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The Effect of Integration of STEM Disciplines into Toulmin's Argumentation Model on Students' Academic Achievement, Reflective Thinking, and Psychomotor Skills*

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ABSTRACT

The aim of this research was to examine the effect of integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. To be able to get this aim, a quasi-experimental method was used. The participants were 40 sixth grade middle school students divided into two groups, an experimental and a control group with 20 students in each group. The students were at the same achievement level and in a similar socioeconomic status in a public middle school. The experimental group received the treatment in the while the control group received traditional learning of the same topic. The data were collected from academic achievement test, reflective thinking test, and psychomotor observation form. The collected data were analyzed by using Mann Whitney U-test, descriptive analyses (e.g., percentage and frequency), and correlation analyses (Pearson's product moment). According to the data obtained from the measurement tools, it was detected that the integration of STEM disciplines into Toulmin's argumentation model can be used for enhancing the academic achievement of students. It was specified that reflective thinking tendency levels of the experimental group were found to be at a high level. It was also documented that psychomotor skills of experimental group were found to be at a high level. The results suggested that the integration of STEM disciplines into Toulmin's argumentation model can be used for increasing academic achievement of students, developing of the reflective thinking, and observing the development of psychomotor skills at the formation of arguments in the classrooms.

Keywords: Toulmin's argumentation model, STEM education, academic achievement, reflective thinking, psychomotor skills.

INTRODUCTION

The discipline of science aims to make individuals develop the awareness of sustainable improvement pertaining to society, economy, and natural resources. The aims also include making individuals recognize the mutual interaction between environment and

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society. To do so, students should be able to make arguments and questions by taking advantage of different disciplines, make claims from these arguments, and also corrupt opponent claims (Hasançebi, 2014; Ministry of National Education [MoNE], 2013b). In order to achieve this goal, it is expected that students should be capable of creating their own arguments effectively by using disciplines such as science, technology, engineering, and mathematics in their daily life (Boran, 2014; Yaman, 2003).

The idea of the argumentation started with Stephen E. Toulmin (1958) in the literature. Toulmin created arguments and logic for the arguments on the philosophy of discussion as seen in Table 1 (Simon, Erduran, & Osborne, 2006; Tümay, & Köseoğlu, 2011). The questions in Table 1 give an idea about how teachers can plan their lessons according to the argumentation model, and in what situations teachers can follow students or in what situations teachers can guide students. Students can use the questions in constructing research inquiry activities and as an assistive framework in writing research reports (Günel, Kabataş Memiş, & Büyükkasap, 2010; Verheij, 2005). Examining a problem with questions is the aim of the argumentation model (Gülen, 2016). The fact that the problem is solved in the context of evidence according to the argumentation model and the evidence is scientifically characterized by the disciplines of science, technology, engineering, and mathematics (STEM) to ensure that students can use more effective expressions in their daily life (Ata Aktürk, Demircan, Şenyurt, & Çetin, 2017; Drew, 2011; Dunne, Hunter, McBurney, Parsons, & Wooldridge, 2011).

STEM is an educational approach that has emerged as a result of societal needs with increasing economic developments and scientific studies (Aydeniz, Çakmakçı, Çavaş, Özdemir, Akgündüz, Çorlu, & Öner, 2015; National Receivers Council (NRC), 2015; Sanchez, Wells, & Attridge, 2009). The primary objectives of STEM education are (a) having a qualified workforce, (b) adopting STEM disciplines and gender equality, (c) ensuring individuals constituting the society to have the 21st century skills. In addition to creative, critical, reflective thinking, increasing literacy in all areas are known as the skills of the 21st century with such learning skills as being able to make arguments (Carnevale, Smith,& Melton, 2011; Century Skills, 2010; Ceylan, 2014;KabataşMemiş, & Ezberci Çevik, 2018; Gülen, 2016).

Table 1. *Questions inviting teachers-students in argumentation model*

Step	Teacher	Student	Purpose
1	What is the preliminary information?	What are my questions?	Identifying the problem
2	Ready for the activities?	What can I do?	Collecting data (possible solutions)
3	Does he/she participate in the activities?	What have I observed?	
4	Is he/she claim?	What can I claim?	Optimal solution proposal
5	Can he/she defend his claim?	What evidence do I use?	Test
6	Can he/she compare it?	What are the opposite claims?	
7	Can he/she compromise?	What has changed?	Contact
8	Can his/her information be configured?	What did I learn?	

Currently, the aims of STEM education are being applied at the level of middle school, primary school, and even kindergarten. Integration is the most important point planned to be implemented in schools in the STEM education approach (DeChenne, Koziol, Needham, & Enochs, 2015; Torres & Cristancho, 2018).

Table 2.*The Approaches to be used/used in STEM education*

Order	Engineering Design Process	Design Based Science Education	Probing Based Learning	5E Model	Argumentation model
1	Problem determination	Great design task	Problem identification	Engagement	Identifying the problem
2	Possible solutions	Mini research	Identification of sources	Exploration	Possible solutions
3	Choosing the right solution	Design solution	Possible solutions	Explanation	Optimal solution proposal
4	Making prototype	Construction of the design	Analyzing the solutions	Elaboration	Test
5	Test	Testing, communication	Submission of the solution	Evaluation	Contact

Researchers have indicated that it is not true to adhere to a certain approach in the program integration of STEM education (Altun & Yıldırım, 2015; Honey, Pearson, & Schweingruder, 2014). Table 2 shows the approaches with their properties that have been used for the integration. When the common characteristics of these approaches are considered and Table 2 is examined, it is considered that the Toulmin's argumentation model can be used besides these approaches.

As stated in Table 2, one of the primary objectives of STEM education is to "solve real life problems." Individuals may have different approaches to solve real life problems (Altun & Yıldırım, 2015; MoNE, 2016). In a scientific process, a student can identify a problem, propose possible solutions, and find more than one solution in the light of evidence that problem (Gülen, 2016). By getting the necessary resources, the student collects and specifies the most appropriate solution. When the desired success is achieved, the student makes announcements about the achievement, presents it, and communicates with society. When the phrases to solving the problem of approaches in Table 2are integrated into STEM education, integrated STEM education around four disciplines, interdisciplinary or disciplinary occurs with behaviors and considerations of student, teacher or teacher connections in a secondary school program (Bozkurt, 2014; Ercan, 2014). This situation suggests that Toulmin's argumentation model can be used to integrate STEM education into the program of secondary school (Gülen, 2016).

Furthermore, students can solve the problems of daily life by using integrated STEM approach and Toulmin's argumentation model approach so that they can solve the problems by using claims, negotiation, and evidence (Ulu & Bayram, 2015). In STEM education, the solution of the problems occurs through different disciplines until finding the most appropriate solution. As in the Toulmin's argumentation model, the importance of evidence for problem solving in STEM education is fairly considerable (Corlu, 2013; Demircioğlu & Uçar, 2014; Fairweather, 2008). For this research study, a lesson plan was prepared at the secondary school level by using disciplines of STEM. The lesson plan is based on the Toulmin's argumentation model with integrated STEM education.

There are many studies on STEM education and argumentation in the related literature. However, there have been limited studies on the integration of STEM disciplines into Toulmin's argumentation model. In this study, researchers investigated the effects of the integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. Academic achievement is defined as the acquisition of the targeted achievements during the learning process and the representation of these achievements with symbolic values (Korkmaz & Kaptan, 2002). Reflective thinking skills are the process of thinking to reveal positive or negative aspects of teaching or learning in problem solving (Ersozlu & Kazu, 2011). Psychomotor skills are in parallel with the physical growth and development of the central nervous system that reflects how the organism gains mobility depending on the demands. It is a process involving the acquisition of the skills that start in the prenatal period and continue until death (MoNE, 2013a; Özer & Özer, 2014).In this study, the following research question was taken into consideration: What is the level of impact of the integration of STEM disciplines into Toulmin’s argumentation model on students' academic achievement, reflective thinking, and psychomotor skills?

Purpose of the research

The purpose of the research was to examine the effect of the integration of STEM disciplines into Toulmin’s argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. In doing so, a lesson plan on the conduction subject of electricity in the sixth-grade science of middle school was prepared.

Problems of Research

1. Was there a statistically significant difference between the academic achievement of experimental group and control group before and after the study?
2. What were the levels of the reflective thinking and psychomotor development of the experimental group?

METHOD

In this research, a quasi-experimental design was used. The quasi-experimental design is a method used to measure variables and control cause-effect relationships among the variables (Büyüköztürk, 2014). In the study, the progress of students’ academic achievement was investigated in both experimental and control groups while the development of reflective thinking and psychomotor skills were only examined in the experimental group so that the analyses were performed on a single group (i.e., experimental group) to determine variables of reflective thinking and psychomotor skills.

a) Participants

The study group of this research was selected via the appropriate sampling method. The participants were 40 students originating from two groups as experimental and control groups. The research was conducted in a middle school with sixth grade students in an urban province of Turkey. Students’ socioeconomic levels were similar.

b) Unit design and procedure

Lesson plan: The following lesson plan of this study was created by Selvi et al. (2015) in the structure of seven-steps plan (i.e., subject, problem, achievement, process, method, test, and evaluation) of Altun and Yıldırım (2015).
Subject: The topic of Transmission of Electricity was selected from the sixth grade of the science curriculum.
Problem: Prepared according to the integration of STEM disciplines into Toulmin's argumentation model and included problems from daily life.

Gain: It consists of five gains in the curriculum on Transmission of Electricity topic.
Procedure: It is planned to be implemented using the integration of STEM disciplines into Toulmin's argumentation model. The following model was derived from the argumentation model of Toulmin (1958) and the integration of the STEM approach. In this model, students can collect data in a sample case and design with their tools using the data. They can determine the positive and negative aspects of the reasons for their claims when they formulate the claims and transact on the designs. They can transform their designs into products by using their tools in the last stage (Kabatas Memiş, 2011; Gülen, 2016).

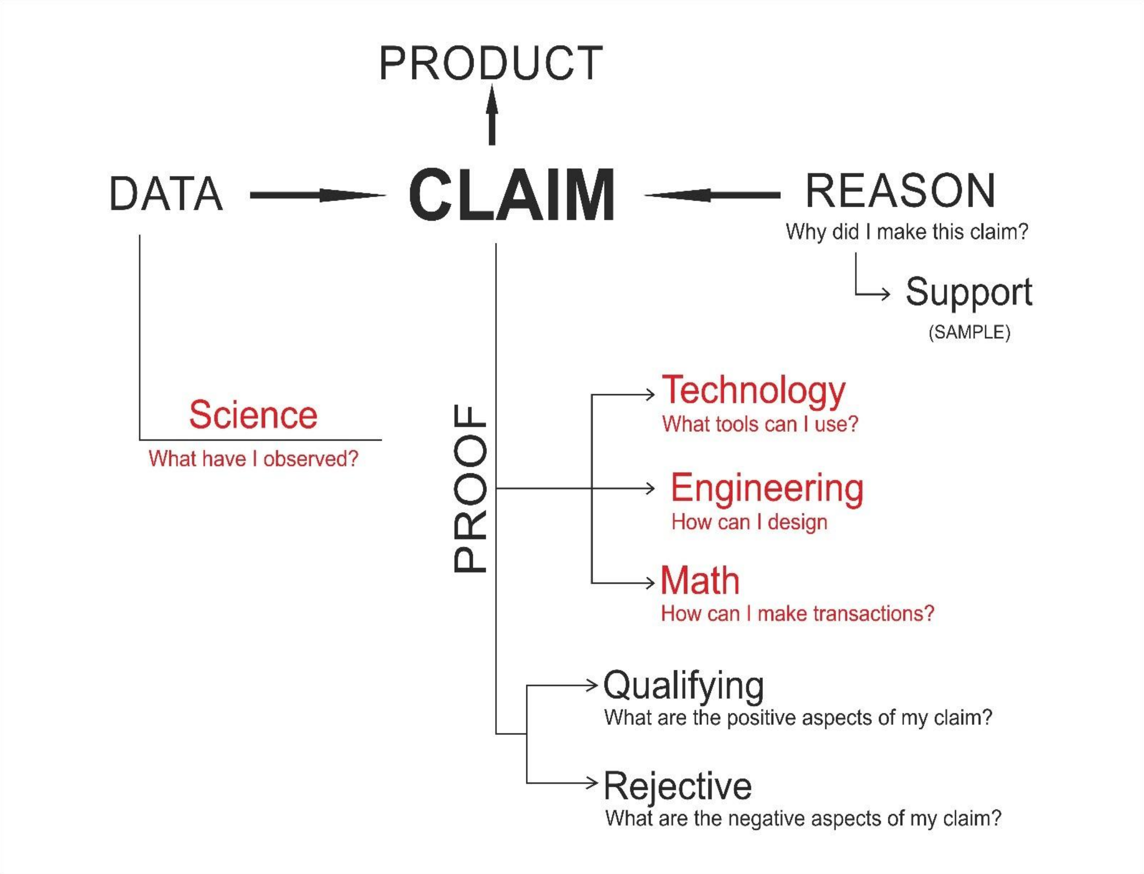

Figure 1. Integration of STEM disciplines into Toulmin's argumentation model in science education

In figure 1 model;

Claim: Opinions or explanations for the solution of the problem.
Data: Events or observations used to support the claim.
Rationale: These are the reasons why the data support the claim.
Support: Examples are given daily.
Qualifier: Conditions that the claim is valid.
Rejection: Conditions that the claim is invalid.
Technology: It is the equipment used in the product to be built.
Engineering: Design of the product to be built and planning with existing technology.
Mathematics: Processes to solve the problem through the product.
Product: It is the concrete model that students use engineering and mathematics with technology.
Science: Container concept covering every step described above (Ceylan, 2012; Günel, Kıngır, & Geban, 2012).

Methodology: It provides a groundwork for students' use of STEM disciplines in activities involving daily life problems. The proposed solution needs to be negotiated among the groups in the prepared activities. The results should be modeled using tools that are brought to the classroom by the researcher.

Test: It is the step that the products prepared by the students are tested for the solution of the problems.

Assessment: The stage in which the process and result are evaluated.

c) Data Collection

Academic achievement test: After the examination of the sixth-grade science program (MoNE, 2013b), an academic achievement test consisting of 68 questions (multiple choices) was prepared. The expert opinion was received for the reliability and validity of the achievement test. The questions with low substance discrimination index were removed after receiving the idea of expert and analysis results in the pilot application and the number of items was reduced to 24. The validity and reliability of the academic achievement test were also taken into consideration. The content validity was censured by thinking of the achievement of the unit, preparing each issue at the appropriate level. Scores of the academic achievement test used as a predictive variable for students' unit success. Structure, appearance, and criterion validity of the academic achievement test was also considered. At the result of reliability calculation, KR20 reliability coefficient was calculated as 0.87. According to this result, it can be said that the test of academic achievement gives reliable results (Büyüköztürk, 2009).

Reflective thinking scale: A scale measuring reflective thinking ability of students in solving problems related to conduction issue of electricity topic created by Kızılkaya and Aşkar (2009) was used. The reflective thinking scale is composed of 14 items including questioning, evaluation, and causing dimensions. Confirmatory factor analysis was carried out using SPSS and AMOS programs to make these items suitable for research. When the obtained data analyzed, it was seen that the indices of compliance were in the "acceptable level" (Gülen, 2016).

Table 3. *Calculated compliance indexes results of confirmatory factor analysis*

Compliance index	Accepted value	Observed value
Kay-square/Degree of freedom	<2.00	1.67
GFI	>0.90	0.92
NFI	>0.90	0.80
CFI	>0.90	0.90
RMSEA	<0.10	0.06

Observation form of psychomotor skills: It is important that the information structured in STEM education can be used in the applications of real life (Bicer et al., 2015). Due to this importance, the psychomotor skills of students need to be determined in order to specify the extent to the fact that the information, configured with the usage of the integration of STEM disciplines into Toulmin's argumentation model in the study, can be applied in the real life applications. In the literature review, it was found that the psychomotor skills include six steps. The steps are perception, establishment, guidance, convert to fool, and conditioning. These steps were compared with the achievement test results of the Electricity Conduction unit, and except for the last step, it was found that the achievement levels were sufficient for all steps (Tutkun, Demirtas, Erdoğan, & Arslan, 2015). Thus, the form was prepared and applied with appropriate criteria for the research. Two experts in science education assisted the preparation process of the achievement test.

d) Data Analysis

All data from the academic achievement test (Mann-Whitney U-test, percent (%), frequency (f)) were analyzed with the SPSS package program. Additionally, the factor analysis of the reflective thinking test was done with the AMOS package program. Reliability and validity analyses of the academic achievement test, reflective thinking test, and observation form of psychomotor skills were done with the support of Microsoft Office Excel package program. The observation forms of psychomotor skills and reflective thinking test were analyzed by using descriptive statistical techniques.

The scores obtained from the variability of the academic achievement test, the reflective thinking test, and the psychomotor skills observation forms were varied. Therefore, all scores were converted to standardized scores (Z scores) to be able to analyze the relationships among scores obtained from the different tests. Pearson's correlation coefficient was calculated to determine the relationship among these scores (Büyüköztürk, Çokluk, & Köklü, 2013; Can, 2014; Güler, 2011).

e) Limitations of the study

This study was limited to the 20 students in the experimental group and 20 students in the control group. Only academic achievement test, reflective thinking, and psychomotor skills developments were observed in the study. Also reflective thinking and psychomotor skills development were limited to the experimental group.

RESULTS

The results of the analysis relating to the variability obtained in the survey are presented in the following section. The results are presented in the order of research problems.

Table 4. *Mann Whitney U test of experimental and control groups according to pre-post test results of academic achievement test*

Tests	Groups	N	Order average	Rank Sum	U	p
Pre test	Control Groups	20	23.75	475	135	0.077
	Experimental Groups	20	17.25	345		
Post test	Control Groups	20	16.50	330	120	0.029
	Experimental Groups	20	24.50	490		

As shown in Table 4, the value of "p" was calculated as 0.077 ($p > 0.05$) while the average value of pre-test *U* was 135 before the application. These findings indicate that there was no significant difference between the two groups before the application. However, the average value *U* of the post-test was 120 after the application, meaning that there was a significant difference between the two groups after the application. The values of rank average indicate that the difference was in favor of the experimental group.

Table 5. *Descriptive statistical values according to reflective thinking dimensions of experiment group*

Factors	Items	$\bar{X}$	Factor $\bar{X}$	S
Questioning	1	3.50	3.36	1.05
	3	3.45		0.82
	7	3.15		0.93
	9	3.35		0.90
	13	3.35		1.13
Evaluation	2	3.35	3.67	1.13
	4	3.60		1.04
	6	3.70		0.80
	10	4.15		0.93
	14	3.55		0.99
Cause	5	4.05	3.67	0.88
	8	3.55		1.05
	11	3.30		1.17
	12	3.75		0.78
General average			3.56	

According to Table 5, the experimental group's average scores obtained in the dimensions of evaluation and causation was 3.67. These scores suggest that the experimental group's showed "medium tendency of reflective thinking in the evaluation and reasoning dimension." However, the average level of inclination toward the test was specified to be 3.56. This value shows a high reflective thinking tendency according to Kandemir (2015) criteria.

Table 6. *Descriptive statistical values of psychomotor skills according to Bloom levels of experiment group*

Steps	Items	$\bar{X}$	Factor $\bar{X}$	S
Perception	1	4.60	4.62	0.68
	2	4.60		0.68
	3	4.65		0.59
Establishment	4	4.65	4.60	0.67
	5	4.55		0.83
Guidance	6	4.50	4.50	0.69
	7	4.35		0.67
	8	4.65		0.49
Convert to fool	9	4.10	4.03	0.85
	10	4.05		0.83
	11	4.00		0.79
	12	4.00		0.79
	13	4.05		0.76
	14	4.00		0.79
Conditioning	15	3.80	3.80	0.77
	16	3.80		0.77
	General average		4,30	

According to the results of Bloom levels of descriptive statistical values to the psychomotor skills of the experimental group, as seen in Table6, the psychomotor skills of experimental group were 4.62 at the level of perception, 4.50 at the level of guidance, 4.60 at the level of establishment, 4.03 at the level of conversion to ability, and 3.80 at the level of suitability to situation. It was indicated the general average of the psychomotor skill levels of the experimental group were 4.30.

DISCUSSION

It was determined that the experimental group, who were taught with the integration of STEM disciplines into Toulmin's argumentation model, had statistically significant higher scores than the control group, who were taught with traditional teaching approach, in the post academic achievement test. There are studies in the related literature demonstrating that the argument-based science learning (ABSL) approach improves the academic success of the students and that the results of the previous related studies are parallel with the results of this study. Researchers such as Altun (2010), Ceylan (2012), Gultepe and Kilic (2015), Günel, Kabataş Memiş, and Büyükkasap (2010), and Uluay (2012) comparing the traditional education approach with the ABSL approach indicated that the ABSL approach is more effective than the traditional method in increasing students' academic achievement. In the study of Okumuş (2012), which compared the current teaching program with the ABSL approach, it is stated that the ABSL approach increases the academic achievement of the students. It was determined that the ABSL approach is more effective in increasing academic achievement in the studies of Koçak (2014) and Demircioğlu (2011),which compared the ABSL approach with the traditional approach. However, Deveci (2009) found that there was no significant difference between the experimental and control groups although the academic achievement level of the experimental and one of the control groups differed significantly in a three-group study. In addition, Demirel (2015) who compared the current curriculum with the ABSL approach found that the ABSL approach has a similar effect with the traditional methods in increasing the academic achievement. The researchers of Ercan (2014) and Ceylan (2014) conducted some of the earliest studies about the impact of the STEM educational approach on the academic success of the students in the national literature. Ceylan (2014) compared the constructivist approach supported by existing science curriculum based teaching practices with the STEM educational approach in his research study and revealed that the STEM educational approach increased the academic achievement of students. Ercan (2014) noted that classroom activities with the STEM approach improved the academic achievement. Additionally, in the studies of Yıldırım and Altun (2015) and Marulcu and Mercan Höbek (2014), it was found that STEM education and practices of engineering increased students' academic achievement. Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004) and Fortus, Krajcik, Dershimer, Marx and Mamlok-Naaman (2005) documented that the academic achievement of the students increased in the STEM studies. The results of the impact of STEM education on the academic achievement in the studies and results of the impact of the integration of STEM education in this study on the academic achievement are similar. Apart from these findings, no study was found on the integration of STEM disciplines into Toulmin's argumentation model.

In the result of the integration of STEM disciplines into Toulmin's argumentation model, it was determined that the average of the reflective thinking skills of the experimental group was 3.56 and this value was "high" within the criteria developed by Kandemir (2015).It was detected that the majority of researches aimed at determining the measurement and development of reflective thinking skills of pre-service teachers. In a research study by Duban and Yanpar Yelken (2010), they demonstrated reflective thinking tendencies of the pre-service teachers and overlapping tendencies with teacher qualities. Özden, Karapınar, and Önder (2015) documented that classroom pre-service teachers' usage of reflective thinking significantly reduced. In Lee's (2005) study, it was specified that the development in the reflective thinking skills of the pre-service teachers is dependent on the contextualization level of their readiness, communication, dialogue making ability, questioning ability. It was found that the level of reflective thinking was high in the study of Kaf Hasircı and Sadık (2011). These results are similar to the results of this research. In their studies, Demirel, Derman, and Karagedik (2015) were specified that there was a moderate relationship between students' reflective thinking levels and problem solving abilities. Scardamalia, Bereiter, and Steinbach (1984) pointed out that students' ability to make loudly speech and ask questions about his/her own thought enhance reflective thinking. In his study, Farewell was indicated that being capable of thinking of what individual learns influence the reflective thinking. There is evidence that the interaction of students in the process of argumentation influences reflective thinking. Erbil and Kocabaş (2015) reported that an activity of collaborative learning positively affected the reflective thinking skills of primary school students. Demiralp and Kuzu (2012) claimed that when teachers use the environment of interactive learning in their classes, students take positive results in the development of reflective thinking skills. These results can suggest that interactions and collaboration among students contribute to developing reflective thinking skills in the activities of integration of STEM disciplines into Toulmin's argumentation model.

Furthermore, the students' scores in this study decreased from high-level to low-level demonstrated that the development of the students' psychomotor skill was in high-level in the activities of classroom based integration of STEM disciplines into Toulmin's argumentation model. Atlı (2007) found that the activities performed in the classroom consisted of a meaningful change in the students' psychomotor skills. Doydu (2012), Ulutaş (2011), and Yüksel (2010) stated that the activities made by the students improved the psychomotor skills. In addition, Türkçapar (2011) specifies that the level of psychomotor skills also increased with the increase in students' cognitive achievement levels. These findings show that students actively participated in the learning environment with the integration of STEM disciplines into Toulmin's argumentation model, met with ease at strutting of their knowledge so that the integration of STEM disciplines into Toulmin's argumentation model effected on the development of the students' psychomotor skills. In contrast to these results, it was found that there was no relationship between the activities performed in the class and the development of students' psychomotor skills in the studies by Kuru, and Köksalan (2012) and Ural (2015).

CONCLUSION and SUGGESTION

From the result of the academic achievement test, it can be said that the integration of STEM disciplines into Toulmin's argumentation activities applied in the experimental group increased the academic success of the student according to the current curriculum applied in the control group.

From the result of the reflective thinking test, it can be said that the reflective thinking tendency levels of the experimental group were in "the tendencies of highly reflective thinking." Furthermore, it was found that the students had a tendency of "moderate reflective thinking tendencies" in the questioning dimension, "high reflective thinking tendency" in the dimension of questioning, and "highly reflective thinking tendency'' in the dimension of evaluation and reasoning. Based on the post-test results, it can be said that high level thinking skills of students developed with the integration of STEM disciplines into Toulmin's argumentation model.

Although there was a decrease in the average scores of high-level steps of the psychomotor skill level of the students in the experiment group, it can be said that it was considerably high when the general average was examined. These results suggest that the integration of STEM disciplines into Toulmin's argumentation model had a high impact on the development of students' psychomotor skills. In addition, when we look at the correlations among the variables obtained in the result of the research, it can be said that the relationships among the students' psychomotor skills, academic achievement, and reflective thinking ability were at a high level. In the light of results obtained in the study the integration of STEM disciplines into Toulmin's argumentation can be used in increasing students' academic achievement.

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