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Computer-Aided Argument Mapping for Improving Critical Thinking: Think Better! Discuss Better! Write Better!

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Abstract

The aim of this study is to investigate the impacts of the use of computer-aided argument maps as a tool to promote prospective teachers' critical thinking skills and dispositions. In this regard, qualitative research method was used in the study. The data of the research were collected through semi-structured interviews. Study group consists of 30 senior prospective teachers from three different classes studying science teaching at a university in Turkey in 2017-2018 academic year. At these three classes mentioned, individual and collaborative argument maps were created in addition to the ABI (Argumentation-based inquiry) activities. The study group was formed on a volunteer basis with 10 students from each class who were selected from, their course performances into consideration. A computer software was used to create the argument maps. Data obtained from interviews were analyzed through NVIVO program. The results obtained indicated that critical thinking skill sub-dimensions such as explanation, analysis, interpretation, evaluation, Self-correction and critical thinking disposition sub-dimensions such as questioning the reliability of sources, being open and fair-minded, being respectful of differences were emphasized more in the group in which the prospective teachers performed computer-aided, individual and collaborative mapping rather than the group in which only ABI activities were performed.
Key words: Argumentation, Argument map, Argumentation-based inquiry (ABI), Critical thinking skills and dispositions.

Introduction

In this age, most of human life is spent by solving the problems that change every day and making decisions regarding the sudden situations that develop. With the ease of access the Internet, there has been an excessive increase in information produced and shared. This information may mislead us about the decisions we make. Hence, when individuals cannot distinguish the accurate information they obtain from many sources from the inaccurate one, it causes more harm than benefit for them.

It becomes even more important for individuals to solve their increasingly complex personal and social problems. This is because individuals are needed to think free of prejudices and intuitive ideas, rationally, in a word, critically, to make healthier decisions with regard to society. In the same direction, Partnership for 21st century Skills (2017) emphasizes the need for the US education system to raise every student with critical thinking skills to ensure their success in their daily lives. In this regard, in line with the trends in the world, Turkish Education System aims to raise generations that have acquired skills such as critical thinking, problem solving, innovativeness, creativity, communication and collaboration within the scope of learning and innovation skills stated by Fadel (2008) as the skills of this century (Ministry of National Education [MoNE], 2017). When considered from this point of view, it is possible to say that students equipped with 21st century skills are prepared for the uncertainty of the future beyond today.

Especially, many educators stated the importance of critical thinking and its encouragement should be one of the most important goals in higher education (Davies, 2011; Harrell, 2011; McMillan, 1987). Besides, it has been emphasized in many national and international studies that critical thinking needs to be improved in higher education (Çınar, 2009; Davies, 2011; Doğan, 2006; Harrell, 2011; McMillan, 1987; Higher Education Council [YOK], 2011; MoNE, 2017, P21, 2017; Common Core State Standards Initiative [CCSS], 2017). It would not be the right approach to care for students attending higher education to graduate as individuals only with the

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content knowledge of their field. Individuals' ability to think critically enables them to judge their knowledge rationally and accurately (Mc Millan, 1987), and thus it makes individuals to be more successful in performing various tasks in business life (Davies, 2013). Accordingly, it can be said that critical thinking is a preferred quality in individuals graduating from higher education.

Despite the constant emphasis on gaining critical thinking, some researchers have argued that higher education programs do not offer the experience to support critical thinking which is necessary for students to solve complex problems (Reimold, Slifstein, Heinz, Mueller-Schauenburg, & Bares, 2006). Considering the studies examining the critical thinking of prospective teachers; it is seen that the results of the mean scores from the critical thinking scales are mostly low (Akgün & Duruk, 2016; Can & Kaymakçı, 2015; Grosser & Lombard, 2008; Halpern, 1998; Hayırsever & Oğuz, 2017; Kuhn, 1999; Tümkaya, 2011) and medium (Çakırlar-Altuntaş, Yılmaz & Turan, 2017; Çevik, 2013; Deniz & Kaptan, 2011; Korkmaz, 2009; Kürüm, 2002; Tufan, 2008; Uluçınar, 2012; Yıldırım & Şensoy, 2017). Nevertheless, it is known that students' learning to think critically depends on the competence of teachers on this subject (Demirci, 2000). The ability of teachers to express themselves clearly in a free and democratic environment, their perspectives on situations or events, and to discuss them within the frame of causality can also be reflected in education and training activities. In this regard, the idea of training teachers thinking critically becomes more of an issue to deal with in teacher education programs.

When teacher training programs in Turkey are examined, it draws attention that activities improving critical thinking of prospective teachers are emphasized to be performed in pre-service, teaching practices and content of academic courses. Along the same line, when examining the qualifications that form the basis of teacher competencies, it is seen that the following statements are specified (MoNE, 2017):

- "They obtain information from a questioning point of view in their field (p, 13)"
- "They make self-evaluation by benefiting from the opinions and suggestions received (p, 16)",
- "They respect individual and cultural differences (p, 16)",
- "They cooperate with the relevant institution, person and colleagues in education and training activities (p, 14)",
- "They create democratic learning environments where students can communicate effectively (p, 14)".

This perception requires teachers to assume the role of a teacher who can think critically and carry out activities that support critical thinking in the educational environment.

Critical Thinking

Critical thinking is the evaluation of how accurate a decision is or the results achieved in solving a problem (Halpern, 1996). It is mentioned in the literature that critical thinking has skill (cognitive) and disposition (affective) dimensions. For instance, Facione (1990) state**d** that critical thinking includes cognitive skills such as interpretation, analysis, evaluation, inference, and self-correction. Halpern (1998) emphasized that in order to acquire these skills it is important for students to have these competencies as well as to want to use them. It is believed that critical thinking is not only limited to a proper use of a skill in a given case. Ennis (1991) stated that besides the skills of critical thinking, it also includes dispositional sub-dimensions such as questioning the reliability of sources, being open-minded, being sensitive and respectful to others' emotional, informational and cultural situations. To explain the relationship between the skill and dispositional dimensions of critical thinking, Sears and Parsons (1991) pointed out that those with critical thinking skills might not be inclined to use any of them. However, it should be known that individuals cannot develop expertise in any field without the willingness to make the necessary mental effort to use a skill (Wagner, Leana, Locke, & Schweiger, 1997). This information reveals that both the skill and disposition dimensions of critical thinking are important for students to grow up as good critical thinkers. Therefore, both skill and disposition dimensions of critical thinking are approached together in this study.

The fact that teachers have knowledge about what critical thinking is and its scope, why it is needed and how it should be improved is important in raising critical thinkers. In this sense, the first question that comes to mind should be "Do teachers have the competence to improve critical thinking?". In their study, Paul, Elder and Bartell (1997) examined to which extent prospective teachers were ready to teach critical thinking skills. Within this scope, the researchers interviewed academicians at university. The results showed that faculty members teaching prospective teachers were not able to make a clear explanation of critical thinking mostly and that they did not have information about the skills that should be developed in students. When recent studies are examined, the study of Janssen, Mainhard, Buisman, Verkoeijen, Heijltjes, van Peppen and van Gog (2019) draws attention. This study reveals conclusions that teachers know very little about how to improve their critical

thinking skills and attitudes towards critical thinking teaching. This result shows that prospective teachers are not equipped with critical thinking competencies.

Critical thinking is the ability to evaluate the evidence and rationale for a claim (van Gelder, 2001). For this reason, the ability to mount arguments, analyzing and evaluating arguments are considered as essential components of critical thinking (Ennis, 1987). In this case, it is important to look at the role played by argumentation in developing critical thinking.

In the development of an argument, stages such as making research on the subject, examining the subject from different perspectives, making a claim and identifying concrete evidences that support or refute this claim, mounting an argument accordingly and examining the factors that can improve this argument are followed (Freely & Steinberg, 2000; Toulmin, 2003). In order to realize this process, the individual should use critical thinking skills. Therefore, what enables the development of students' critical thinking is the effective use of these skills in the argumentation process (Allen, Berkowitz, Hunt & Louden, 1999; van Gelder, 2001; Twardy, 2004). Given this need, the Argumentation-Based Inquiry (ABI) approach provides an environment that supports the use of high-level cognitive skills. ABI is an important tool for creating an effective learning environment in which students create arguments, support their claims and actively use their speaking and writing skills in this process (Hand & Keys, 1999). Students' performing activities accompanied by inquiry conducting interactive group work, exchanging ideas and arguments through collective negotiation and creating meaning and reflective writing are series of activities required by the ABI approach (Keys, Hand, Prain, & Collins, 1999). Two templates have been developed to be used by students and teachers in the ABI approach (Keys et al., 1999). In this context, there are some activities including meaningful thinking, writing, reading and discussion skills of students in the teacher template (Table 1.). As another component of ABI, the student template is used individually or as a group during the negotiation phases.

Table 1. Teacher and student template

A template for teacher-designed activities to promote laboratory understanding.	A template for student.
1. Exploration of pre-instruction understanding through individual or group concept mapping.	1. Beginning ideas- What are my questions?
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.	2. Tests- What did I do?
3. Participation in laboratory activity.	3. Observations-What did I see?
4. Negotiation phase I-writing personal meanings for laboratory activity. (For example, writing journals.)	4. Claims-What can I claim?
5. Negotiation phase II-sharing and comparing data interpretations in small groups. (For example, making group charts.)	5. Evidence- How do I know? Why am I making these claims?
6. Negotiation phase III-comparing science ideas to textbooks for other printed resources. (For example, writing group notes in response to focus questions.)	6. Reading- How do my ideas compare with other ideas?
7. Negotiation phase IV-individual reflection and writing. (For example, creating a presentation such as a poster or report for a larger audience.)	7. Reflection-How have my ideas changed?
8. Exploration of post-instruction understanding through concept mapping.	

In simplest terms, an argument is a structure consisting of justified claims after considering different perspectives and data. Argument map is defined as a clear presentation of the reasoning elements regarding this structure and the relations between them using graphics or other non-verbal techniques (van Gelder, 2003). That is to say, in classroom practices, students see their own reasoning manners when they create an argument map using graphical representations. From this point of view, it seems that the 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.

Argument maps have some advantages over traditionally generated arguments. Hoffman (2005) was the first to state that the use of graphical techniques in argument mapping facilitates the analysis of the argument structure. Additionally, the structure of argument maps, which reveals the hierarchical and clear relations between the argument elements, helps to reduce the complexity of the problems. van Gelder (2001) stated that those who

created argument maps were provided with a considerable ease in evaluating and organizing their thoughts. For these reasons, it can be said that argument mapping can be used to support the development of critical thinking. In some studies, effects of the ABI approach on thinking have been examined. For instance, Keys, et al. (1999) and Opstal and Daubenmire (2015) indicated that laboratory practices based on the ABI approach had a positive effect on students' use of metacognitive thinking skills. Roviati, Widodo, Purwianingsih and Riandi (2019) shared conclusions in their study that ABI-based laboratory activities significantly improved university students' critical thinking skills. In another study, it was revealed that ABI, which is an argument-based approach to science teaching of primary school students, improved critical thinking skills (Hand, Shelley, Laugerman, Fostvedt, & Therrien, 2018). Similarly, in a study conducted with 8th grade students, the ABI approach was reported to have a positive effect on the acquirements in critical thinking skills (Jang & Nam, 2013). These studies indicate that the practices based on the ABI approach improve students' critical thinking at different grade levels.

It is crucial for students to see and evaluate their thoughts and reasoning in a concrete way to think critically. van Gelder (2002) emphasized the necessity of creating a mental picture of an entire argument using tools such as an argument map in the application of these activities. This is because during the argumentation process, a student's ability to distinguish between weak and strong arguments and reporting the effectiveness of his own arguments affect his critical thinking (Sanders, Wiseman, & Gass, 1994).

In line with this information, argument mapping, which is a tool used in creating an argument, should be examined.

Argument Mapping

Argument mapping is defined as a completely explicit presentation of the elements of reasoning about the structure of an argument and the relationships between them by using graphics or other non-verbal techniques (van Gelder, 2003). Compared to developing traditional arguments, the visual structure of argument maps enables students to evaluate themselves by revealing the reflection of their thinking. By seeing the visual representation of the thought, a student can better evaluate the logic used and make adjustments (van Gelder, 2001). The repetition of this reasoning process is called deliberate practice according to the Quality Practice Hypothesis (van Gelder, 2001; van Gelder, Bissett & Cumming, 2004). According to the hypothesis: deliberate practices are often required to improve critical thinking. Practices have been associated with gaining expertise in physical and cognitive skills (Charness, Tuffiash, Krampe, Reingold, & Vasyukova, 2005). To this respect, Plant, Ericsson, Hill and Asberg (2005) expressed deliberate practice as students' performing activities intensely from easy to difficult by guidance based on the skills that were aimed to be improved. In order for these practices to be effective, it has been reported that it is important to provide sufficient feedback and redo them until the skill is acquired (van Gelder, Bissett & Cumming, 2004).

Computer-aided argument maps provide more opportunities for deliberate practices than argument maps created using paper and pencil. This is because in computer software developed for the argument map, guidance is provided by offering scaffolding that will ensure the necessary support in individual studies. For instance; when students select a component while creating argument maps with the help of scaffolds, the system can give them some advice on what to do next (van Gelder, 2001). Accordingly, computer-aided argument mapping allows intensive practice within a limited time, thanks to its visual and easily editable structure that reduces the complexity of the arguments. In this respect, computer-aided argument map is a tool to support comprehensive deliberate practices in the improvement of critical thinking.

When the literature is examined, it is seen that computer programs are developed in which argument mapping can be done to help develop quality arguments. For instance, van Gelder (2001) stated that by using the "Reason! Able" argument mapping software, university students made a significant progress in their critical thinking skills as a result of their 12-week practice. In addition, the results of the study indicated that the improvement of critical thinking was at a high level compared to the results of the studies performing teaching practices to improve critical thinking. Similarly, in the study of Donohue, van Gelder, Cumming, and Bissett (2002) university students created argument maps using "Reason!Able" software. California Critical Thinking Skills Test was used to evaluate students' critical thinking skills after they engaged in argument maps activities over a term and the results indicated that argument mapping significantly contributed to students' critical thinking skills. In parallel with other studies, Twardy (2004) also found that the argument maps created through software significantly improved the critical thinking skills of university students. In addition to these results, the fact that some of the students had difficulty in creating an argument map and more time was required to give a

wide feedback to these maps were stated as the limitations of using a software. Nonetheless, the researcher reported that the software was a good experience for most students in terms of improving critical thinking skills.

Some software offers students some features to create argument maps collaboratively and individually. Considering the cognitive processes required to create an argument, it is seen that they include skills such as students' creating a conceptual understanding of the subject, collecting evidence and analyzing it; justifying, sharing and defending discussions; trying to persuade their peers and reaching an agreement at the end of the discussion (Voss & Means, 1991). In this regard, it is possible to say that creating an argument involves both social and cognitive activities. The participation of students in collaborative discussion enables them to increase their social and cognitive interaction. In this way, students can develop their higher-order cognitive skills by having to reason, reflect and synthesize (Akyol, Garrison & Özden, 2009; Darabi et al., 2013; Ioannou, Demetriou & Mama, 2014). In addition to these skills, it is crucial for teachers to provide environments for their students which will encourage them to assume responsibility and support many affective features such as being respectful for different views, seeking for reason, seeking for accuracy.

In the light of this information, this study was carried out to examine the impacts of the use of computer-aided argument maps as a tool to promote prospective teachers' critical thinking skills and dispositions.

Research questions are as follows:
How do ABI activities influence prospective teachers' critical thinking skills and dispositions?
How do computer-aided individual argument mapping in addition to ABI activities influence prospective teachers' critical thinking skills and dispositions?
How do computer-aided collaborative argument mapping in addition to ABI activities influence prospective teachers' critical thinking skills and dispositions?

Method

Qualitative research method was used in the study. In this context, semi-structured interviews were held at the end of the processes in order to collect data on critical thinking skills and dispositions of prospective teachers during the activities.

Study Group

Study group consists of 30 senior prospective teachers from three different classes studying science teaching at a medium-scaled state university in Turkey in 2017-2018 academic year. In one of these three classes mentioned, only activities based on the ABI approach were conducted; in the second one, individual argument mapping were conducted in addition to the ABI activities; and in the third one individual and collaborative argument mapping were conducted in addition to the ABI activities. Study group consists of 30 prospective teachers in total, with 10 prospective teachers from each class. While determining prospective teachers, the fact that their performances were at all levels (good, intermediate and weak) considering experimental reports and voluntary basis were taken into account.

Semi-Structured Interviews

Semi-structured interviews were carried out by the researchers to evaluate to which extent prospective teachers emphasized critical thinking during activities based on ABI approach, individual and collaborative argument mapping. For example, questions were asked to the students whether they made preparations before participating in the activities and about the situations they paid attention to when choosing the resources for those who did, thus existence of the dimension of questioning the reliability of the sources under the disposition dimension of critical thinking was tried to be examined. Each interview was recorded using a voice recorder with the permission of the prospective teacher. Prospective teachers in groups, in which individual and collaborative argument maps were created, were asked questions to determine the skill and disposition dimensions of critical thinking, which they emphasized in the process of creating an argument map (individual, collaborative) and ABI. In the other group, prospective teachers were asked questions about their critical thinking during the ABI experiment activities. For instance, the existence of questioning the reliability of the sources sub-dimension under the disposition dimension of critical thinking was tried to be examined by asking

the prospective teachers in all three groups about whether they made preparations before participating in the activities, and the situations taken into consideration by those who did when choosing the sources.

Research Settings

In all three classes, lessons were carried out for eight weeks based on the ABI approach. The treatment process of the study consists of two parts: ABI and argument mapping activities. The research process was summarized in Figure 1.

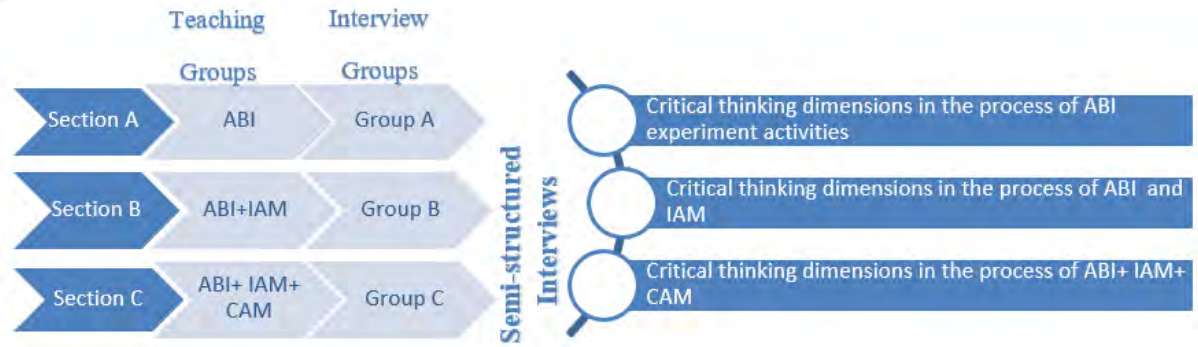

Figure 1. Research Process

Procedures of the ABI Approach

As part of ABI activities, prospective teachers carried out a total of eight activities within the scope of a preparatory activity in small groups and seven "Optics" subjects (light and shadow, mirrors (plane and spherical mirrors), mirror systems, lenses, lens systems and refraction). The preparatory activity was implemented to introduce ABI process and to make the process of creating arguments more efficient by understanding the structure between the claim, the evidence and the claim-evidence. Subsequently, students were asked to make preparations in the scope of the specified topics and come to the class by forming initial questions. In the class, whether the questions created by the prospective teachers were proper to search was evaluated. In order to investigate the questions, they determined, they designed an experiment by making small group discussions consisting of – people. Afterwards, prospective teachers made their claims in line with the experiment they carried out by the nature of the ABI approach. After small group discussions, the students made a large group discussion by presenting the questions they researched, their claims they made as a result of the data they obtained and observations, and their evidence supporting these claims to the class. In the meantime, the researcher asked questions to start and continue the negotiation phase. At the end of the large group discussion, while collecting information on the subject, the researcher asked questions to enable students to make preparations for the next lesson and to draw their attention to the subject. Then, she asked the students to come to class with the questions they wanted to investigate. Throughout this process, the researcher asked questions that sometimes started or continued the discussion and that triggered the prospective teachers to think higher; and acted as a guide.

Procedures of Individual and Collaborative Argument Mapping

An introduction course on argument mapping was given before the experiment activities started in groups (Group B and Group C) that were asked to create an argument map. In this course, students were explained what the argument map was, for what purpose it was created, how it would be used, and the computer program (Rationale-Argument Mapping) where they would create an argument map was introduced. In order to log into the program, each student was provided with pre-created account information and asked to create weekly argument maps through this account. The prospective teachers on both groups created an individual argument map pre-treatment on the subject of "Mysterious Death" activity first so that they could get used to the process. These maps were evaluated by the researchers immediately and deficiencies were eliminated by providing individual feedback. In this way, students made claims, supported these claims with evidence, explained their thoughts with reasonable grounds, and practiced to create their arguments by establishing connections of claim-reason-evidence. Afterwards, the prospective teachers were given the task of creating a total of seven individual argument maps (see Appendix A) on the subject that reflected the main idea of that activity after each

experiment activity. They were asked to send the argument maps they created individually to the e-mail address stated by the researchers within the specified timeframe. The researchers gave the students feedback about the process by evaluating their individual argument maps every week. One of these two groups (Group C) created an collaborative argument map (see Appendix B) in addition to the individual argument map. So as to make the interaction more efficient in a short time while creating a collaborative argument map, the students worked in small groups of two people. Two students within a group shared one computer to generate their argument maps in a computer laboratory. The prospective teachers started to create an argument map within the framework of a claim made by the researchers before the experiment activity (For example, reflection occurs in the lenses). There was another small group where each small group together would create an argument map. The groups had the opportunity to discuss and create collaborative argument maps simultaneously. The students attempted to use the data in line with their claims or to persuade the other group by referencing different sources (own information, book or internet) and sharing their visuals. The researchers, on the other hand, were involved in the simultaneous discussions of them with the opportunity to access the argument maps of all groups. By taking the role of a guide, they asked questions triggering the prospective teachers to make inquiries regarding their claims, reasons and evidence; and added supportive or disproving statements to their maps. Throughout this process, the prospective teachers produced 4 collaborative argument maps in accordance with the nature of the subjects (shadow, mirror, refraction and lens). Each collaborative argument mapping was carried out in about two-hour time period. At the end of each collaborative and simultaneous argument mapping, the students were given feedback after the evaluation of their argument maps by the researchers in terms of the accuracy and explanation of the statements, whether the claims were hierarchical, the validity of the evidence, and the interaction levels of the groups.

Data Analyses

In order to evaluate the data obtained through semi-structured interviews, the interviews were transcribed into written documents. The data obtained from the interviews were analyzed based on definitions of critical thinking skills and dispositions published by Facione (1990) as the Statement of Expert Consensus on Critical Thinking Educational Assessment and Instructional Purposes within the scope of Delphi research project. Content analysis was conducted using NVivo 11 program.

Trustworthiness of The Study

In this study, the procedures stated by Creswell and Miller (2000) that should be used to ensure validity in qualitative research such as long-term observation in the research environment, detailed description of the research environment, participants and the themes created, and supervision of the research process by both someone involving in the research and someone outside the research were taken into consideration. Since the treatments were carried out by the researchers, sufficient time was spent with the participants in the research environment. The researchers met prospective teachers before starting the practice and interacted with them during process. It is one of the measures to be taken in order to increase the quality of the research by asking the experts having general knowledge of the study and specialized on qualitative research methods to examine the research from various perspectives. In this regard, the researchers aimed at ensuring internal audit with two field experts involving in all stages of the research process. In the method of the research, the research environment and the characteristics of the prospective teachers participating in the interviews were tried to be defined. Interview questions were created with two of the field experts on the subject, and the points to be considered in semi-structured interviews were emphasized. Examinations were made on the significancy and integrity of the findings obtained from the interviews. The consistency of the themes between sub-themes and codes and with other themes was evaluated and whether they constitute a meaningful whole was examined. The results were presented by giving direct quotations from the interview text.

Results and Discussion

As a result of the analyses of the interviews with the prospective teachers participating in the ABI experimental activities, collaborative and individual argument mapping, Critical Thinking theme and, within this scope, two sub-themes as Critical Thinking Skill and Critical Thinking Disposition were determined. The codes of explanation, analysis, inference, interpretation, evaluation and Self-correction as part of Critical Thinking Skill sub-theme; the codes of open and fair mindedness, seeking for alternatives, seeking for accuracy, seeking for causes, curiosity, evaluating a complex subject regularly, seeking for a clear expression of the problem statement, questioning the reliability of the sources, seeking for the certainty of the subject, evaluating the

subject holistically, being respectful and sensitive to the knowledge, emotion and cultural status of someone else and attitude towards decision- making in cases where the reason and evidence are insufficient as part of Critical Thinking Disposition sub-theme were formed. Themes, sub-themes, frequently mentioned codes and sample expressions regarding these were presented in Table 2.

Table 2. Results Related to Critical Thinking Theme

Theme	Sub Theme	Code	Sub Code	Frequency (*f*)* Section A	Section B	Section C
Critical Thinking	Critical Thinking Skills	Explanation	Presenting Arguments	12	14	17
			Justifying Procedures	15	17	23
			Stating Results	2	4	6
		Analysis	Identifying Arguments	1	5	7
			Analyzing Arguments	1	10	13
			Examining Ideas	9	11	15
		Inference	Conjecturing Alternatives	-	1	4
			Querying Evidence	3	5	7
			Drawing Conclusions	7	7	8
		Interpretation	Clarifying Meaning	3	5	7
		Evaluation	Assesing Claims	12	14	17
			Assesing Arguments	3	5	9
		Self-Discipline	Self-Examination	5	15	16
			Self-Correction	-	2	3
		Total		**73**	**116**	**152**
	Critical Thinking Dispositions	Questioning the reliability of the sources		5	6	8
		Seeking for causes		1	-	-
		Curiosity		1	-	-
		Attitude towards decision- making in cases where the reason and evidence are insufficient		1	1	2
		Being respectful and sensitive to the knowledge, emotion and cultural status of someone else		3	3	15
		Evaluating a complex subject regularly		-	1	1
		Evaluating the subject holistically		-	-	3
		Seeking for a clear expression of the problem statement		3	4	8
		Seeking for alternatives		5	4	5
		Seeking for the certainty of the subject		3	6	5
		Open and fair mindedness		3	3	15
		Seeking for accuracy		5	8	6
		Total		**28**	**36**	**70**

***** Each prospective teacher can highlight the sub-codes more than once during the interviews.

Results Related to the Critical Thinking of Prospective Teachers (Group C) Participating in ABI, IAM and CAM in the Process

Sub-Theme of Critical Thinking Skills

When the data in Table 2 are examined, it is noteworthy that under the sub-theme of Critical Thinking Skill, the prospective teachers who expressed their opinions about ABI, IAM and CAM processes made statements mostly on the situation "*Justifying Procedures*" under the code of "*Explanation*". They stated that while evaluating the claims presented by other groups, the experiment process should be examined in order to be convinced of the suitability of the experimental environment, the accuracy of the methods used and the results they obtained. A prospective teacher stated the following regarding this situation: "*After all, we have information. We conducted the experiments, too. It's the same thing after all. We state what is missing in their claims. It's okay if they can show the things that are not clear in our minds on the experiment*." Another prospective teacher explains as in the following that he or she uses the "Justifying Procedures " situation to

persuade other students who evaluate their claims: "*When only our observations were sufficient to explain, we tried to convince them with our observations; when that was not enough, we tried to convince them with the experiment we carried out. In other words, when they were not convinced of the statement we made we were showing it through experiment*." A prospective teacher emphasized that the process should be proved in order to ensure the accuracy of the results they obtained during the phase of explaining the arguments with this statement: "*When someone says something, I think they can see that situation inaccurately. Or, they may misunderstand and misinterpret. But the reason why we are five people there is to correct when it is wrong or to prove it if it is accurate. We were always testing this among us. So, it's nice to have different views*."

One of the codes under Critical Thinking Skill sub-theme that the prospective teachers frequently emphasized regarding the practices was "*Analysis*". For example, a prospective teacher used the following expressions related to the sub-code of "*Examining Ideas*": "*Creating an argument map helped me a lot to understand and establish connections between concepts. Apart from questioning on my own, when making the claim, I was always questioning and discussing in the group on the reason, accuracy and provability*." Another prospective teacher mentioned that creating an argument during the process has a positive effect on himself regarding the sub-code "*Identifying Arguments*" as follows: "*The first argument map I created and the present one is very different. I always asked questions based on my claims on the most recent argument map. I can understand whether I have created a valid argument based on my answers. Unnecessary information creates confusion. Thus, just adding supportive information is important for a good argument. Now I'm paying attention to these*."

It was seen that the prospective teachers expressing their opinions on the practice highlighted the explanations about the "*Assessing Claims*" situation under the code of "*Evaluation*" within the scope of Critical Thinking Skill sub-theme. The prospective teachers mostly made evaluations about the quality of the claims they made in the ABI and CAM processes. They were asked questions about how they made the evaluation of the experimental stages of the claims that put through in small and large group discussions and what their evaluation criteria were. It was stated that, while evaluating the claims made by their friends, the prospective teachers paid attention to the accuracy of the results they obtained by conducting experiments and the use of those results as evidence. In this regard, they stated that the claims which could be proved with sufficient evidence, comprehensible and clearly formed were found to be of higher quality. For example, a prospective teacher explained this situation as follows: "*The claims made should be clear and understandable. They should refute the opposite view completely. So, I think there should be more supporters of the claims. In order to be a qualified claim, they must have supporters explaining every situation*." Another prospective teacher mentioned the criteria he or she took into consideration for the claim to be quality as follows: "*You need to have a good evidence for a good claim. There must be a lot of evidences*". When the prospective teachers were asked about the effect of argument mapping on the process, those in Group C stated that they frequently made "*Self-Examination*" and, in this regard, some went through "*Self-correction*". For instance, a prospective teacher's opinion on Self-correction is as follows: "I think it's good to see that my idea is wrong. Because you attend the class to learn and to correct your mistakes. I mean, you may assume something is correct. However, when you try it there you may say what I saw was wrong. I think it is not a bad thing." The statement of another prospective teacher on making self-examination is as follows: "In this process, I was constantly sounding my own knowledge. You cover a topic this week and then move on to other topics. You don't need to study it over again. But, it is not like that in these activities. The information is interconnected. I cannot find support for it or make a claim without knowing that subject. You learn the subject completely by finding the right way to correct that mistake and support it." Another prospective teacher pointed out the "Self-Regulation" code while evaluating ABI, IAM and CAM process: "At the beginning of the treatment, I did not know how to express myself and create a map to refute or support my claim. Especially, collaborative mapping is very different from the individual one in this respect. Now, I know better how to provide an evidence to support my claim. I had an effort to show what I know on the individual argument map, but I think there is more in the collaborative one. Because you are proceeding mutually. It proceeds in an interrogatory way. People may question themselves, but may not be able to look from a different angle. When it is collaborative, we can respond differently." Additionally, the prospective teachers were asked to compare the report preparation process, which was a writing activity in ABI process, and the argument mapping process, which was another writing activity used in addition to that process. For example, a prospective teacher made comparison with the following statements: "What we said in one of the CAM activities was refuted. On one occasion we refuted ourselves, too. Because what we wrote about the concepts of reflection and refraction were confused at first. When we wrote something inaccurate at that point, we realized our mistake about those concepts and refuted ourselves. Since the information was always in front of our eyes on the argument map, I could see the difference more clearly. As there is only one experiment in the report, we just wrote it immediately. But, on the argument map, we considered whether it was okay or not. There was the time another idea could come to our mind during the process. Therefore, I think the argument map was a bit more effective than the report" The prospective teachers

were asked questions about at which stage and how they expressed their ideas in small group discussions. In this regard, while the prospective teachers in Group C mentioned that they had small group discussions at the stage of obtaining data in order to create a quality claim in the ABI activities, they frequently pointed out "*Drawing Conclusions*" situation under the code of "*Making Inferences*" within the scope of Critical Thinking Skill sub-theme. For example, a prospective teacher mentioned that they paid attention to determining the correct results by organizing their experiments repeatedly: "*For example, when two thin-edged lenses were used and the object was placed between the two lenses, the reverse image was reflected on the screen. No, erect image was reflected. But, I was examining whether it was erect or reverse when we reflected on the wall. We questioned ourselves about where exactly the image was. "No," one of us said. "First we need to bring the lens closer to the object". Then another friend said, "No, we need to bring the lenses closer to each other or keep them a little further away from each other. We observed what was correct by experimenting* "

Sub-Theme of Critical Thinking Dispositions

During the semi-structured interviews, prospective teachers were asked whether they made preparations before coming to class; and if they did, what resources they scanned and according to which criteria they selected these resources. It was seen that prospective teachers frequently emphasized the code of "*Questioning the Reliability of the Sources*" by stating that they paid attention to the reliability of the resources while choosing them. Additionally, they pointed out the situation of "*Open and Fair-Mindedness*" by stating that they did not hesitate to explain their ideas in small and large group discussions and that they reached a compromise by discussing. They stated that preparing a collaborative argument map provided more opportunities to be open and fair-minded. For example, a prospective teacher stated the following sentences about this situation: "*If somebody is shy, they will not speak out in the class. With collaborative argument map, they can express their thoughts more easily in an electronic environment*." Another prospective teacher expressed this situation as follows: "*When on the board, not everyone can talk to the class because they cannot be comfortable. They may be shy. We can object to each other very comfortably in groups where we create collaborative argument map; we present our knowledge although it is accurate or not at that moment. If it is wrong, they can correct me. In this way, they reinforce their knowledge, as well*."

In the interviews, when the prospective teachers were asked about the contribution of small group discussions to the process, they stated that situation enabled different ideas to arise. They emphasized that having different ideas enabled them to make the inquiry more comfortably and to reach more accurate results. They pointed out the code of "*Being Respectful and Sensitive to the Knowledge, Emotion and Cultural Status of Someone Else*" within the scope of Critical Thinking Disposition dimension by stating that situation was important in terms of creating stronger arguments, and therefore they respected different ideas. A prospective teacher who stated that his or her ideas are cared by the group members and that he or she also cared about that situation presented the following sentences: "*Differentiation of ideas prompted us to think. Because when you say something, group ideas are consulted. When I say anything in this group, it can be put into perspective. Actually, it makes me feel good because I can express myself*." The prospective teachers were asked to compare the processes of creating collaborative and individual argument maps. In this regard, they stated that creating an argument map contributed more to the "*Evaluating the Subject Holistically*" situation. For example, a prospective teacher explained this situation as follows: "*If I look at it from different aspects, there is something that they all contributed to me. In the individual argument map, I create a map which can show me what I know and have learnt, and which can contribute to me in the future. I convey all I know to there. I convey what I know in the collaborative one, as well. But when a contradictory thought is presented, my map gets wider because it leads me to the different things that I do not know. Since my knowledge is expanding, I think collaborative one is more useful. But we cannot say the other one is useless*." Another prospective teacher made the following explanations about this situation: "*I am planning to use it when I become a teacher, as well. Because you look at things from a general aspect. That is to say, all the information is included*."

Results Related to the Critical Thinking of Prospective Teachers (Group B) Participating in ABI and CAM in the Process

Sub-Theme of Critical Thinking Skills

As a result of the analyses of the interviews regarding ABI, IAM and CAM treatment, the prospective teachers mostly emphasized the importance of "*Justifying Procedures*" situation within the scope of Critical Thinking Skill dimension by mentioning having knowledge of the experimental process in order for them to be able to evaluate the claims. A prospective teacher explained this situation with the following sentences: "*For example,*

if it is necessary to conduct an experiment in a large group discussion, it is very important for that person to do the experiment and to tell the calculation steps. Have those steps handled correctly? In the meantime, the result has been found as 10, but was it 8+2 or 6+4?" With this statement, the prospective teacher emphasized that the control of the valid method and obtaining reliable results, that is to say "*Justifying Procedures*", was effective in evaluating the claims. In addition to this situation, the prospective teachers in group B mentioned that comparing ideas and concepts within the scope of "*Analysis*" code was important in identifying problems and investigating the effect of the part on the whole. For example, a prospective teacher stated the following expressions for the sub-code of "*Examining Ideas*": "*Sometimes the groups put forward the same claims. In that case, we compared our own process with theirs. We compared our results with theirs. In this process, we questioned and discussed theirs as well as ours in a large group. We tried to find what changed the result we reached*."

The prospective teachers in group B frequently emphasized the sub-code of "*Assesing Claims*" under the "*Evaluation*" code by mentioning the quality of the claims and the characteristics that a good claim should have. A prospective teacher mentioned that he or she evaluated his or her own claims according to these criteria in order to make a strong claim while preparing an argument map as follows: "*After finding a claim, we consider it more comprehensively. We evaluate it with different interpretations and approaches. In this process, we need to have an opposing idea to refute this claim*."

It was observed that the prospective teachers emphasized the "*Self-Examination*" situation under the code of "*Self-Regulation*" during the practice of argument mapping. For instance, a prospective teacher stated the following expressions about the situations he or she noticed individually when evaluating the argument map processes that he or she created regarding the same subject with the claims made in the ABI activities: "*During the large group discussion, the least criticized claim was ours, which could not be refuted, in the mysterious death activity we conducted before the experiments. While creating argument map, I was almost going to refute my own claim. I realized what I did not notice neither in the large group discussion nor in the report while creating argument map. I thought I needed more supporters*." Another prospective teacher emphasized having difficulties in associating the ideas he or she thought was correct and noticing this situation while preparing an argument map individually: "*The argument map was good for reviewing the subject and it made us realize our mistakes. It is related to where I put the information I give on the map and with which one I establish a connection. Actually, the information is not wrong but the connections are wrong. I noticed that."*

Sub-Theme of Critical Thinking Dispositions

The prospective teachers, who were asked about their thoughts on having different ideas in small group discussions, emphasized the code of "*Seeking for the Certainty of the Subject*" by stating that they dealt with a situation in different aspects and investigated the certainty of the situation. A prospective teacher stated the following about this situation: "*At the end of the process, I realized that we needed to make evaluations through these discussions. Because you have to base things upon something. Things have to be certain for the result to be solid*." Another prospective teacher explained with the following sentences that the use of reasoning and objections in the process of individual argument mapping affected the certainty of the claim: "*In the first argument map, I did not form a sentence starting with "But", "However". I went on using the conjunction "Because", that was how I formed the sentences. It is like a ladder. However, in the last one, I knew that I should use all of them to increase the strength and certainty of the information. I will use them accordingly*."

Results Related to the Critical Thinking of Prospective Teachers (Group A) Participating in the ABI Activities in the Process

Sub-Theme of Critical Thinking Skills

Within the scope of Critical Thinking Skill dimension, the prospective teachers in Group A emphasized the sub-codes of "Justifying Procedures", "*Presenting Arguments*" under the code of "*Explanation*" and the sub-code of "*Assessing Claims*" under the code of "*Evaluation*". The prospective teachers in Group A emphasized the situation of "*Drawing Conclusions*" under the code of "*Explanation*" more than those in Group B and C. When the prospective teachers were asked about the characteristics of a good claim, they stated that making it with valid methods and reliable results was crucial. They stated that this situation could only be evaluated by indicating the results. For instance, a prospective teacher expressed the following statements about this situation: "*The results have to be explained. For example, there should not be different results. Everyone should reach the*

same result." Another prospective teacher expressed with the following sentences that it caused the claim to be weakened when the results obtained were not recorded or stated: "*When our friends asked questions and we could not answer them, we would be refuted. Instructor sometimes asked questions but we could not give an answer. Actually, we conducted that experiment, but sometimes we could not support our claim because we could not find what she wanted from us. We needed to answer the questions of our friends. If we were not able to give an answer, we would be automatically refuted. So, we did the experiment correctly. However, since we could not answer the questions, we were refuted*." When the prospective teachers were asked about their opinions regarding the reports they created during the ABI process, those in group A stated that stage provided the opportunity of "*Self-Examination*". For example, a prospective teacher explained this situation as follows: "*It enabled me to see the change in myself. In my first report, there was nothing in my mind about what to ask or what to do. I was not aware of anything till now as to what I knew or what I learnt. The report writing process made me be aware of myself. I learnt that I needed to ask questions and to think about how I reached a result. During this process, I realized what I knew before and what I gained. That's why I cared about the report a lot and I filled it carefully. As I said before, my first and last report is different from each other. I noticed the improvement in myself*."

Sub-Theme of Critical Thinking Dispositions

As a result of the analyses of the semi-structured interviews, it was observed that prospective teachers in group A mostly emphasized the code of "*Conjecturing Alternatives*" within the sub-theme of Critical Thinking Disposition dimension. For example, when asked about the effect of small group discussions on the experimental process, a prospective teacher explained as in the following that they experienced the situation of seeking for alternatives during the design and implementation phase of the experiment due to different ideas: "*Everyone in the group expressed their ideas, and then we conducted the experiment again accordingly. When someone stated that something was wrong or when we could not reach a result, they thought of trying again in another way. So, we tried in another way, as well. We proceeded with a common idea of everyone. We did not experience anything that would affect the experiment negatively."* Another prospective teacher similarly emphasized the code of "*Conjecturing Alternatives*" with the following expressions while experiencing the same process: "*For example, in experiments that we could not carry out, we tried to reach a result through changing the way or experiment setup by looking at our drawings, reviewing our thoughts again or exchanging ideas with our friends again.*"

Conclusion and Recommendations

In this study, which sub-dimensions were indicated by the prospective teachers, who participated in ABI, IAM and CAM practices, within the scope of skill and disposition components of critical thinking during the practices was addressed in a holistic approach. Although the tools used to measure critical thinking in the literature mostly examine only one dimension of critical thinking, they do not provide a deeper knowledge about its sub-dimensions (E.g. The California Critical Thinking Disposition Inventory, Cornell Critical Thinking Test, Watson-Glaser Reasoning Test). Also, this study presents the idea that interviews can be used as an alternative in the analysis of critical thinking, since studies of adapting scales to every language and level are either not conducted or are not up-to-date. In this respect, it is possible to say that this study will contribute to the relevant literature.

Additionally, it is important to conduct studies in which different approaches are applied in learning environments and the effects of argument mapping are examined. This study was limited to interviews as the data sources used. For future research, the evaluation of in-class observations on argument mapping practices and the argument maps produced at the end of the process is recommended now that it will provide evidence not only for the quality of the arguments, but also for the process itself. Consequently, it is emphasized that students and teachers' knowing the structure of an argument and creating quality arguments are crucial both for their academic and business lives. Therefore, more integration of the argument maps in learning environments will be an important step to accomplish this aim.

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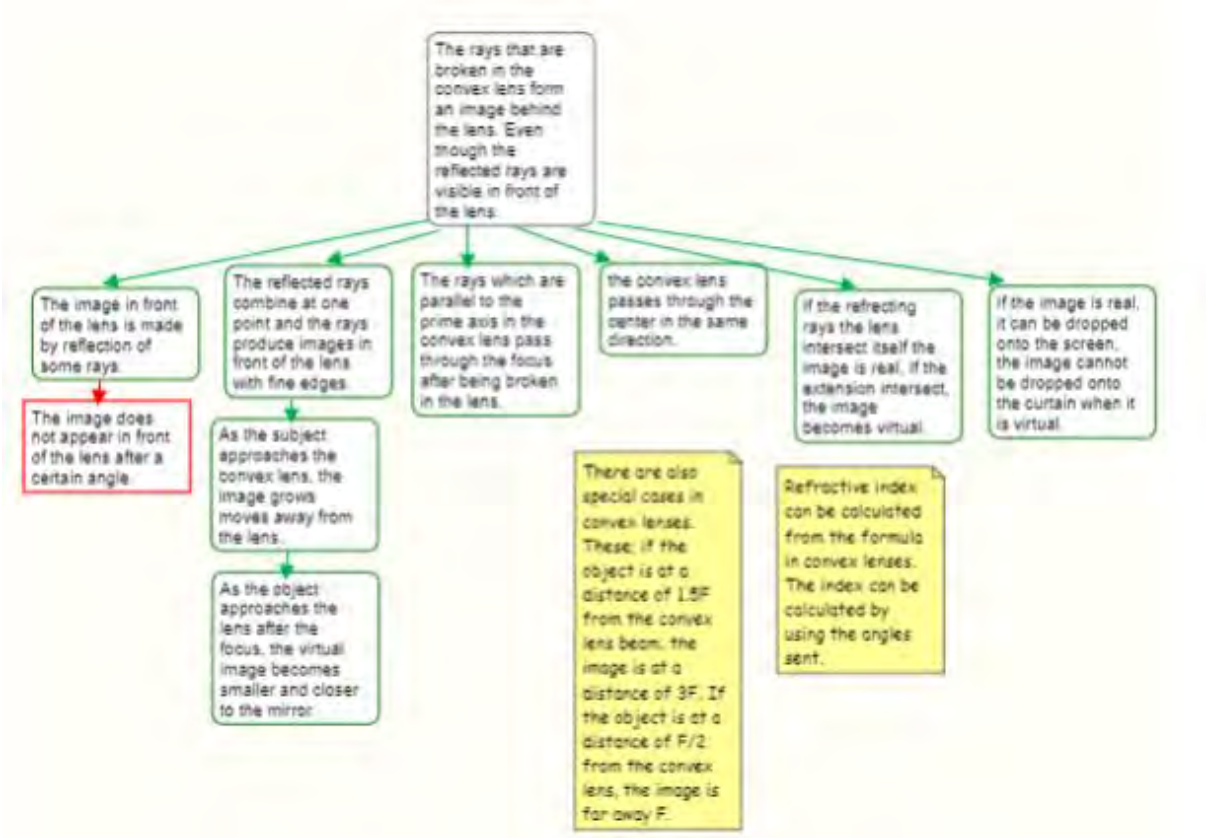
Appendix A. An Example of Indiviual Argument Map



Appendix B. An Example of Collaborative Argument Map