for the training of the students who are responsible for their own learning experiences, are more active in the learning process, can inquire and question and know the ways of reaching new information.

Integrating argument mapping into ABI-based applications allows students to reflect, evaluate and correct themselves by looking at visual representations of their arguments (van Gelder, 2001). It has been argued that the intensive realization of argument mapping from easy to difficult in the instructional process is effective in the development of critical thinking (van Gelder et al., 2004). Since computer-assisted argument mapping guides by providing frameworks that will give the necessary support in individual studies, computer-assisted argument mapping offers more opportunities for effective implementations compared to traditional methods using paper and pencil. For example, when students select a component while creating argument maps with the help of frameworks, the system can advise them on what to do next (van Gelder, 2001). Also, due to its visual and easily editable structure that reduces the complexity of arguments, computer-assisted argument mapping allows intensive implementation in a limited time. In this regard, computer-assisted argument mapping is considered a tool that supports effective practices in the development of critical thinking.

There are studies examining the effectiveness of argument mapping on the development of critical thinking (Butchart et al. 2009; Dwyer et al. 2012; Kunsch et al. 2014; Sönmez, et al. 2020; Ucar & Cevik 2020; van Gelder et al. 2004). It is noteworthy that most of the studies were carried out within the scope of the critical thinking course, and the students made argument mapping individually (Butchart et al. 2009; Dwyer et al. 2012; Kunsch et al. 2014; van Gelder et al. 2004). In addition, it was observed that the effect of argument mapping on critical thinking skills was also examined in these studies. Although the results of the previous studies show that argument mapping has a significant impact on the development of critical thinking, as the present study, when it is carried out in different disciplines such as the context of physics subjects and based on different instructional applications such as individual or interactive, it has been observed that there has not been enough study on the effect of argument mapping on the development of critical thinking holistically in both skill and tendency dimensions.

For this reason, skills and dimensions of critical thinking were discussed together with a holistic perspective within the scope of this study. The argument mapping process was carried out individual and as collaborative mapping that enables social negotiation in computer environment.

When the above-mentioned factors are taken into consideration, it is striking that critical thinking has a significant place in education. Thus, it is important to incorporate practices, which will develop the critical thinking skills of the students from all phases of education, into the courses. In particular, supporting critical thinking in children, who are the adults of the future, as of early ages is important. This is possible only by training teachers who have strong critical thinking skills. Also, the necessity of using practices, which might play a role in the development of critical thinking in the learning process in an effective manner and involving the students in these practices, has arisen. In this scope, the aim of this study is to examine the impact of the argument map creation process on the critical thinking of pre-service teachers. Research questions was as follows:

1. What is the effect of individual and collaborative argument mapping on pre-service science teachers' critical thinking?

a) Is there a statistically significant difference between individual and collaborative argument mapping groups in terms of critical thinking scores?

b) Is there a statistically significant difference between individual argument mapping and control groups in terms of critical thinking scores?

c) Is there a statistically significant difference between the cooperative argument mapping and control groups in terms of critical thinking scores?

METHOD

RESEARCH DESIGN

Research design is quasi-experimental pre-test-post-test control group design. According to this design, CTT is applied as a pre-test to the control and experimental groups that are selected impartially. Then, individual argument mapping is applied in one of the experimental groups, and individual and argument mapping intervention conditions are applied in the other. After the implementations, CTT is applied to the experimental and control groups as a post-test. Due to the presence of the control group and the unbiased assignment of the groups eliminated the basic intervention conditions against internal validity (Christensen, Johnson, Turner, & Christensen, 2011), the quasi-experimental design was used. Critical thinking levels of pre-service teachers is the dependent variable of the research. Independent variable whose impact on the dependent variable is the teaching approach. Research design is summarized in the Table 1.

Table 1. *Research Design*

<table>
<tr><th>Groups</th><th>Activities Before</th><th>Experiment activities</th><th>Activities after</th></tr>
<tr><td>Experimental Group1(n=32)</td><td rowspan="3">Critical Thinking Test (CTT)-Pre Test</td><td>8 Week ABI Actives
8 Week Individual Argument Map Practices and
4 Week collaboratively Argument Mapping Practices</td><td rowspan="3">Critical Thinking Test (CTT)-Post Test</td></tr>
<tr><td>Experimental Group2 (n=23)</td><td>8 Week ABI Actives
8 Week Individual Argument Mapping Practices</td></tr>
<tr><td>Control Group (n=29)</td><td>8 Week ABI Actives</td></tr>
</table>

SAMPLE

The sample of the research involved senior pre-service science teachers (n = 84) studying in the Faculty of Education at a public university located in the western Black Sea region in the fall semester of 2017-2018 academic year. These pre-service teachers belonged to three different sections, one of which was randomly selected as a control group while the other ones were determined as experimental groups at the beginning of the research.Convenient sampling technique, which is one of the random sampling methods, was used to determine the sample of the study. The sample of the study consists of senior pre-service science teachers (n=84) studying at the Faculty of Education of a state university in the Western Black Sea region in the fall semester of the 2017-2018 academic year. This sampling technique was preferred for the researchers to easily reach the participants, who may be involved in experimental implementation that require a long time, such as an academic term (Monette, Sullivan ve De Jong, 2005). These pre-service teachers belong to three different groups that were randomly selected at the beginning of the study, one of which was determined as the control group and the others as the experimental group.

DATA COLLECTION TOOLS

INFORMATION FORM

A form was created that includes variables such as age, gender, GPA, and previous courses or training on critical thinking and argumentation to collect information about pre-service teachers.

CRITICAL THINKING TEST

Critical Thinking Test (CTT) was used as a data collection tool in the study. CTT was applied to the control and experimental groups as pretest and posttest in order to examine the impact of teaching approaches of the pre-service teachers on their critical thinking skills. CTT was developed by Akdere (2012) for the pre-service teachers. After the necessary permissions were taken, it was used in the present study. The test consists of 10 scenarios in total. Scenarios include a logical error or a problem requiring a solution or a situation requiring a decision depending on the interpretation of a situation described with 4-5 sentences, dialogues or a graphic presentation. After each scenario is given, there is an open-end question concerning this scenario. Participants are asked to answer this question with 4 or 5 sentences. The following 3rd question of the test is given as example:

"A report of a newspaper mentions a study comparing the success rates of the high schools where single-sex education is provided and the mixed high schools. Results of the study show that high schools where single-sex education is provided are more successful. Also, it is expressed that, based on the result of this study, authorities are planning to increase the numbers of single-sex high schools. Based on this report, do you support this initiative? Explain your reasons."

The test was developed to measure the Cognitive (skill) and Affective (disposition) dimensions of critical thinking with a holistic approach. The cognitive dimension of the Critical Thinking Test is based on reasoning, and interpreting, analysing and evaluating arguments, whereas the affective dimension is based on avoiding emotional reasoning, evaluating alternative perspectives and paying attention to information sources. Statements written in response to each question are scored from one to five, depending on whether they indicate the indicators for the skill and tendencies sub-dimensions in the rubric (Outstanding: 5, Good: 4, Avarage:3, Below avarage: 2, and Poor: 1). The reliability of the CTT was calculated as Cronbach Alpha (α = 0 .78). Akdere (2012) also developed a rubric for the CTT. Answers given to the questions in the test are assessed on the basis of this rubric. In the present study, CTT was applied to 84 pre-service teachers as pretest before the practice and posttest after the practice. Answers of the pre-service teachers were assessed through the rubric and were transformed into digital values. For this study, the test was found reliable with the value of KR20 as .82.

DATA ANALYSIS

The answers given by the participants to the CTT were scored using the holistic rubric developed by Akdere (2012). To test the reliability of the data collected through CTT, consistency between encoders was checked. To determine the consistency among the coders, each researcher randomly selected five CTT answer sheets from the pretest and posttests of all groups and evaluated them separately according to the rubric. Accordingly, the inter-coder reliability was calculated as 80%, which indicates high inter-coder reliability (Thomas ve Magilvy, 2011).

After the reliability tests, ANOVA analysis was conducted to examine whether the experimental and control groups had similar critical thinking scores in the pretest. Then, ANCOVA was applied to examine the effect of argument mapping on critical thinking by processing the participants' CTT pretest data as a covariate.

PROCEDURES

The laboratory activities on the topic of "Optics" were carried out in both experimental and control groups based on ABI approach for 8 weeks. Students in the experimental groups were asked

to create argument maps throughout the semester. While one of the experimental groups created individual argument maps after each activity within the scope of the "Big Idea" grounded on the main idea of the activity based on the ABI approach, collaboratively argument maps were created by the students one of the experimental groups in addition to these individual argument maps. In this respect, experimental groups were named as individual and collaboratively experimental groups. Practices held within the scope of the study are detailed under the headings of ABI practices and argument mapping practices.

ABI PRACTICES

During the study, eight ABI activities including the subjects of light and shadow, mirrors, mirror systems, lenses, lenses systems, refraction and preparation activity within the scope of the subject of "Optics" were performed jointly in the control and experimental groups. First, students were informed about the practices to be made during the study. They were also expected to design the experiments, to collect data and to analyse them. During the activity, researchers facilitated students' learning in a meaningful way through asking open-ended questions to foster them in critical thinking as a natural consequence of the argumentation practices.

Before the ABI experiment activities, students were asked to split into smaller groups consisting of five-six persons and to pick a name for their groups so that they can feel the sense of belonging more for the group activities. Afterwards, a preparation activity was performed prior to the ABI activities on the subject of "Optics". Within the scope of the preparation activity, texts narrating a mysterious event were distributed to the students and they were asked to solve this event, to raise a claim and turn the storyline into a scenario by stating the evidence supporting the claim. After that, each group shared their claims, evidence and scenarios with the other groups and tried to convince one another. The aim of the preparation activity was to introduce the ABI process to those who have not experienced it and to make the argument creation process more efficient through the structure between claim and evidence. Students were then asked to make preparations for the subject titles specified by the researchers and come to the lectures with start questions. Students wrote these questions on the blackboard before the lecture. Questions written by the students on the blackboard were evaluated by the researcher together with the whole class in terms of being open to inquiry. In this respect, groups had the chance to revise or reformulate the research questions.

Students sought answers for their questions by holding discussions in small groups. Meanwhile, the researcher visited all groups and asked various questions to the students. The aim of these questions was to ensure that the students thought more intensely without being distracted from the target, became mentally active and thought at a higher level. Also, questions in this process (student-student and teacher-student) play a significant role in the initiation and continuation of the discussion process which is key for the ABI. In small group discussions, peer to peer interaction was experienced as intensely as guidance of the researcher. Students tried to complete the process by communicating with their groupmates in the experiment design and implementation phases. This communication took place through sharing knowledge or asking questions.

Following the small group discussions, all groups shared the questions they examined, their claims based on the data obtained and observations as well as the evidence supporting these claims with their classmates. During the large group discussion, researcher asked further questions to students such as "Why do you think like that?" and "What do you think about your friends' opinions?" to motivate the students to think and to participate in the group discussions. Researchers continued asking following questions as "Why?" or "How?" in order to make them better express and question themselves and to initiate the discussion, which is essential in ABI process. Also, researchers directed the questions to different students when needed. While compiling the information related to the subjects in line with the large group discussion held, researchers also asked questions to request the students to make preparations for the activity of the next lecture and attract attention to the subject.

Later on, students were asked to come to the class with the questions they wanted to inquire on this subject. At the end of each lecture, students were asked to fill in the experiment reports, which constitute a part of the ABI approach.

INDIVIDUAL ARGUMENT MAPPING PRACTICES

An introductory lecture on argument mapping was delivered to both experimental groups before the experiment activities. In this lecture, students were informed about what an argument map is, for what purposes it is created and how it is used, and Rationale-Argument Mapping, the online computer program with which the argument map would be created, was introduced. Each student was provided with the previously created account information for entrance into the program and was asked to create argument maps on a weekly basis through this account. In both experimental groups, students were asked to create individual argument maps primarily in the preparation activity. By this means, they formed their claims and supported them with evidence, explained their thoughts with logical reasons and practiced for mounting arguments by establishing the claim-reason-evidence connections. Afterwards, students were asked to create eight individual argument maps on the subject reflecting the main idea of the activity at the end of each activity. They were asked to send the individually created argument maps to the e-mail address specified by the researchers. Researchers assessed the first individual argument maps prepared by the students and gave feedbacks with the aim of helping them create better argument maps and increasing the impact of the process.

COLLABORATIVELY ARGUMENT MAPPING PRACTICES

One of the experimental groups created collaboratively argument maps, as well, in addition to the individual argument maps. While preparing the collaboratively argument maps, students worked in 17 small groups consisting of two persons. These practices were performed in the computer laboratory where students could work on a computer in pairs. collaboratively experimental group students started to create an argument map with respect to an argument mounted by the researchers prior to the practices. Each small group has another small group to create the argument map together. Owing to collaboratively argument mapping, a discussion environment, where the claims, reasons and evidence of a small group could be assessed by the other small groups, was created. Students attempted to convince the other group by referring to different data and sources (their own knowledge, books or internet) and sharing the images in accordance with their claims. As for the researchers, they were involved online in the argument maps created by the interaction groups consisting of two small groups. They asked leading questions concerning the claims, reasons and evidence presented by the students to motivate them for questioning and added supporting or refuting statements. In other words, researchers were involved in the collaboratively map creation process as guides. After the practice was performed, students were asked to send the collaboratively argument maps to the researchers online. Four collaboratively argument mapping activities were performed with the students in accordance with the nature of the subjects. Each practice lasted for about 2 hours. At the end of each collaboratively practice, argument maps were assessed by the researchers in terms of the accuracy and clarity of the statements, whether the claims were presented in a hierarchical order, validity of the evidence and interaction levels of the groups, and feedbacks were given to the students.

VALIDITY OF THE STUDY

Necessary adjustments were made to control factors that could threaten the internal validity of this study, such as the different past experiences of the subjects, maturation, test effect, and loss of subjects (Christensen et al., 2011). In this regard, groups consisting of academically similar and approximately the same age group participants were randomly assigned as control and experiment. Since it is possible to experience loss of subjects, the study was started with more participants than necessary. However, there was no loss of participants. Experimental and control groups received an eight-week training after the pre-test of the Critical Thinking Test. After enough time for the

participants to forget the content of the test, the same test was applied as a post-test in three groups. The threat of the participants' experiences in the pretest to affect the posttest performance was eliminated by the length of the time between the pretest and the posttest, as well as the presence of the control group. When the Information Form was examined, it was determined that the participants in the experimental and control groups had not taken any courses or participated in the training on critical thinking and argumentation in the past. In this regard, it was expected that the participants in the experimental and control groups would reach similar cognitive and psychological maturation levels and experience similar behavioral changes since they had similar backgrounds and were in the same age group.

RESULTS

CTT pre-test was applied to determine whether there were significant differences between the groups in terms of critical thinking, critical thinking skills and critical thinking dispositions. The 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). When the pre test scores 185 obtained from ANOVA were examined, a significant difference could not be detected between the groups. Results of CTT pretest ANOVA analysis are given in the Table 2.

Table 2: *Pre-Critical Thinking Test Results*

		Sum of Squares	*SD*	*Average of Squares*	*F*	*p*
Critical Thinking Skills	Between groups	82.779	2	41.389	.534	.589
	Within groups	6205.727	81	77.572		
	Total	6288.506	83			
Critical Thinking Disposition	Between groups	38.329	2	19.165	1.006	.370
	Within groups	1543.421	81	19.055		
	Total	1581.750	83			
Critical Thinking Total	Between groups	198.632	2	99.316	0.823	.443
	Within groups	9648.235	81	120.603		
	Total	9846.867	83			

Statistically significant differences at the level of p< .05 could not be found between the total test scores of the groups in terms of critical thinking skill ($F_{(2,83)}$= .534, p=.589), critical thinking disposition ($F_{(2,83)}$=1.006, p= .370) and critical thinking according to the results ($F_{(2,83)}$=0,823, p= .443) obtained from the test applied at the beginning of the study. This showed that the groups were not different at the onset of the study with respect to critical thinking skill, critical thinking disposition and critical thinking. One-way ANOVA analysis was applied to determine whether the groups had differences in terms of CTT after the argumentation practices and individual and collaboratively argument maps created by the experimental groups. Descriptive statistical findings concerning the CTT post-test are found in the Table 3 while findings of ANOVA analysis are found in the Table 4.

Table 3: *Results of Post-CTT Descriptive Statistics*

	Groups	*N*	*M*	*SD*
Critical Thinking Skills	Experimental1 group	23	61.95	1.45
	Experimental2 group	32	64.21	1.47
	Control group	29	49.24	2.24
Critical Thinking Disposition	Experimental1 group	23	13.95	0.95
	Experimental2 group	32	13.87	0.80
	Control group	29	9.93	0.73
Critical Thinking Total	Experimental1 group	23	75.91	2.02
	Experimental2 group	32	78.09	1.92
	Control group	29	59.17	2.31

Table 4: *Results of Post-CTT One-way ANOVA Analysis*

		Sum of Squares	*SD*	*Average of Squares*	*F*	*p*	*Sig.*
Critical Thinking Skills	Between group	3806.836	2	1903.418	21.098	.000	Ex.1>Control Ex.2>Control
	Within group	7307.736	81	90.219			
	Total	11114.571	83				
Critical Thinking Disposition	Between group	300.574	2	150.287	7.913	.001	Ex.1>Control Ex.2>Control
	Within group	1538.319	81	18.992			
	Total	1838.893	83				
Critical Thinking Total	Between group	6222.210	2	3111.105	24.964	.000	Ex.1>Control Ex.2>Control
	Within group	10094.683	81	124.964			
	Total	16316.893	83				

CTT post-test ANOVA analysis results given in the Table 3 show that there is a statistically significant difference between the groups in terms of critical thinking skill ($F_{(2,83)}$=21.098, p=.000), critical thinking disposition ($F_{(2,83)}$=7.913, p=.001) and overall critical thinking ($F_{(2,83)}$=264,964, p<.0001). When the descriptive statistical findings in the Table 2 are examined, it is seen that this difference is in favor of the experimental groups taking part in the argument mapping practices. It was found out that there was not a statistically significant difference between the experimental group performing both individual and collaboratively argument mapping and the group performing only individual argument mapping in terms of critical thinking skill, disposition and test total score.

During the study, the impact of individual and collaboratively argument mapping process on critical thinking was examined, as well. It was determined that critical thinking disposition, skill and total test scores did not differ significantly between the experimental groups. At this point, average scores of the experimental groups were examined. It was found out that the critical thinking skill (M=64,21, SD=1,47) and test total average scores (M=78.09, SD=1.92) of the experimental group participating in individual and collaboratively argument mapping practices were higher than the skill (M=61.95, SD=1.45) and test total scores (X=75.91, SD=2.02) of the experimental group participating only in individual argument mapping practices. Effect size was calculated in order to detect how collaboratively argument mapping practices affected the total scores of the experimental groups. According to Sullivan & Feinn (2012), small effect size values were obtained for the critical thinking skill

(η_p^2=0.49) and test total (η_p^2=0.44). This means that collaboratively argument mapping practices had a slight impact on the difference between the critical thinking skill and test total scores of the groups (Pallant, 2016).

DISCUSSION AND CONCLUSION

The primary objective of the present study was to examine the impact of argument mapping on critical thinking skills, critical thinking dispositions and overall critical thinking of the pre-service science teachers. The impact of individual and collaboratively argument mapping on critical thinking was examined, as well. When the findings of CTT pre-test applied in the study were examined, it was seen that control and experimental groups were not different in terms of critical thinking skill, critical thinking disposition and overall critical thinking. However, when the findings of CTT post-test were examined, a significant difference was detected with respect to critical thinking skill, critical thinking disposition and overall critical thinking in favour of the experimental groups. In line with the findings, it can be stated that experimental groups are more successful than the control group in relation to critical thinking, critical thinking skills and critical thinking dispositions. Also, the present study examined the impact of individual and collaboratively argument mapping on critical thinking. When the relevant findings are examined, it can be seen that individual or collaboratively mapping has not led to a statistically significant difference between the experimental groups in terms of critical thinking skills, critical thinking dispositions and overall critical thinking. However, critical thinking skill and CTT posttest average scores of the experimental group participating in the collaboratively argument mapping practices are higher. Therefore, effect size for the critical thinking skill was calculated as η_p^2=0.49 while effect size for the test total was found as η_p^2=0.44. This result shows that collaboratively argument mapping practice has led to a slight impact when compared to the individual argument mapping.

The findings reveal that pre-service science teachers participating in argument mapping practices have differentiated from those not taking part in such practices in terms of critical thinking skill, critical thinking disposition and overall critical thinking. Also, collaboratively argument mapping practices performed by the pre-service teachers have had an impact on the development of critical thinking skills and dispositions. Studies available in the literature emphasize how effective argument mapping is for the development of critical thinking (ter Berg & van der Brugge, 2013; Twardy, 2004; van Gelder, 2005; 2015). van Gelder (2015) stressed that reasoning and discussion are at the core of critical thinking and these complicated processes need to be understood in an easier manner. Based on this, it can be stated that the pre-service teachers participating in the individual argument mapping practices visualised their own reasoning processes with argument maps. By this means, students can evaluate their own reasoning steps and revise their thinking processes in case of need.

As for the collaboratively argument mapping process, it can be thought as a discussion platform where different ideas are confirmed by using evidence in a computer environment. Ford (2008; 2012) drew attention to the importance of the argumentation process and stated that in order to improve scientific knowledge, claims and evidence should be established and these claims and evidence should be criticised. Recognising the relationship of evidence to the argument is considered a fundamental achievement, and forming an evidence-based claim is seen as the most fundamental and key element of argumentative writing (Hemberger, Kuhn, Matos, & Shi, 2017). In the collaboratively argument mapping practices, students come across many different ideas including both their own ideas and the ideas of the peers. At this point, they try to detect the correct idea out of many options and present evidence for that idea. In the practices, incorrect connections between the ideas and evidence were emphasized by the peers, and the pre-service teachers tried to correct these incorrect connections. As already specified, pre-service teachers used several skills requiring high level thinking together with their peers during the collaboratively argument mapping process. Although a statistical significant

difference could not be found between the critical thinking skill, disposition and general average scores of the experimental groups, average scores of the experiment group participating in the collaboratively argument mapping practices were higher. It can be stated that this difference is a result of these high level thinking activities performed by the pre-service teachers during the collaboratively argument mapping process.

In the literature, individual and collaboratively dimensions of argument mapping have not been examined separately and the number of the studies on the skill dimension of critical thinking is higher (van Gelder, 2013; van Gelder 2005; van Gelder 2015). Thus, it is thought that the present study, where both individual and collaboratively argument mapping practices were performed and the impact of argument mapping on both dimensions (skill and disposition) of critical thinking was examined, makes a significant contribution to the relevant literature. In addition to these, it is thought that the study makes significant contributions in terms of concretising the relationship between critical thinking and argumentation. One of the aims of this study is to enable pre-service teachers to present the complexity of weekly topics in an interconnected and summative way during the argument-mapping phase. In this case, it is possible to say that they find the opportunity to combine the common thinking structures in the critical thinking and argumentation process as expressed by Andrews (2015).

Critical thinking is a way of thinking incorporating many skills. According to van Gelder (2005), critical thinking includes the use of various low-level cognitive skills in an effective and masterful manner. These cognitive skills are interpretation, analysis, assessment, deduction, explanation and self-regulation (Facione, 2015). Based on this, these skills need to be incorporated into the learning process and be actively used for the development of critical thinking. Also, the importance of integrating evidence-based discussions into the main courses is emphasized (ter Berg & van der Brugge, 2013).

It is stated that the dialogic and dialectical nature of the argument as well as its structure that explores the distinction and difference between ideas encourage critical thinking (Andrews, 2007). In the argument mapping process, mounting a claim, presenting reasons for or objections to a claim and establishing the relation between the main idea and other ideas are important activities. During these activities, it is necessary to be mentally active and use the above-mentioned critical thinking skills intensely. Argument mapping, which is highly effective in the development of critical thinking, ensures that low-level cognitive skills are used actively and effectively.

Argument maps help students avoid of the complicated structures of the arguments and identify the reasoning problems in the argument (ter Berg & van der Brugge, 2013). This is because of the fact that, during argument mapping, individuals present reasons supporting the main claim, try to refute the claim by using counter claims, mount new claims in connection with the main claim and understand the basic structure of an argument through visualisation (Davies, 2010). Argument maps help us organise and manipulate complex information, promote the clear expression of our reasoning and allow us to convey this logic quickly and effectively (van der Brugge, 2018). While performing these activities, they actively use many skills including thinking in an active manner, assessing reasons and objections, explaining ideas by using evidence and revising the wrong ideas or negative thoughts. This is in conformity with the requirements specified by Twardy (2004), who argues that a student needs to perform reasoning, define the outline of the claims and assess the evidence to be able to think critically. Similarly, it is stated by Davies and Barnet (2015) that critical thinking is closely related to the development of various skills such as argumentation and making sound judgements at the end of such argumentation. Argument maps help students evaluate reasoning, making it easier to evaluate each inference step of an argument and see how the evaluations of each step affect the result (Davies, Barnett, & van Gelder, 2019). In particular, it can be said that cognitive skills such as making inferences and evaluating, used in the process in which the argument structure is analysed, support critical thinking. Although individuals have critical thinking skills, they cannot use these skills provided that

they lack the critical thinking dispositions (Kabataş Memiş, 2016). Kuvaç and Koç (2014) point out to the importance of developing critical thinking dispositions in individuals in addition to the critical thinking skills. Based on this, the necessity of developing critical thinking dispositions of the individuals along with their critical thinking skills has come to prominence. One of the most significant results of this study is the significant differentiation of experimental groups from the control group in terms of critical thinking disposition. In the literature, it is stated that the prerequisite for an individual to use critical thinking skills is to have critical thinking disposition. Thus, it can be argued that significant differentiation of experimental groups with respect to critical thinking disposition had an impact on the use of critical thinking skill. It can be stated that argument mapping practices were effective in the development of the critical thinking dispositions of the pre-service teachers. Supporting critical thinking skills and dispositions through argument mapping ensures that pre-service teachers feel more enthusiastic about critical thinking. It can be said that argumentation practices are a good method that enables the use of critical thinking skills in the classroom in terms of providing a visual structure that both supports cooperation and individually encourages students' self-evaluation and self-regulation (Sönmez et al., 2020).

ABI approach used in the learning environments naturally encourages students to perform numerous activities including research, questioning, discussing with peers and teachers and writing. Although individuals have the opportunity to review the reasoning and argumentation process with their test reports (writing activity) after the discussion activities in the Science Writing Heuristic (SWH) process, they do this in standard prose. It is much more difficult to see changes in argument structure and results using prose alone without the visual cues provided by the mapping software (Davies, Barnett, & van Gelder, 2019). In the present study, in addition to the ABI approach, the impact of computer-aided argument mapping on critical thinking was examined. Here the aim is to reveal the difference caused by computer aided argument mapping. Studies examining the impact of argument mapping in addition to different approaches used in the learning environments are recommended. It is important to examine whether the combination of argument mapping with different approaches will yield results similar to those obtained in our study. Also, it is of great importance that individuals understand the elements of an argument structure and the relations between these elements. Thus, integration of the argument mapping practices into learning environments much more will be a significant step to this end.

SUGGESTION AND LIMITATIONS

Within the scope of this study, argument mapping practices were carried out during an academic term on the subject of "Optics". The CTT test used in the study can generally measure tendency and skill sub-dimensions. The use of open-ended tests is limited in that it allows us to measure the critical thinking of the participants to the extent of their expression skills. However, considering the positive effects of argument mapping practices on the development of critical thinking according to the results obtained, it is recommended to enrich teaching by integrating argument mapping into higher education programs. Since the current study was conducted only on "Optics" in the field of science, it would be beneficial to study argument mapping in terms of both critical thinking and other instructional outcomes within the scope of different fields and subjects.

AUTHOR CONTRIBUTION

-The first author contributed research design.
-All three authors actively participated in the implementation of the research, the collection and analysis of the data, and the reporting of the research.
-The second author contributed to revisions of the article in the journal evaluation process.

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