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STEM Education Practices: Examination of the Argumentation Skills of Pre-service Science Teachers[1]

Ibrahim Erdogan[1] Ayse Ciftci[1*] Bekir Yıldırım[1] Mustafa Sami Topcu[2]
1.Department of Mathematics and Science Education, Muş Alparslan University, Muş, 49000, Turkey
2.Department of Mathematics and Science Education, Yildiz Technical University, Esenler, Istanbul, 34000, Turkey

Abstract
The aim of this research is to examine the pre-service science teachers' progress in structuring their argumentation components during the STEM education practices. In the research were worked with 9 pre-service science teachers who are 3rd grade students and took the course of 'Science Laboratory Practices' in a state university. The research is a case study. In the research, structured and unstructured activities were applied for 9 weeks. In structured practices, instructions were followed to show how simple machines are constructed. Unstructured practices were based on the design of pre-service science teachers. The data of the research is obtained through voice recordings, unstructured observation. Argumentation components were examined according to the descriptive analysis approach. As a result of analysis of obtained data; pre-service science teachers have made great progress in constructing argumentation components (claim, evidence, reasoning and rebuttal), and the average score of the rebuttal was found to be lower than the other components. The results obtained from this study demonstrate that STEM education is an effective approach to improving the argumentation skill. Argumentation takes part in engineering design processes which have great importance in STEM practices; given its major role in identifying problems, development of possible solutions and determination, evaluation and discussion of most plausible ones. Therefore argumentation approach can be included as part of STEM education.
Keywords: STEM education, argumentation, science education, pre-service science teachers

1. Introduction
In the 21st century, the basic qualifications that an individual has to earn have changed and the importance given to the cultivation of qualified human power has increased, as the progresses in the fields of science and technology are so fast. In the century we live in, new approaches such as STEM (Science, Technology, Engineering, Mathematics) education and argumentation play an important role not only in the training of entrepreneurial individuals who are curious for science, problem-solver, productive, open to innovation but also for the desired quality human power. Therefore, it is important to include STEM education and argumentation practices in learning environments that support the development of 21st century skills, engage in scientific inquiry and scientific explanations.

1.1. STEM Education
STEM education, which includes interdisciplinary approaches to science, technology, engineering and mathematics, has gained worldwide significance with its innovative approach to education (Gonzalez & Kuenzi, 2012). "The notion of STEM education is aroused based on the need of raising citizens who can contribute to nations' economic and cultural competency, in the new information era that we are living." (Soylu, 2016, p.38). According to Bybee (2013), the STEM reform has four themes that make it different: citizens' understanding global challenges, changing perceptions about environmental issues, recognition of 21st-century workforce skills and ongoing national security issues. In accordance with the above definitions and explanations, we can say that STEM education is an interdisciplinary approach that contributes to the development of 21st-century workforce skills and high-level thinking skills and to the development of countries.

In the 21st century, importance is attached to the development of skills such as critical thinking, problem solving, entrepreneurship, productivity, innovation, leadership, responsibility, knowledge, media and technology literacy (Partnership for 21st Century Skills, 2009). The 21st century workforce skills are also compatible with scientific research and engineering design (Bybee, 2010a) and have a great importance in professional success (Akyıldız, 2014). In this century, many professions require STEM knowledge (Lacey & Wright, 2009) and STEM education has an important role in preparing students for the 21st century workforce (Sahin & Top, 2015). In addition, STEM education plays a fundamental role in the economic, technological and scientific development of countries (Means, Wang, Young, Peters & Lynch, 2016; Sahin, 2013; Sahin & Top, 2015). Therefore, this situation necessitates the implementation of STEM education in learning environments to acquire the knowledge

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and skills required by the 21st century.

According to Bybee (2013, p. x), education should contribute to: "a STEM-literate society, a general workforce with 21st-century competencies, and an advanced research and development workforce focused on innovation." In the realization of the stated objectives and in the dissemination of STEM education throughout the country, teachers with the necessary education and competence in the STEM field have a key importance (Wang, 2012). Teachers have difficulty linking STEM disciplines (Kelley & Knowles, 2016). Teachers need to have knowledge and competence in other STEM areas outside their own fields, so that they can integrate STEM practices into their lessons (Eroglu & Bektas, 2016).Therefore, for STEM education, there is a need for teachers who know interdisciplinary integration, how to integrate the course, have sufficient field knowledge, and follow the developments in the field of education (Akgündüz, Ertepinar, Ger, Kaplan Sayi & Türk, 2015). In addition, STEM literacy should be the main goal of programs implemented in schools to improve STEM education (Bybee, 2010b). One of the indicators of STEM literacy is evidence-based conclusions on STEM-related issues (Bybee, 2013), and argumentation plays a central role in improving it.

1.2. Argumentation

An effective science education can be realized in a classroom environment where students can comfortably express their opinions, support ideas with evidence, and establish counter arguments in order to refute their friends' claims (Kaya &Kılıç, 2010). Helping students to provide evidence for their claims is one of the main objectives of science education (Driver, Newton & Osborne, 2000). Therefore, it is important to include students in the argumentation process. The argumentation used by scientists in the construction of scientific knowledge throughout the history of science and is an indispensable component of scientific reasoning in everyday life and science (Aslan, 2012; Tümay & Köseoglu, 2011). Argumentation is an effective strategy that supports science literacy in science education (Köseoglu, Tümay & Budak, 2008).

Encouraging students to engage in scientific explanations and argumentation is one of the key elements of scientific research (Duschl & Osborne, 2002), encouraging students to explain and debate scientifically can provide numerous benefits. For example; producing and supporting claims can help students improve their content knowledge (Zohar & Nemet, 2002). Interrogating and evaluating many different perspectives in the context of the argumentation process can help students to change their misunderstandings about science concepts and help them learn in a meaningful way (Ozcan, 2016). In addition, the argumentation provides opportunities for students to use evidence and reasoning processes to understand how and why a phenomenon has taken shape (Krajcik & McNeill, 2009). The argumentation supports the learning of science from a cognitive-based perspective, allowing students to focus on mental processes such as reasoning, problem solving, and inquiry (Lee, 2011). The argumentation is recognized as an intellectual skill which has a crucial pre-requisite to adapt to the 21st century world as well as the stated contributions (Torun & Sahin, 2016), and provides the development of higher-order thinking skills (Nussbaum, 2002).

When the relevant literature is examined, it is generally observed that published research is concerned with examining the effect of STEM education on the students' interest, perception and attitudes about science, mathematics, technology and engineering (Gülhan & Sahin, 2016b; Meng, Idris &Eu , 2014; Weinberg, Pettibone, Thomas, Stephen & Stein, 2007; Yamak, Bulut & Dündar, 2014); the effect of STEM education on the academic achievement (Oner, Navruz, Bicer, Peterson, Capraro & Capraro, 2014); the effect of STEM education on the science process skills, and science literacy (Sullivan, 2008). However, little research has been done on the role of the argumentation in the STEM education (Arnberg, 2014; Arnold, 2016; Erdoğan, Yıldırım, Çiftçi & Güleryüz, 2016; Smyrnaiou, Petropoulou & Sotiriou, 2015). For example; Smyrnaiou et al. (2015) investigated the argumentation approach in their research that they applied the argumentation approach in STEM education as a way of promoting the knowledge construction and the skill of the students in the context of scientific research. For this purpose, they have provided the implementation of the argumentation approach in a collaborative learning environment. The findings of the research have shown that participation of students in a debate and debating about their own lives increase the rate of positive attitudes towards STEM fields and motivate them to participate more in the negotiation of scientific issues.

When the relevant literature is examined, the researches about the effect of STEM education practices on the argumentation skills were not reached. Therefore, it is thought that since this research may be the first study in this subject and it contributes to the mentioned deficiencies, it is important. In light of the deficiencies mentioned above, the research will examine the pre-service science teachers' progress in constructing their argumentation components during STEM education practices. According to this goal, the following research question was tried to be answered:

1. Did the argumentation skills of pre-service science teachers' show improvement by STEM education practices?

2. Methods

In this section, information about the research model, study group, implementation process, data collection tools and data analysis are given.

2.1. Research Model

The research is a case study aimed at revealing conclusions about the development of argumentation skills of preservice science teachers. "In case studies, it is important to understand the changes and processes that take place in a case" (Yıldırım & Şimşek, 2013, p. 83).

2.2. Research Group

In the research were worked with 9 pre-service science teachers who are 3rd grade students and took the course of 'Science Laboratory Practices' in a state university in Turkey. Two groups (A and B groups) who were interested in STEM education and volunteered to participate in the research were selected. Participants are between the ages of 20 and 23, and gender information is given in Table 1.

Table 1. Gender Information of Participants

Gender	Frequency	Percent
Female	4	44.4
Male	5	55.6

2.3. Implementation Process

The implementation process of the research lasted 9 weeks. In this process, structured and unstructured practices are included. The structured practices were carried out by following the progressive instructions of the activity. On the other hand, during unstructured practices preservice teachers drew and made their own designs. In the first week, pre-service science teachers were provided with the introduction of STEM education, and a research homework which is about the definition, history and importance of STEM education was given. In the second week, pre-service science teachers shared their knowledge in the classroom environment as a result of their research on STEM education. In the 2nd, 3rd, 4th, 5th and 6th weeks, structured practices are included. These practices were carried out by following the instructions on the construction of simple machines. In the 7th, 8th and 9th week, pre-service science teachers made unstructured practices, that is, their own designs. In unstructured practices, pre-service science teachers have already drawn their designs. During the practices, they made designs according to their drawings. Practices conducted by pre-service science teachers in group A on the basis of design; pencil case construction, spider construction, an earthquake resistant bridge have been made while in the group B on the basis of design; making helicopters that take photos and videos, making cars that work with the wind, and an earthquake resistant bridge. Information about the implementation process is given in detail in Table 2.

Table 2. Implementation Process

Group	Week	Activities	Activity Type
A	1	Introduction of STEM Education	
	2	Crane Construction	Structured
	3	Tongs Construction	Structured
	4	Generator Construction	Structured
	5	Wind Turbine Construction	Structured
	6	Water Turbine Construction	Structured
	7	Pencil Case Construction	Unstructured
	8	Spider Construction	Unstructured
	9	Designing Earthquake-Resistant Bridge	Unstructured
B	1	Introduction of STEM Education	
	2	Crane Construction	Structured
	3	Tongs Construction	Structured
	4	Generator Construction	Structured
	5	Wind Turbine Construction	Structured
	6	Water Turbine Construction	Structured
	7	Construction of a helicopter that takes photo and records video	Unstructured
	8	Wind-Driven Car Construction	Unstructured
	9	Designing Earthquake-Resistant Bridge	Unstructured

2.4. Data Collection Process

In this research, data related to the development of the pre-service science teachers' argumentation skills during STEM education were collected. In the research, data was obtained through voice recordings and unstructured observation. A total of 780 minutes were recorded. 110 pages of written documents were obtained from voice recordings.

2.5. Data Analysis

In this research, "The claim, evidence, reasoning and rebuttal framework" which was developed by McNeill & Krajcik (2011) was used. This framework was originally formed as "The claim, evidence and reasoning" (McNeill & Krajcik, 2008; McNeill, Lizotte, Krajcik & Marx, 2006) and the fourth component, rebuttal, was added later (Krajcik & McNeill, 2009). Examples of argumentation components from "Designing Earthquake-Resistant Bridge Activity" and definitions of argumentation components are given in Table 3.

Table 3. The Framework of "The Claim, Evidence, Reasoning and Rebuttal" Developed by McNeill & Krajcik (2011) and Example Expressions

Components	Level		
	0	1	2
Claim It is a statement that is given as a response for a question asked or a conclusion.	There is no claim or a false claim.	There is a true but incomplete/missing claim.	There is a true, complete and accurate claim.
	"It will make the bridge steady if it is fixed with tape."	"The bridge will not move if its basement is fixed well."	"If moving columns are placed below the bridge, it will be durable and will not collapse."
Evidence It is scientific fact that supports the claim. The data must be appropriate and sufficient to support the claim.	Evidence is not provided or it is provided but it doesn't support the claim.	Appropriate but insufficient evidence is provided. It may contain some inaccurate evidence.	Appropriate and sufficient evidence is provided to support the claim.
	"The reason why the bridge is durable is that the materials used are hard."	"The reason why the bridge is not durable is that its base is not fixed."	"The Japanese put balls to the basement of the buildings to make them durable, just as we did here."
Reasoning It is a justification that allows evidence to be associated with the claim. Using appropriate and sufficient scientific principles, it shows why the data is accepted as evidence	Reason is not provided or A judgment is made that does not associate the claim with the evidence.	A judgment is made that associates the claim with the evidence. Evidence is repeated and / or it includes some more scientific principles which are insufficient.	It is a judgment that associates the claim and the evidence. It contains appropriate and sufficient scientific principles.
	"The bridge did not move because the equilibrium point was found."	"Since the piers of the bridge fixed to the basement and the basement is moveable, we don't have any problem with the top."	"Since the equilibrium point was not found and the balance was not established, when the basement and the piers of the bridge moved at the same time, the balance wasn't established."
Rebuttal Alternative explanations are given and explained. Counter-evidence and reasoning are provided to show why alternative explanations are not appropriate.	Available alternative explanation is not given. Rebuttal is not provided or a false rebuttal is given.	Alternative explanations are given. Insufficient counter-evidence and reasoning which are proper but not sufficient to build a rebuttal are given.	Alternative explanations are given. Sufficient counter-evidence and reasoning which are proper and sufficient to build a rebuttal are given.
	"I think the bridge you built is fixed. It can't move."	"I do not think your suggestion makes sense. Decorations used on the bridge will damage the bridge due to the heavy-weight."	"I think you should not have used the tape on fixing the piers of the bridge to its basement. Because the tape is not strong enough to carry the piers of the bridge."

The arguments in the obtained data from the voice recordings taken during the practices were analyzed according to the descriptive analysis. "In descriptive analysis, the aim is to present the findings to the reader in an organized and interpreted way." (Yıldırım & Şimşek, 2013, p. 256). For this reason, the students' arguments have been examined according to the rubric (see Table 3) developed by McNeill and Krajcik (2011). Arguments are coded in this direction by claim, evidence, reasoning and rebuttal. Claim, evidence, reasoning and rebuttal were scored according to the level of their situation. Scoring was done as following; 1 point was given to Level 0, 2 points to Level 1, and 3 points to Level 2. Then averages of the scores obtained from these components were calculated. In the process of coding the arguments, the opinions of a researcher who had previously worked on this subject were frequently referred to. In addition, the obtained data were coded by two researchers. As a result of independent coding by two researchers, the coding reliability was calculated as 98% for the claim, 97% for the evidence, 92% for the reasoning, and 89% for the rebuttal.

3. Findings

In this section, findings related to the average scores of claim, evidence, reasoning, and rebuttal of pre-service science teachers are given.

As shown in Figure 1, in the structured practices at the beginning of STEM-based practices, the average score for the claim in group A was 1,5 and in unstructured practices at the end of the practice this score increased to 2,5. In the group B, the average score of the claim increased from 1, 7 to 2, 5. Therefore, we can say that in the practices that require design, we managed to establish higher quality claims compared to the practices that are followed by the instructions only. There is an increase in scores of both groups. But this increase is more in the group A.

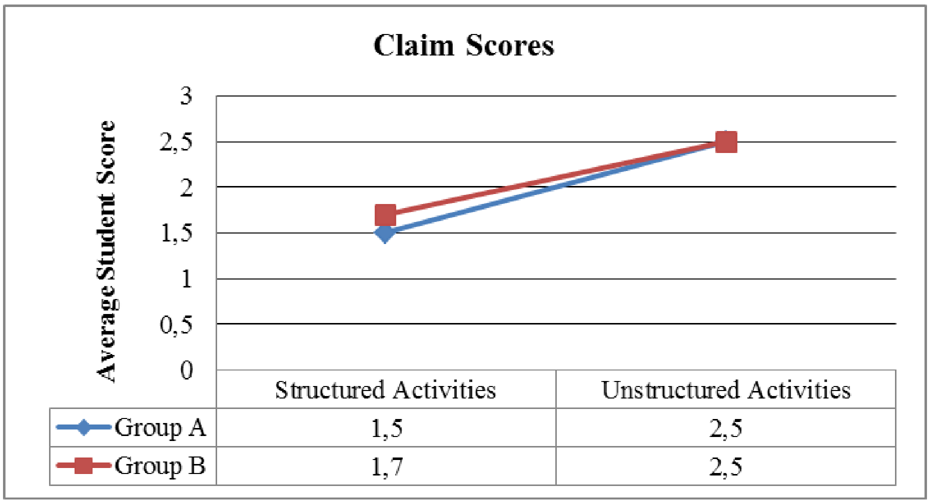

Figure 1. Average Scores of Claim

As shown in Figure 2, the average score of the evidence for both groups increased, and the group A was with the highest increased score. While the average score of the evidence of the group A was 1.1 for structured practices, it increased to 2.7 in unstructured practices which require design. The average score of the evidence for group B was 1.8 for structured practices, and it increased to 2.7 in unstructured practices. As a result, we can say that practices that require design based on STEM education can provide pre-service science teachers produce better quality evidence.

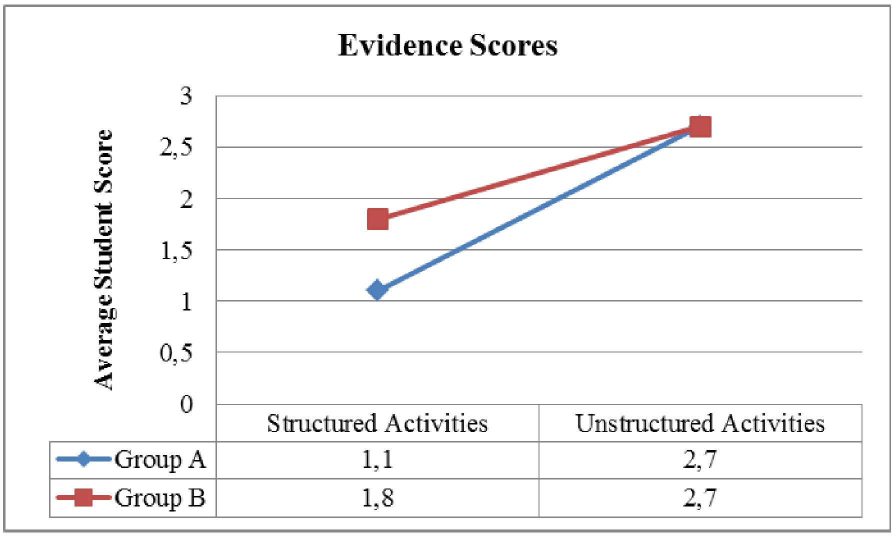

Figure 2. Average Scores of Evidence

As shown in Figure 3, it can be seen that at the end of the practice, the average reasoning scores of the groups are both increased and the score of group A is higher than B. While the average reasoning scores of the group A was 0.8 for structured practices, and the score increased to 2.5 for unstructured practices. On the other hand, for the group B, the average reasoning score was 2.3 for structured practices and the score increased to 2.7 for unstructured practices. It can be inferred that pre-service science teachers improved their reasoning skills during STEM practices.

Figure 3. Average Scores of Reasoning

In Figure 4, it can be seen that both of the groups increased their rebuttal skills and the group B had higher score. While the average rebuttal score of group A was 0.5 for structured practices, the score increased to 1.1 for unstructured practices. For the group B, the average rebuttal score was 1 for structured practices, the score increased to 2 for unstructured practices. Thus, we can say that STEM-based unstructured practices increase the quality of the rebuttal.

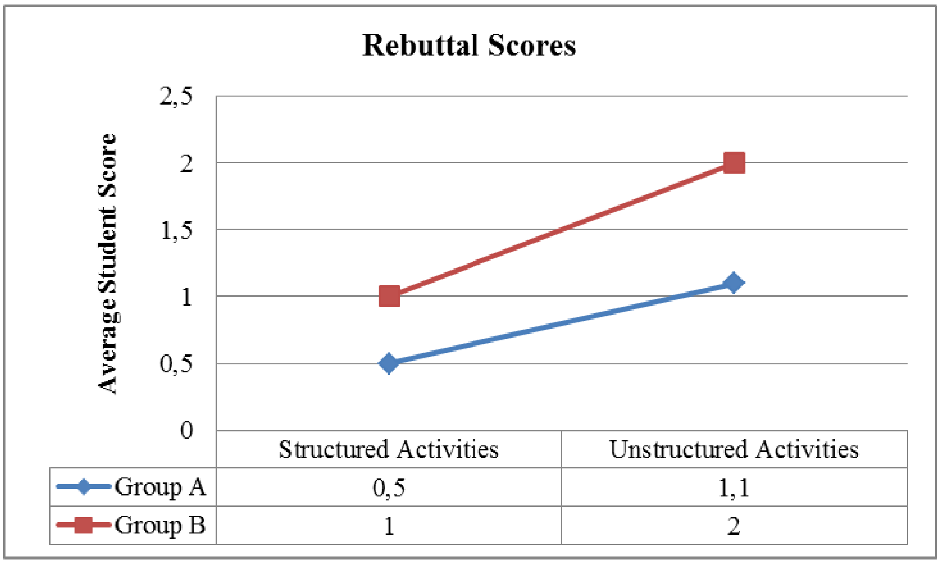

Figure 4. Average Scores of Rebuttal

The claim, evidence, reasoning and rebuttal scores increased both in group A and in group B. While the highest increase in claim, evidence and reasoning is in the group A, the highest increase in rebuttal is in the group B. It was determined that the pre-service science teachers in the group B got a better score than the pre-service science teachers in the group A in the practices that were followed by the instructions in the first weeks. As a result of the observations made during the practices, while the pre-service science teachers in group B discussed different ideas even in the structured activities in which the instructions were followed, pre-service science teachers in group A were found to be consistent with the instructions. Therefore, it can be considered that this is the reason why pre-service science teachers in group B got higher scores in the first weeks.

4. Discussion

In this research, it is seen that the argumentation skills of pre-service science teachers are improved with STEM education practices. There are many researches that emphasizing that argumentation training improves the skill of argumentation (Cetin, 2014; Erduran, Simon & Osborne, 2004; Reznitskaya, Anderson, McNurlen, Nguyen-Jahiel, Archodidou & Kim, 2001; Torun & Sahin, 2016; Yeh & She, 2010). In this study, argumentation skills of the pre-service science teachers have been developed without argumentation training. Therefore, it can be said that STEM education practices contribute to the improvement of the argumentation skills and that pre-service science teachers are not only influenced by the STEM education but also by the unstructured activities. In this research, unstructured STEM practices based on design; were found to be more effective than the structured activities in the development of the claim, evidence, reasoning and rebuttal. Fortus, Dershimer, Krajcik, Marx and Mamlok-Naaman (2004) stated that design-based activities are effective in structuring scientific knowledge in the research they conducted in order to determine the effect of STEM education on students' learning levels. According to the research which is done by Smyrnaiou et al. (2015), it was determined that participation of students in argumentative discourse and debates about their own lives increased the positive attitudes towards scientific subjects and STEM fields. Also STEM fields should contribute to the development of socially and civically responsible students (Garibay, 2015).

STEM education is an inquiry based approach. “Learning with inquiry should involve the use of argument—a form of reasoning that emphasizes the use of evidence in support of a claim.” (Crippen & Archambault, 2012, p. 160). One of the indicators of STEM literacy is evidence-based conclusions about STEM issues (Bybee, 2013). However, while students and even adults construct scientific explanations, they often have difficulty in using reasoning and using appropriate and sufficient evidence on their claims (Jime´nez-Aleixandre, Rodriguez & Duschl, 2000; Krajcik & McNeill, 2009; Kuhn, 1991; Sandoval & Millwood, 2005). “People‘s quality of ‘argument’ about scientific issues and their critical capabilities can be enhanced in science lessons” (Osborne, Erduran & Simon, 2004, p. 4). The argumentation ensures that claims are justified by evidence and forms the basis of logic in STEM fields (Erduran, Ozdem & Park, 2015). STEM education and argumentation provide students with a scientific culture by developing scientific thinking skills and scientific process skills (Arnold, 2016; Kennedy & Odell, 2014; Zohar & Nemet, 2002). Furthermore, the use of scientific knowledge and scientific interrogation together is important for science applications (Bybee, 2011; Gencer, 2015) and STEM education and argumentation play an important role in this. Therefore, science applications with STEM education and argumentation should be included in learning environments. In this context, in education environments students must be exposed to asking important questions, gathering quality evidence, critically reasoning, and using information to make and evaluate their decisions (Crippen & Archambault, 2012, p. 160).

The STEM programs are mainly devoted to two main purposes: to create a science-literate society and to develop a conceptual work force in STEM (Akyıldız, 2014). For STEM education, science literacy is one of the fundamental issues for public debate. Such issues in school curriculums are increasing day by day. This gives teachers more responsibility for having information about STEM and for engaging in argumentation (Kim, Anthony & Blades, 2012). Therefore, pre-service and in-service teacher education should be emphasized so that teachers can have competencies in STEM education and argumentation (Akyıldız, 2014; Chalmers & Macbeth, 2013; Driver et al., 2000; Lee & Nason, 2012), and the training of STEM teachers should be supported. "STEM Educators must use problem-based and project-based learning with a set of specific learning outcomes to support student learning." (Kennedy & Odell, 2014, p. 256). In addition, researches involving the use of STEM education and argumentation together should be done. Moreover, argumentation takes part in engineering design processes which have great importance in STEM practices; given its major role in identifying problems, development of possible solutions and determination, evaluation and discussion of most plausible ones. Therefore argumentation approach can be included as part of STEM education.

5. Conclusion

In this research, the effects of STEM education practices which are taught in the course called "Science Laboratory Practices" on the development of pre-service science teachers' argumentation components were examined. As a result of the analysis of the data, it was determined that with the STEM practices, the pre-service science teachers in both group A and B increased their scores of claim, evidence, reasoning and rebuttal. The lowest average score was on the rebuttal for both of the groups. Therefore, it can be said that design-based STEM practices have increased the quality of the claims, evidence, reasoning, and rebuttal that pre-service teachers have offered.

STEM education practices contribute us being busy with science applications, discovering the world we live in, and associating the information we learn with everyday life. Argumentation, on the other hand, promotes the development of high-level thinking skills by engaging in scientific inquiry and scientific explanations. Therefore, it is important for the pre-service science teachers to have information and skills about STEM education and argumentation practices in order to apply these approaches in their teaching lives. This research is important because it may be first research to examine the effects of STEM education on the argumentation skill. It is also thought that this research is a guide for the future researches on the use of STEM education and argumentation at the same time.

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