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Original article

Argumentation Practices in Science Education

Fen Eğitiminde Argümantasyon Uygulamaları

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Abstract

This study aimed to teach the method of argumentation concept to pre-service teachers and to determine the change in argumentation quality of them through activities involving socio-scientific issues and science concepts. 48 pre-service teachers from a public university participated in this study. Convenience sampling technique was used as a non-random sampling method for forming the study groups. The pre-service teachers forming the working group had not received a course or training about argumentation in their formal education program before the current study. The activities of the study were conducted before and after instructed them about the Toulmin Argument Pattern (TAP) and argumentation concepts. Throughout the activities, pre-service teachers found an opportunity to engage in groups and exchange ideas with one another. Data were collected through both written and verbal arguments. The written arguments containing the common views/opinions of the group were taken from each group of students. Verbal arguments were also recorded as video besides to written arguments. The frequency of use of the elements of the students in the TAP was also presented in the study. It is determined that there is no substantial change in the written and verbal argument quality of the students.

Keywords: *Pre-service teachers, Argumentation, Written Arguments, Oral Arguments*

Özet

Bu çalışmada öğretmen adaylarına argümantasyon kavramının öğretilmesi ve sosyo-bilimsel konular ile fen kavramlarını içeren etkinlikler yoluyla argümantasyon kalitesindeki değişimin belirlenmesi amaçlanmıştır. Bir devlet üniversitesinde eğitim gören 48 öğretmen adayı bu çalışmaya katılmıştır. Çalışma gruplarını oluşturmak için rastgele örnekleme yöntemi olarak uygun örnekleme tekniği kullanılmıştır. Çalışma grubunu oluşturan öğretmen adayları, mevcut çalışmadan önce örgün eğitim programlarında argümantasyona (bilimsel tartışma) ilişkin bir ders veya eğitim almamışlardır. Çalışmada kullanılan etkinlikler, Toulmin Argüman Modeli ve argümantasyon hakkında eğitim almadan önce ve aldıktan sonra gerçekleştirilmiştir. Etkinlikler boyunca öğretmen adayları gruplar halinde çalışarak grup içi ve gruplar arası fikir alışverişi yapma fırsatı bulmuşlardır. Veriler hem yazılı hem de sözlü argümanlarla toplanmıştır. Grubun ortak görüşlerini içeren yazılı argümanlar her öğrenci grubundan alınmıştır. Sözlü argümanlar yazılı argümanların yanı sıra video olarak da kaydedilmiştir. Araştırmada Toulmin Argüman Modelindeki unsurların kullanım sıklığı da tespit edilmiştir. Çalışma sonucunda, öğrencilerin yazılı ve sözlü argüman kalitesinde önemli bir değişiklik olmadığı belirlenmiştir.

Anahtar Kelimeler: *Öğretmen adayları, Argümantasyon, Bilimsel Tartışma, Yazılı Argümantasyon, Sözlü Argümantasyon*

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INTRODUCTION

In recent years, there has been an increase in the number of studies on the subject of argumentation in science education (Aydeniz & Gürçay, 2013; Çetin, 2014; Kaya, 2013; Kaya, Erduran, & Çetin, 2012). Simon, Erduran and Osborne (2006) made a distinction between argument and argumentation. According to them '*Argument* refers to the substance of claims, data, warrants, and backings that contribute to the content of an argument; whereas *argumentation* refers to the process of assembling these components (in other words, of arguing)'. Argumentation is defined by Toulmin (1958) as the 'the processes of justification of claims with evidence'. According to Toulmin (1958), argument includes six elements, which are claim, data, warrant, backing, rebuttal, and qualifier. There of these six elements which are claim, data, and warrant are the basic elements and the rest of them which are backing, rebuttal, and qualifier are the more complex elements. Toulmin defines *claim* as 'an assertion about what exists or values that people hold', *data* as 'statement that are used as evidence to support the claim', *warrant* as 'statement that explain the relationship of the data to the claim', backing as 'underlying assumptions that are often not made explicit', rebuttal as 'statement that contradict either the data, warrant', backing or qualifier of an argument', qualifier as 'special condition under which the claim holds true'. The relations of these elements with each other are presented in Figure 1.

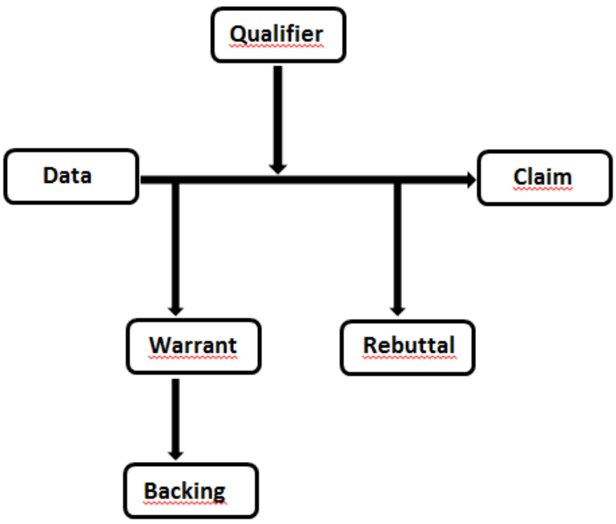


Fig.1. Toulmin's Argumentation Pattern (Toulmin, 1958)

(Claims: Assertions about what exists or values that people hold; Data: Statements that are used as evidence to support the claim; Warrants: Statements that explain the relationship of the data to the claim; Qualifiers: Special conditions under which the claim holds true; Backings: Underlying assumptions that are often not made explicit; Rebuttals: Statements that contradict either the data, warrant, backing or qualifier of an argument)

The first part of the paper (sections 'Toulmin's Argument Pattern' and 'Using TAP to identify students' use of rebuttals') describes how TAP was used to define the quality of argument and hence to quantify arguments generated in whole-class discussions between teachers and students. Erduran, Osborne and Simon were used TAP in order to analyze the components of the arguments that takes place in the class discourse and thus the quality of the argumentation (Erduran, Simon, & Osborne, 2004; Osborne, Erduran, & Simon, 2004; Simon, Erduran, & Osborne, 2006). They stated that the presence of rebuttal is an important indicator of the quality of the argumentation in students' small group discussions, since it promotes students' to assess the validity and strength of arguments. Simon, Erduran, and Osborne (2006) conducted a series of workshops to develop materials and strategies to support the teaching of argumentation in scientific contexts over a 1-year period. Argumentation implementations were recorded by audio-recording and video-recording at the beginning and end of the year. They reported quantitative results with regard to the frequency and complexity of the arguments using TAP occurring in the teachers' discourse. They compared teachers' use of argument with each other and determined the changes that occurred during one year (See Figure 2). They found that five of the 12 teachers showed a significant change in terms of argument complexity. Figure 2 represented the more complex argumentation in Year 2. (The more involve the TAP components, the higher frequency of argumentation/The higher frequency of argumentation means involving more TAP components).

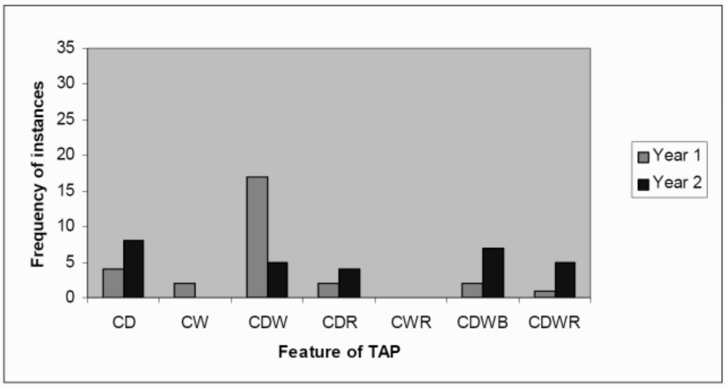


Fig.2. Year 1 versus Year 2 for one teacher

(C=Claim, D=Data, W=Warrant, B= Backing, R=Rebuttal) (Simon, Erduran, & Osborne, 2006 p.245)

Data analysis of the current study was conducted in the light of the prevous studies.

Argumentation and Science Education

A scientific argument was defined in many ways. Erduran and Jiménez-Aleixandre (2008) define argumentation 'a scientific discussion and social interaction process in which scientific claims are supported and evaluated with experimental or theoretical evidence'. Venville and Dawson (2010) mentioned that argumentation is used to refer 'a process of debate and structured discussion to reason about problems'. They also defined socio-scientific issues as scientific subjects in which individuals and groups in society have conflicting perspectives. They explored the effect of classroom argumentation about socio-scientific issues on high school students' argumentation skills and the results indicated that a targeted professional development on argumentation and a brief classroom intervention can improve students' argumentation skills.

The study of Zohar and Nemet (2002) examined the teaching of argumentation skills in the context of dilemmas in human genetics. Integrating explicit teaching of argumentation into the teaching of dilemmas in human genetics enhanced the performance in both biological knowledge and argumentation. An increase was also found in the quality of students' argumentation. Cross et. al. (2008) reported on the observed association between the systematic contribution of quality argumentative statements and the demonstrated increased understanding of the scientific concepts through increased scores. They also stated that 'engaging in argumentation leads to a more secure understanding of pre-existing concepts, but also allows students to hear new ideas that extends their existing knowledge and possibly eliminates misconceptions'. Aydeniz et. al. (2012) reported that argumentation-based learning had a positive impact on students' conceptual understanding of the properties and behaviors of gases. The study of Aydeniz and Gürçay (2013) with pre-service physics teachers indicated that students failed to develop strong scientific arguments. While almost all of the participants provided evidence to justify their claims, they failed to effectively coordinate evidence, claim and theory to develop an argument. Kaya (2013) examined the impact of argumentation practices on pre-service teachers' understanding of chemical equilibrium and concluded that the instruction based on argumentative practices effective in concept teaching in science education. Çetin's (2014) study with first-grade science teachers demonstrated that argumentation-based intervention caused significantly better acquisition of scientific reaction rate-related concepts and positively impacted the structure and complexity of pre-service teachers' argumentation. The study of Özdem et. al. (2017) indicatated that the teachers developed a meta-level understanding of argumentation through a graduate course, which was supported with meta-level discussions with experts and other graduate students.

Argumentation has drawn considerable attention from science educators especially in the last 10 years. The limited number of argumentation in science classes requires the development of science teachers' argumentation skills (Martín-Gámez & Erduran, 2018). Therefore, this study focused on pre-service teachers' argumentation skills to contribute to the relevant literature.

METHODOLOGY

Research Design and Study Group

This is a qualitative study using Toulmin Argumentation Pattern (TAP) and investigates the change in pre-service teachers' argumentation skills. Three activities developed by the researchers were used for this purpose. The 48 pre-service teachers studying at Science Teacher Education program in a public university constituted the study group of the study. Before the study, the students were randomly assigned to two sections: A and B, regardless of the current study. Convenience sampling technique was used as a non-random sampling method for forming the study groups for each two section of students.

Procedure of the Study

This study, which is the part of a long-term scientific research supported by TUBİTAK 2218 Domestic Postgraduate Scholarship Program, aimed to teach the method of argumentation concept to pre-service teachers and to determine the change in argumentation levels through activities involving socio-scientific issues and science concepts.

The pre-service teachers had not received a course or training about argumentation in their formal education program before the current study. Students first discussed the presented cases or situation in group before between group discussions. After the implementation of all three activities, these candidates were trained. Once all three activities were conducted, they were trained by one of the researchers of the study for two and half hours about argumentation and the Toulmin Argument Pattern (TAP). During this training, scientific definitions from literature on arguments and argumentation concepts were shared with the candidates, TAP and its six elements were explained thoroughly. Moreover, argument examples from literature on various subjects were presented in the language of the students and the features that should be in a good argument were also emphasized. Same activities were repeated following the training about argumentation. Throughout the activities, pre-service teachers found an opportunity to engage in groups and exchange ideas with one another. All discussion process was recorded for analysis. All of the above procedure was repeated for students in both sections of A and B. Table 1 gives information about the names and contents of the applied activities.

Table 1. Name of the activities conducted before and after study

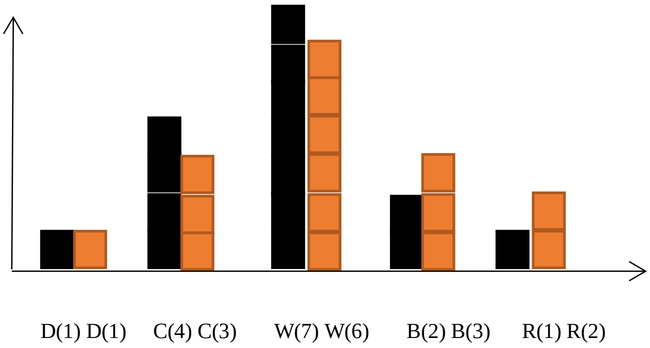
Air Bubbles	The change in the volume of air bubbles with the pressure in the sea.(Boyle-Mariotte Law)
Air pressure	About the change in air pressure with altitude
Mountain Climbing	About air pressure-boiling point relationship and its relationship with daily life events

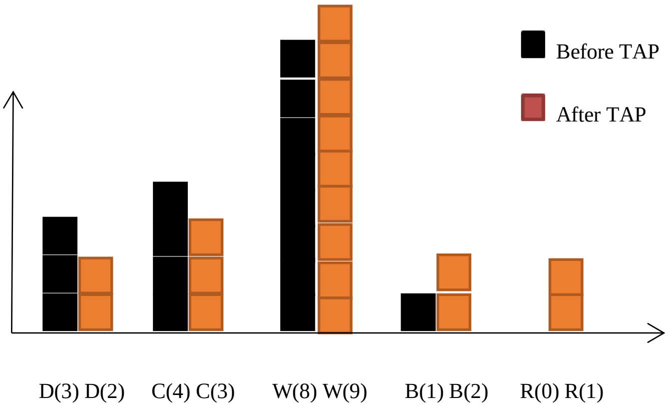
Data Analysis

Data were gathered by written and verbal arguments of pre-service teachers and transcribed by the investigators of the study. The written arguments containing the common views/opinions of the group were taken from each group of students. Verbal arguments were also recorded as video besides to written arguments.

Results of the Study

Case of Atmospheric Pressure





(D:Data, C:Claim, W:Warrant, B:Backing, R:Rebuttal)

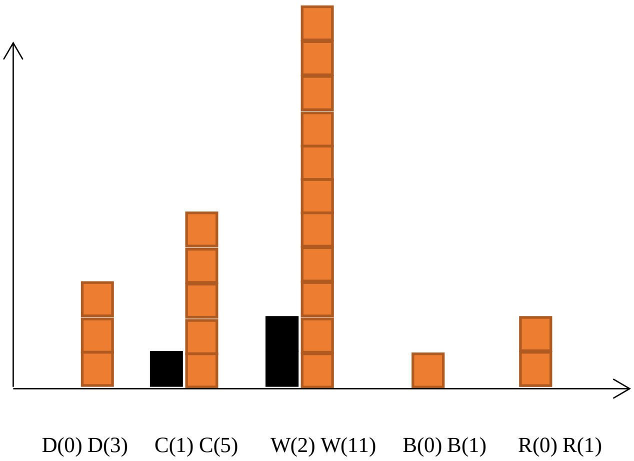
Graph (1) Written Argument Analysis for Section A

Graph (2) Written Argument Analysis for Section B

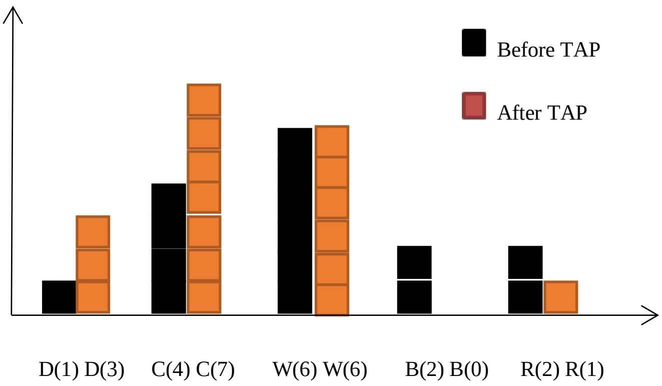
Graph 1 and Graph 2 show the pre- and post-analysis of the written arguments of the two groups about the atmospheric pressure case. In the examination of written arguments, there was no substantial change in the components used in the Toulmin Argument Pattern (TAP) after training. However, the higher number of warrants and the presence of rebuttal were remarkable in the discussion process for section B. Even before training, most of the students were agreed on that 'atmospheric pressure decreases as you move from sea level to higher'.

In section A, while the decrease in air pressure was first explained by the temperature before training, even after training it was explained by the accumulation of light gases in the upper layers of the atmosphere unlike heavy gases. Despite all the time to search it out and preliminary discussion, they wrote that '*while heavy gases increase the density at downs, light gases reduce the density upwards'*. On the other hand, the decrease in air pressure at upwards was explained correctly in written arguments before and after the study in section B.

The belove graphs indicate the same group of students' oral arguments about the same case.



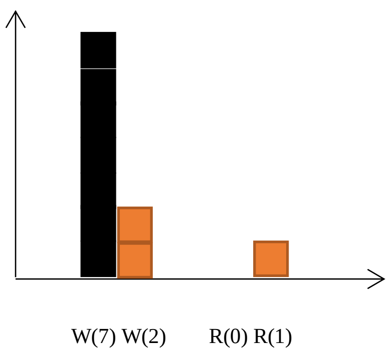
Graph (4) Oral Argument Analysis of for Section A



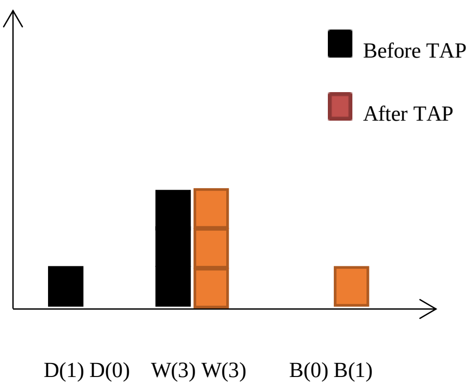
Graph (5) Oral Argument Analysis of for Section B

Students in section A insisted on arguments about heavy and light gases related to the reduction of air pressure at upwards. Even they made the following sentence 'the air pressure reduces as ascending from sea level because the heavy gases increase the density at downs. When we look at the density principle, the dense ones remain at bottom, and the ones with low density go upwards. The lightest gases were also remaining above sea level'. The possible effects of pressure drop above sea level on human being were generally explained correctly for both sections of students. In addition to these, the presence of statements including 'sparse of oxygen molecules as you reach the top of the mountains' and 'decrease in the density of oxygen molecules as going to higher altitudes' by section B students even after the whole discussion process.

Case of Bubbles in the Sea

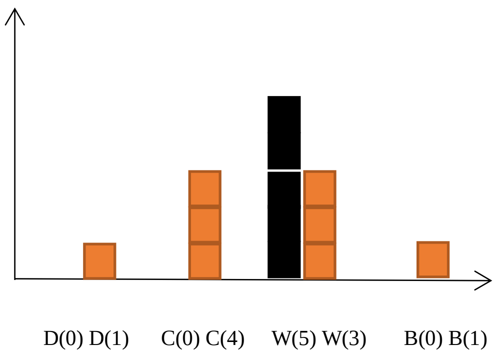


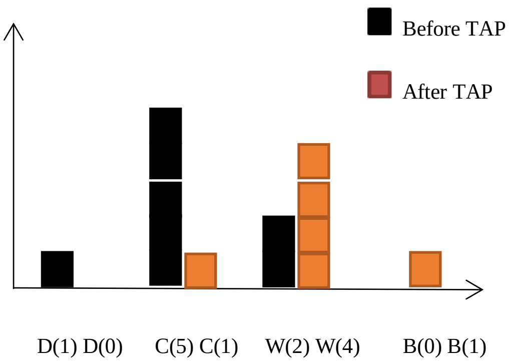
Graph (6) Written Argument Analysis for Section A



Graph (7) Written Argument Analysis for Section B

As seen from Graphs 6 and 7, there was no significant difference in the Section A and Section B students' in terms of the uses of TAP elements about the bubble case. When the written arguments of students were examined, they mostly correlated the increase the volume of the bubbles from deep to the surface of the sea with the pressure change. Besides to pressure change, one group of students in section A wrote that 'The amount of dissolved oxygen increases as it reaches the sea surface, the volume of air bubbles increases'. Similiarly, after TAP training, the following statement were written by the same group of students in section A: 'As going upwards in sea, the amount of oxygen increases and the pressure decreases'. Thereupon, students were asked why they thought that the amount of oxygen is increased as it moves towards the sea surface. They explained like that 'The fact that plants making anaerobic respiration at the deepest can live at a certain depths instead of existing in an arbitrary location proves that oxygen content is different at every level of the sea'.

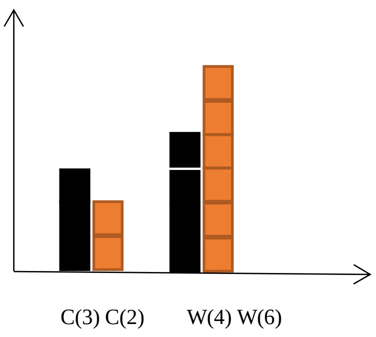




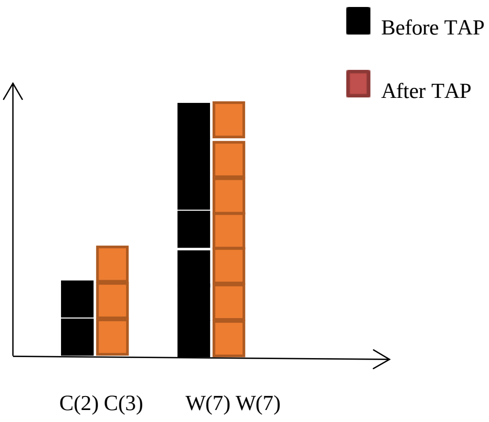
Graph (8) Oral Argument Analysis of for Section A Graph (9) Oral Argument Analysis of for Section B

Verbal argument analysis were also supported the written arguments. When the 8th and 9th graphs were examined, an increase in the use of TAP elements was observed. While increase in the volume of air bubbles was explained by the pressure change, the idea of varying oxygen content at different depths of the sea had continued to exist (They were asked to interpret by assuming that the sea temperature was the same in every point of the sea). For instance, they said 'We think that the volume of bubbles increases due to the increase in the the amount of oxygen as approaching the surface of the sea' and 'As the amount of dissolved oxygen increases as moved to the surface, the volume of air bubbles increases'. Besides, the presence of anaerobic plants in the depths of sea made them think/suggested to low amount of oxygen.

Case of Mountain Climbing

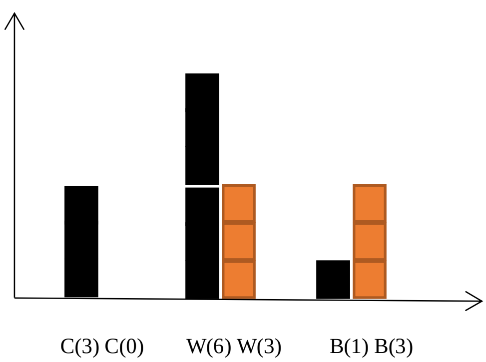


Graph (10) Written Argument Analysis for Section A

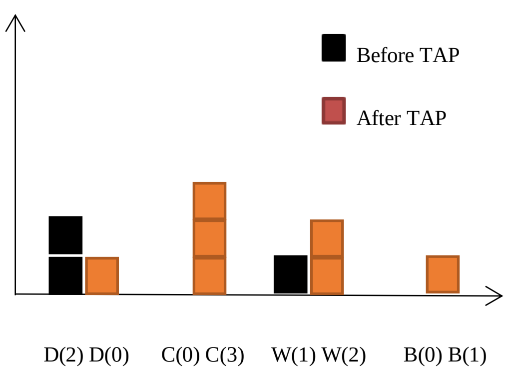


Graph (11) Written Argument Analysis for Section B

Students in both sections established/explained the relationship between air pressure and boiling point with the right reason. Students in both sections have a confusion/contradiction about the terms of ‘oxygen amount’ and ‘oxygen pressure’. For instance, students in section A before training wrote that ‘As a result of decreasing of oxygen level at higher altitude, the amount of oxygen goes to brain decreases’. Likewise, after the training they formed the similar following sentence: ‘The oxygen level decreases at higher altitudes/above sea level’. Students in section B, after training they gave the following answer to the question of ‘Why the people living in uplands or plateau are ruddycheeked?’: ‘Since the amount of oxygen decreases at higher altitudes, they need to use the oxygen efficiently’. The written arguments of the students in section B showed the similarity to those in section A. For example, they said that ‘The amount of oxygen decreases at higher altitudes, so the amount of hemoglobin increases’ and ‘The lungs of people living at the altitude above sea level are wider due to the lack of oxygen’.



Graph (12) Oral Argument Analysis of for Section A



Graph (13) Oral Argument Analysis of for Section B

As Graph 12 and Graph 13 were examined, unlike section A, there was an improvement in the use of TAP elements in verbal arguments of students B. The oral arguments of the students supported the written arguments in terms of the subject matter. For instance, students were also agreed on that atmospheric pressure decreases at higher altitudes and as the pressure acting on the water decreases, the boiling point decreases. On the other hand, after all discussions, students in section A hold the idea that 'the amount of oxygen decreases as going towards uplands'. As for the section B students, the expressions including oxygen number and amount decrease at higher altitudes were replaced by explanations with the decrease in oxygen pressure above sea level.

CONCLUSION

This study aimed to identify the changes in students' thoughts and the ways of expressing their thoughts and the elements in Toulmin Argument Pattern which the candidates use more frequently in this model. As Newton et al. (1999) stated students should engage in groups, listen to each other, and express their own ideas in order for argumentation to take place, therefore, in this study students worked in groups.

The written and verbal argument analysis showed that the quality of the arguments changed according to the subject of discussion. For instance, the improvement was determined in the use of elements of Toulmin Argument Pattern (TAP) in the activities related to the atmospheric pressure and the effect of atmospheric pressure on boiling point. Even before training, most of the students were agreed on that 'atmospheric pressure decreases as you move from sea level to higher'. In one section of students, students insisted on that '*while heavy gases increase the density at downs, light gases reduce the density upwards'* and and they thought that this would lead to lower air pressure at higher altitudes. Likewise, students in both sections established/explained the relationship between air pressure and boiling point with the right reason. On the other hand, students in both sections have confusion about the terms of 'oxygen amount' and 'oxygen pressure'. Some students believed in that the amount of oxygen decreases at higher altitudes after scientific discussions.

As for the air bubbles case in the sea, no significant improvement was identified in both sections of students in terms of the uses of TAP elements. Written argument analysis indicated that most of the students agree on that the increase the volume of the bubbles from deep to the surface of the sea with the pressure change. Even after scientific discussions after TAP, some of the students believed in that the amount of dissolved oxygen increases as it reaches the sea surface so the volume of air bubbles increases and anaerobic plants living at deeps were generally proposed as a reason for this event. The oral arguments of the students were also supported the written arguments.

Cross et. al. (2008), who explored the relationship between learning gains, measured through pre and post-assessment, and engagement in scientific argumentation, emphasized that quantity does not equal quality, and that the type of argumentative statements and the quality of the information provided in statements are critical. The use of TAP enabled to identify arguments and assess their quality.

Analysis of written and oral arguments of the current study showed that the quality of the argument asserted by the students and the use of the elements in the Toulmin Argument Model are related to the preliminary knowledge in the subject matter depended on the students' prior knowledge about the topic/issue especially the subject is particularly relevant to science learning or science concepts; because, if the preliminary information on the subject matter is inadequate, especially in discussions involving concepts of science, the process of argumentation discourse would not be continued as it should be due to the lack of knowledge.

There are many studies in the literature that demonstrate the effectiveness of argumentation-based education (Aydeniz & Gürçay, 2013; Çetin, 2014; Kaya, 2013; Kaya, Erduran, & Çetin, 2012; Özdem et. al. 2017). The teaching of what should be in a good argument can improve the quality of the students' arguments, but if the students' pre-knowledge involving science concepts in the discussion is insufficient, argumentation discourse may not be completed as desired. Therefore, the effectiveness of the argumentation-based teaching can be better understood if the activities are repeated with different topics in different student groups.

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