Journal of Education in Science, Environment and Health

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To cite this article:

Balci, C. & Yenice, N. (2016). Effects of the scientific argumentation based learning process on teaching the unit of cell division and inheritance to eighth grade students. *Journal of Education in Science, Environment and Health (JESEH), 2*(1), 67-84.

Journal of Education in Science, Environment and Health
Volume 2, Issue 1, 2016 ISSN: 2149-214X

Effects of the Scientific Argumentation Based Learning Process on Teaching the Unit of Cell Division and Inheritance to Eighth Grade Students

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Abstract

The aim of this study is to analyse the effects of scientific argumentation based learning process on the eighth grade students' achievement in the unit of "cell division and inheritance". It also deals with the effects of this process on their comprehension about the nature of scientific knowledge, their willingness to take part in discussions and their attitude towards the course of science and technology. The study employed the design of pretest-post test matched control group design which is part of semi-experimental design techniques. The participants of the study were 77 students, 38 of whom were in the experiment group and 39 of whom in the control group. The data of the study were collected using four tools: achievement test for the unit of cell division and inheritance, the nature of scientific knowledge scale, argumentation survey and the science and technology course attitude scale. All data collection tools were administered to experiment and control groups as pre- and post test. The data collected were analysed through t- test and ANCOVA (covariance analysis). The findings indicated that academic achievement, comprehension, willingness to discuss and the attitudes towards the course of science and technology of experiment students were significantly better than those of control students at the end of the implementation.

Key words: Scientific argumentation, Science education, Cell divison and inheritance, Nature of scientific knowledge, Attitudes towards the course of science and technology

Introduction

Social and economic expectations from individuals have changed due to the changing science and technology in recent period. In this process science education has a significant role to play. The major goal of science education is to make students have a scientific perspective and to make it possible for them to use it to learn how scientific knowledge is constructed (MONE, 2013). Scientific knowledge is not absolute and unchangeable, but may change based on conditions. Scientific knowledge is constructed when several arguments are expressed and discussed (Kuhn, 1992). Therefore, an efficient science education can be realized in a classroom setting where students can easily and freely express their views, justify these views based on evidence, develop counter arguments related to the arguments by their peers and scientific argumentation based learning process is dominant (Kaya and Kılıç, 2010). In the scientific argumentation based learning process students have social communication with one another, improve their knowledge base and support their arguments. This learning process makes it possible for students to understand the relationship among evidence, claims and justifications and improves their critical thinking skills (Erduran, Simon and Osborne, 2004). Research suggests that the scientific argumentation based learning process have positive effects on students' learning of higher level of cognitive skills such as interpretation of events from different perspective using quality arguments, improving claims through analyses and syntheses and developing sophisticated views (Jiménez-Aleixandre, Rodriguez and Duschl, 2000; Duschl and Osborne, 2002; Erduran et. al., 2004; Osborne, Erduran and Simon, 2004; Kaya, 2005; Uluçınar Sağır, 2008; Von Aufschnaiter, Erduran and Osborne, 2008; Deveci, 2009; Tekeli 2009; Erdoğan, 2010; Gültepe, 2011; Gümrah, 2013; Boran, 2014; Çınar and Bayraktar, 2014). Tekeli (2009) concluded that eighth grade students who took the course of science and technology through scientific argumentation based learning process had significantly better comprehension of conceptual change about acid - base and the nature of science, better scientific reasoning skills and better attitudes towards the course. It was also found that their willingness to participate in discussions was improved. The program of the course of science and technology indicates that using the scientific argumentation based learning process in the course requires several activities. This study provides different ways of using such activities in classrooms.

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Scientific Argumentation

There are different definitions of scientific argumentation. Hakyolu (2010) argues that scientific argumentation is a process of mental and social activities in which individuals exchange ideas to reach a conclusion about a topic and try to persuade other people about their views using scientific evidence. Jimenez-Aleixandre and Erduran (2008) state that scientific argumentation refers to the evaluation and justification of views in order to account for the relationship between claims and data. Therefore, scientific argumentation can be defined as a social activity which attempts to explain different views and ideas using positive critical thinking to overcome "undecided" position, to reveal truth and unknown in detail. This activity employs not only verbal communication but also visual materials to persuade people about a certai subject. Scientific argumentation takes place in an environment in which arguments are developed. Realist arguments are needed to persuade people and to have significant discussions in the process of scientific argumentations (Yeşiloğlu, 2007). Therefore, scientific argumentation includes the presentation and justification of several ideas about a topic (Küçük, 2012).

The Toulmin Model of Argumentation

Toulmin (1958) developed a model of argumentation in his book *The Uses of Argument* in order to account for how scientific argumentation takes place in its natural process. The model explains the basic constituents of argumentation and functional relations of them. This model is used in many fields of study, including science courses for the analysis of discussions (Newton, 1999; Driver, Newton and Osborne, 2000; Erduran et. al., 2004). Three major constituents of the model are grounds, warrant and claim. It also includes three supporting elements, namely backing, rebuttal and qualifiers. The model is given in figure 1.

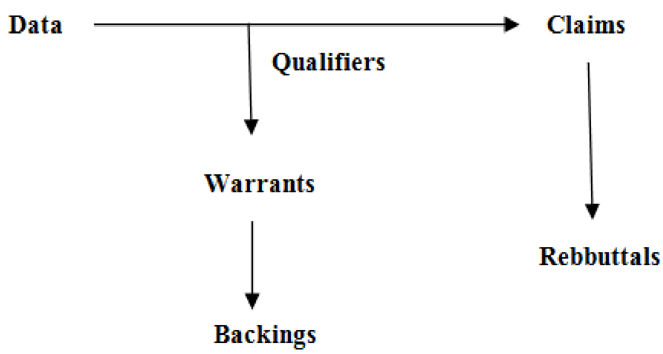

Figure 1. The Toulmin Model of Argumentation (Toulmin, 1958)

In this model the basic constituents of scientific argumentation are explained and given as follows (Driver et. al., 2000).

Claim: The position or claim being argued for; the conclusion of the argument.
Data: Reasons or supporting evidence that bolster the claim.
Warrant: he principle, provision or chain of reasoning that connects the grounds/reason to the claim.
Backing: support, justification, reasons to back up the warrant.
Rebuttal: exceptions to the claim; description and rebuttal of counter-examples and counter-arguments.
Qualifiers: specification of limits to claim, warrant and backing. The degree of conditionality asserted.

Science, Scientific Argumentation and Science Education

One of the distinctive features of science is that it includes reasoning processes supporting explanations and models and employs rational ways such as argumentation. Therefore, science can be regarded as a process in which arguments are backed by grounds and are confirmed by proper explanations (Tümay and Köseoğlu, 2011). Similarly, scientific argumentation is consisted of intragroup or individual interactions based on attempts of persuasion presenting valid and acceptable alternatives (Clark and Sampson, 2007). In science courses discussion can take place using proper strategies and therefore, students are provided with an opportunity to defend their ideas through the elements of scientific argumentation. Some of the activities and strategies that can be used for this end are given as follows:

- *Expression Tables:* In this activity students are given a table of statements about a scientific topic. This table includes both correct and incorrect statements. Students are asked to state with which statements they agree and with which statements they do not agree and also, to tell their reasons (Osborne et. al., 2004).
- *Concept maps*: Students are given a concept map, which includes several scientific concepts prepared based on the review of related literature. Then they discuss each concept in a group setting and develop arguments concerning whether or not these concepts are correct (Osborne et. al., 2004; Yeşiloğlu, 2007; Ceylan, 2012).
- *Competing theories- Stories:* Students are given two or more competing theories in the form of stories and are asked to answer the questions such as which theory they are supporting and why.
- *Competing theories- cartoons:* Students are given two or more competing theories in the form of cartoons. They are asked to choose a cartoon which they think that it includes the correct theory and to explain the reasons for their preference with related arguments (Osborne et. al., 2004).
- *Ideas and evidence:* Students are given two or more competing theories about the topic at hand. They are also given evidence statements about each theory. The class is divided into small groups and each group of students discusses each evidence statement (Solomon et. al. 1992, cited in Osborne et. al., 2004).
- *Developing arguments:* Students are given at most four ground statements about how a physical event takes place. Then they are asked to choose the best statement which explains the event and to develop arguments about the reasons for it (Osborne et. al., 2004).
- *Predict- Observe – Explain:* Students are shown a picture of an event without giving any detail. They are divided into small groups and develop arguments about the potential results of the event. At the end of the activity the result of the event. Then students are asked to make comparisons between the actual result of the event and their predictions about it (Özkara, 2011).
- *Designing an experiments:* The class is divided into small groups. They are given several hypothese such as "sound is much faster transmitted in solids." They are asked to design about the hypothesis they are given. They are also asked to develop arguments in support for their design following discussions with other groups (Osborne et. al., 2004).
- *Experiment reports:* Students are given a report and findings of an experiment carried out by other students. They are asked to develop arguments about the experiment based on this report (Golds Worthy, Watson and Wood- Robinson, 2000; cited in Osborne et. al., 2004).
- *Evidence cards:* Students are given two or more claims about a scientific topic and evidence cards to prove these claims. They are expected to present grounds and justification for the claims they selected. In activity students work in groups and reach a conclusion based on group discussions (Osborne et. al., 2004).
- *Discussion with models:* In the activity students are asked to develop or draw a model about a scientific topic or concept given. Then they are asked to develop arguments how they developed the model and which grounds they used for it. They are expected to present evidence supporting the model and rebut the other models giving counter arguments (Osborne et. al., 2004).

All the activities some of which given above aim at improving students' scientific thinking skills and their attempts to defend their position in a scientific manner. These activities make it possible for students to ask questions, defend their position using acceptable grounds, evaluate counter arguments and to follow a scientific way to achieve these activities. Activities of scientific argumentation are the basis for both science and science education (Kuhn, 1986; cited in Altun, 2010).

In Turkey the effects of scientific argumentation on student achievement in science education, student attitudes, debate skills of students and other related skills on different group of participants, including student teachers (Acar, 2008; Demirci, 2008; Tümay, 2008; Özdem, 2009; Aslan, 2010; Ceylan, 2010; Hakyolu, 2010; İşbilir, 2010; Top and Can, 2010; Kutluca, 2012; Şekerci, 2013; Boran, 2014), high school students (Yeşiloğlu, 2007; Özer, 2009; Çelik, 2010; Gültepe, 2011), primary and secondary students (Kaya, 2005; Kaya and Kılıç, 2008; Uluçınar Sağır, 2008; Kaya, 2009; Deveci, 2009; Tekeli, 2009; Altun, 2010; Erdoğan, 2010; Hacıoğlu, 2011; Keçeci, Kırılmazkaya and Kırbağ, 2011; Özkara, 2011; Ceylan, 2012; Küçük, 2012; Okumuş, 2012; Uluay, 2012; Cin, 2013; Çınar, 2013; Öğreten, 2014; Polat, 2014). These studies generally concluded that scientific argumentation has positive effects on the variables analysed. On the other hand, there are less studies concerning the effects of scientific argumentation on the eighth grade science and technology course (Kaya, 2009; Tekeli, 2009; Özkara, 2011; Okumuş, 2012). Some of the studies are about the use of scientific argumentation in specific topics (i.e., global warming, environment, etc) covered in the course of science and technology (Deveci, 2009; Domaç, 2011; Karışan, 2011; Keçeci et. al., 2011; Yaman, 2011; Kutluca, 2012; Soysal, 2012).

There is no specific study about the effects of scientific argumentation on the students' achievement in the unit of "cell division and inheritance" covered in the eighth grade science and technology course, on their comprehension about the nature of scientific knowledge, their willingness to take part in discussions and their attitude towards the course of science and technology. Therefore, the findings of this study will provide new insights about the use of scientific argumentation in science education.

Aim

The study aims at identifying the effects of scientific argumentation on the students' achievement in the unit of "cell division and inheritance" covered in the eighth grade science and technology course, on their comprehension about the nature of scientific knowledge, their willingness to take part in discussions and their attitude towards the course of science and technology. In parallel to these aims the study tries to answer he following research questions:

1) Do the scores of the experiment students and of the control students from achievement test for the unit of cell division and inheritance significantly vary?
2) Do the scores of the experiment students and of the control students from the nature of scientific knowledge scale significantly vary?
3) Do the scores of the experiment students and of the control students from the argumentation survey significantly vary?
4) Do the scores of the experiment students and of the control students from the scale for attitudes towards science and technology course significantly vary?

Method

Model of the Study

The study is deasigned as a pretest-post test matched control group research which is part of semi-experimental design techniques (Balcı, 2005).

Participants

The participants of the study were 77 eighth grade students attending two sections of a public secondary school in Sultangazi district of Istanbul during the school year of 2014-2015. Students in one section were assigned to the experiment group in which scientific argumentation was employed as learning process. The remaining students in the other section were assigned to the control group in which the course was delivered through traditional teaching methods. The experiment group consisted of 38 students of which 21 were females (55.3%) and 17 males (44.7%). There were 39 students in the control group of which 18 were females (46.2%) and 21 males (53.8%).

Data Collection Instruments

Achievement test for the unit of cell division and inheritance was developed by the author to determine the current knowledge of students about the topic. The test included 60 items developed based on the stated goals for the unit. It was used in a pilot study and then item analysis was carried out. Following the analysis the number of test became thirty. The analysis showed that its KR-20 reliability coefficient was .86.

Nature of Scientific Knowledge Scale

The nature of scientific knowledge scale was developed by Rubba and Anderson (1978) to reveal student understanding about the nature of scientific knowledge. The scale specifically addresses the understanding of students at the ages of 12-15. The scale was translated into Turkish by Taşar (2006). It was developed based on the model of scientific knowledge. It is a 5-point Likert scale, which covers 48 items of which 24 are positive statements and 24 are negative statements. The maximum score is 240, while the minimum score is 48. Higher scores in each dimensions mean that students have correct understanding about the nature of scientific knowledge. In the study it was found that the scale has six dimensions and the Cronbach's Alpha coefficients for the dimensions are as follows: for the dimension of ethics .87, for the dimension of creativty .87, for the dimension of development .86, for the dimension of simplicity .86, for the dimension of testability .86, and for the dimension of combination .86. The overall Cronbach's Alpha coefficient for the scale was found to be .84.

Argumentation Test

Argumentation test was administered to the experiment students to determine if any change took place in their willingness to participate in discussions. The test was developed by Infante and Rancer (1982). It was translated into Turkish by Kaya (2005). It is a 5-point Likert type scale of which Cronbach's Alpha coefficient was found to be .79.

Attitudes towards Science and Technology Course Scale

Developed by Tekeli (2009) the attitudes towards science and technology course scale was employed to reveal the particpants' attitudes towards the course. It is a 5-point Likert type scale which is consisted of fifteen items. Of these items, ten are positive statements and five negative statements. The original Cronbach's Alpha coefficient of the scale was found to be .96. In this study the reliability analysis of the scale was carried out on 118 eighth grade students. The results of confirmatory factor analysis showed that the scale did not have necessary statistical conditions for a single dimension (x^2/sd= 4.14; RMSEA= .164). Then the scale was analysed using exploratory factor analysis. It was found that the Kaiser Mayer Olkin (KMO) coefficient for four dimensions was .85. It was also found that the result of the Barlett's test was 804.866 ($p< .01$) and that it accounted for 68,09% of the total variance. Confirmatory analysis showed that four dimensions had x^2/sd=1.26. It is suggested that the rate between chi-square consistency and degree of freedom should be at most 5 or lower. In the analysis the x^2/sd rate was found to be lower than two, indicating that factor consistency is perfect (Kline, 2005). In addition, consistency indexes of four dimensions indicated that mean error square root RMSEA was .047. If the value of RMSEA is between 0 and .05, it refers to good consistency. The value of RMSEA between .05 and .08 reefrs to an acceptable consistency (Brown, 2006; Şimşek, 2007; Yılmaz and Çelik, 2009). In the current study the value of RMSEA was found to be .047, indicating that the consistency was good. Non-normalized fit index (NNFI) was found to be .94, and comparative fit index (CFI) was found to be .95. In short, the factor analysis showed that the scale had four dimensions: positive attitude towards science and technology course, negative attitude towards science and technology course, importance attached to the science and technology course and interest in science and technology course. The Cronbach's Alpha coefficients of these dimensions are found as follows: for the dimension of positive attitude towards science and technology course it was .88, for the dimension of negative attitude towards science and technology course it was .80, for the dimension of importance attached to the science and technology course it was .71 and for the dimension of interest in science and technology course .77. The overall Cronbach's Alpha coefficient of the scale was found to be .88.

Activities of Scientific Argumentation

In order to develop study sheets for the classroom activities based on scientific argumentation several studies were reviewed (i.e., Osborne et. al., 2004; Uluçınar-Sağır, 2008; Altun, 2010; Şahin and Hacıoğlu, 2010; Hacıoğlu, 2011; Özkara, 2011; Yaman, 2011; Kutluca, 2012; Puig, Torija and Jimenez-Aleixandre, 2012; Soysal, 2012). In the study the following scientific argumentation-based activities and strategies were employed: developing arguments, competing theories-cartoons, predict-observe-explain, competing theories-ideas and evidence, expressions table, concept maps and competing theories-stories. Study sheets were developed by the author. These sheets were reviewed by science education specialists and science and technology teachers in terms of scope validity.

Procedure

The unit was delivered in the control group through activities covered in the textbook. It was delivered in the experiment group through the activities mentioned above. All these activities were based on the Toulmin model of argumentation. The activities were implemented by the scholar. Table 1 shows the strategies of scientific argumentation and small group techniques used in the activities.

Table 1. Strategies of scientific argumentation and small group techniques used in the activities

Activities	The Strategies	Group Techniques
In The Activities of Introduction to and Preparation for Scientific Argumentation	Developing Arguments	Pair Talk
I am Examining Mitosis	Developing Arguments	Listening Triads
In the Activities of Living Beings and Their Chromosome Numbers	Competing Theories- Cartoons	Pairs and Quadruples
Astonishment of The King	Case Text- Developing Arguments	Pairs and Quadruples
I'm Geeting to Know Mendel	Predict- Observe – Explain Competing Theories- Cartoons	Pair Talk
Hereditary diseases	Case Text- Developing Arguments	Pair Talk
Let's Draw Irem's Family Tree	Competing Theories-Ideas and Evidence	Ambassadors
I am Learning Meiosis	Developing Arguments	Pair Talk
Differences Between Mitosis and Meiosis	Expression Tables	Listening Triads
My Concept Map	Concept Map	Pairs ad Quadruples
Nucleotides, DNA, Genes, Chromosome	Expression Tables	Listening Triads
Modification- Mutation	Case Text- Developing Arguments	Pair Talk
Genetic Engineering	Competing Theories- Stories	Discussions
Living Clone	Competing Theories- Cartoons	Ambassadors
Why are we taller than our grandparents?	Case Text- Developing Arguments	Discussions

As Table 1 shows in the activities the following small group techniques based on scientific argumentation were used: pair talk (in the activities of introduction to and preparation for scientific argumentation, I am geting to know Mendel, hereditary diseases, I am learning meiosis, modification- mutation), listening triads (I am examining mitosis, differences between mitosis and meiosis, nucleotides, DNA, genes, chromosome), pairs and quadruples (in the activities of living beings and their chromosome numbers, astonishment of the king, my concept map), ambassadors (in the activities of let's draw Irem's family tree, living clone) and discussions (in the activity of genetic engineering and why are we taller than our grandparents?).

In the experimental group students were informed about how scientific argumentation based learning process would be carried out. Two additional activities titled "young or old?" and "fraudulent tracks" were made. The study lasted for 24 class hours. Students were randomly divided into small groups during the activities where necessary.

Data Analysis

The pre-test scores of both groups were analysed using t-test, which indicated that the groups had similar scores ($p>.05$). The comparison of the post-test scores of the groups was made by ANCOVA. The distribution of ANCOVA analysis and introgroup regressions were analysed (Leech, Barrett and Morgan, 2005). The analysis showed that all conditions were proper for the ANCOVA analysis.

Results

Results of the Achievement Tests

Table 2 shows mean pre- and post-test scores of the experiment and control groups in the achievement test, standard deviation and corrected post-test mean scores and standard deviation in the Bonferroni test.

Table 2. Mean pre- and post-test scores of the experiment and control groups in the achievement test, standard deviation and corrected post-test mean scores and standard error

Groups	N		Total Points		Corrected Post-Test Mean Scores	
			$\bar{X}$	S.S	$\bar{X}$	S.e
Experiment	38	Pre test	11.50	4.688		
		Post test	19.05	4.724	18.99	.606
Control	39	Pre test	11.33	4.468		
		Post test	16.20	5.161	16.26	.599

Table 2 indicates that mean post-test score of the experiment group is 19.05, while that of the control group is 16.20. Following the correction of the pre-test scores mean post-test score of the experiment group is 18.99, while that of the control group is 16.26. Therefore, it can be stated that the academic achievement of the experiment students is much higher than that of the control students. In order to see whether or not the corrected post-test scores of the groups significantly vary ANCOVA analysis was used. The results of the ANCOVA analysis are given in Table 3.

Table 3. Results of the ANCOVA analysis about the corrected post-test scores of the groups

Source	Sum of Squares	df	Mean Square	F	Sig.
Pre test(regression)	804.066	1	804.066	57.534	.000
Groups (experiment/control)	143.218	1	143.218	10.248	.002*
rror	1034.188	74	13.976		
Total	25874.000	77			
Corrected Total	1994.312	76			

Table 3 indicates that when the pre-test scores of the groups are controlled there appears a statistically significant difference between the post-test score of the experiment group and that of the control group ($F_{(1,74)}$= 10.248, $p< .05$). More specifically, the corrected mean post-test score of the experiment group (X= 18.99) is higher than that of the control group (X= 16.26). Therefore, using a scientific argumentation based learning process has significant and positive effects on the student achievement in regard to the unit of cell division and inheritance.

Results of the Nature of Scientific Knowledge Scale

Mean post-test scores of the experiment students was found to be 27.21 for the dimension of ethics. It was found found to be 29.86 for the dimension of creativity, 28.63 for the dimension of development, 26.13 for the dimension of simplicity, 33.57 for the dimension of testability and 29.86 for the dimension of combination. For the control group the following mean post-test scores were found: for the dimension of ethics it was 25.46, for the dimension of creativity it was 28.12, for the dimension of development it was 25.89, for the dimension of simplicity it was 23.53, for the dimension of testability it was 30.87 and for the dimension of combination it was 28.12.

When the pre-test scores of the experiment students are controlled their mean post-test scores for the dimension of the scale were found to be higher ethics ($\boldsymbol{X}_D$=27.33; $\boldsymbol{X}_K$= 25.33), creativity ($\boldsymbol{X}_D$=30.28; $\boldsymbol{X}_K$=27.72), development ($\boldsymbol{X}_D$=28.68; $\boldsymbol{X}_K$= 25.84), simplicty ($\boldsymbol{X}_D$=26.07; $\boldsymbol{X}_K$=23.59), testability ($\boldsymbol{X}_D$=33.41; $\boldsymbol{X}_K$= 31.03) and combination ($\boldsymbol{X}_D$=32.44; $\boldsymbol{X}_K$= 32.33)) than those of the control students. Therefore, it safe to argue that the experiment students had much more developed views about the nature of scientific knowledge than the control students. In order to see whether or not the corrected post-test scores of the groups significantly vary ANCOVA analysis was used. The results of the ANCOVA analysis are given in Table 4.

Table 4 indicates that when the pre-test scores of the groups are controlled there appears a statistically significant difference between the corrected mean post-test scores of both groups for five dimensions of the scale: ethics ($F_{(1,74)}$= 6.407, $p< .05$), creativity ($F_{(1,74)}$= 6.188, $p< .05$), development ($F_{(1,74)}$= 7.933, $p< .05$), simplicity ($F_{(1,74)}$= 10.190, $p< .05$) and testability ($F_{(1,74)}$= 9.128, $p< .05$). The experiment students had higher mean post-test scores for the dimensions mentioned above than the control students. For the sixth dimension, namely combination, the mean corrected post-test score for the experiment group ($\boldsymbol{X}$=32.44) was higher than that of the control group ($\boldsymbol{X}$=32.33). However, when the pre-test scores of both groups are controlled, it appears that this difference is not statistically significant ($F_{(1,74)}$= .017, p> .05). These findings suggest that the experiment students had much more developed and correct understandings about the ethical, creativity, developmental, simplicity and testability dimensions of scientific argumentation than the control students. Therefore, it can be argued that scientific argumentation based learning process has positive and significant effects on the student understanding about the nature of scientific knowledge.

Table 4. Results of the ANCOVA analysis about the corrected post-test scores of the groups

Subdimension	Source	Sum of Squares	df	Mean Square	F	Sig.
Ethics	Pre test(regression)	465.114	1	465.114	38.808	.000
	Groups(experiment/control)	76.793	1	76.793	6.407	.013*
	Error	886.894	74	11.985		
	Corrected Total	1410.883	76			
Creativity	Pre test(regression)	889.980	1	889.980	44.298	.000
	Groups(experiment/control)	124.327	1	124.327	6.188	.015*
	Error	1486.722	74	20.091		
	Corrected Total	2434.987	76			
Development	Pre test(regression)	821.054	1	821.054	42.211	.000
	Groups(experiment/control)	154.299	1	154.299	7.933	.006*
	Error	1439.378	74	19.451		
	Corrected Total	2404.312	76			
Simplicty	Pre test(regression)	332.703	1	332.703	28.517	.000
	Groups(experiment/control)	118.883	1	118.883	10.190	.002*
	Error	863.331	74	11.667		
	Corrected Total	1325.455	76			
Testability	Pre test(regression)	511.795	1	511.795	43.242	.000
	Groups(experiment/control)	108.036	1	108.036	9.128	.003*
	Error	875.827	74	11.835		
	Corrected Total	1528.675	76			
Combination	Pre test(regression)	480.964	1	480.964	41.679	.000
	Groups(experiment/control)	.198	1	.198	.017	.896
	Error	853.947	74	11.540		
	Corrected Total	1340.312	76			

Results of Argumentation Test

Table 5 shows the pre- and post-test mean scores of the groups in the argumentation test and standard deviation. It also indicates the corrected post-test mean scores and standard deviation which were found as a result of the ANCOVA analysis.

Table 5. Pre/post-test mean and corrected post-test mean scores

Groups	N		Total Points		Corrected Post-Test Mean Scores	
			$\bar{X}$	S.S	$\bar{X}$	S.e
Experiment	38	Pre test	64.13	12.760		
		Post test	71.13	13.293	71.14	.968
Control	39	Pre test	64.15	10.080		
		Post test	66.79	11.772	66.78	.956

Table 5 indicates that the mean post-test score of the experiment group was found to be 71.13. It was found to be 66.79 for the control group. When the pre-test scores are controlled the mean post-test score for the experiment group was found to be 71.14, and it was found to be 66.78 for the control group. Therefore, it can be stated that willingness of the experiment students to participate in discussions is higher than that of the control students. ANCOVA was employed to see whether or not there was a significant difference between the corrected post-test scores of the groups. The results of the analysis are given in Table 6.

Table 6. ANCOVA results about the pre- and post-test scores of both groups

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Pre test(regression)	9169.192	1	9169.192	257.453	.000
Groups (experiment/control)	365.563	1	365.563	10.264	.002*
Error	2635.509	74	35.615		
Total	378074.000	77			
Corrected Total	12166.675	76			

Table 6 indicates that when the pre-test scores of the groups are controlled there appears a statistically significant difference between the corrected mean post-test scores of the groups ($F_{(1,74)}$= 10.264, $p< .05$). More specifically, the corrected mean post-test score of the experiment group ($\boldsymbol{X}$= 71.14) is higher than that of the control group ($\boldsymbol{X}$= 66.78). Therefore, it can be argued that scientific argumentation based learning process has positive and significant effects on the student willingness to participate in discussions.

Results of the Attitudes towards Science and Technology Course Scale

The mean post-test scores for the experiment group were found to be 25.02 for the positive attitudes, 12.18 for the negative attitudes, 12.65 for the importance given to the course and 13.15 for the interest in the course. For the control group the mean post-test scores were found to be 22.64 for the positive attitudes, 12.17 for the negative attitudes, 12.41 for the importance given to the course, and 11.76 for the interest in the course. When the pre-test scores are controlled, the mean post-test scores for the dimensions for the experiment group (positive attitude ($\boldsymbol{X}_D$=25.11; $\boldsymbol{X}_K$= 22.55), negative attitude ($\boldsymbol{X}_D$=12.68; $\boldsymbol{X}_K$=12.38), importance ($\boldsymbol{X}_D$=12.63; $\boldsymbol{X}_K$= 12.43) and interest ($\boldsymbol{X}_D$=12.93; $\boldsymbol{X}_K$=11.98) were higher than those for the control group. Therefore, the attitudes of the experiment students towards the science and technology course much higher than those of the control students. ANCOVA was employed to see whether or not there was a significant difference between the corrected post-test scores of the groups. The results are given in Table 7.

Table 7. ANCOVA results about the pre- and post-test scores of both groups

Subdimension	**Source**	**Sum of quares**	**df**	**Mean Square**	**F**	**Sig.**
The Positive Attitudes	Pre test(regression)	446.563	1	446.563	66.977	.000
	Groups(experiment/control)	126.097	1	126.097	18.913	.000*
	Error	493.386	74	6.667		
	Corrected Total	1049.455	76			
The Negative Attitudes	Pre test(regression)	115.741	1	115.741	41.661	.000
	Groups(experiment/control)	1.784	1	1.784	.642	.426
	Error	205.582	74	2.778		
	Corrected Total	331.169	76			
Importance	Pre test(regression)	73.484	1	73.484	33.463	.000
	Groups(experiment/control)	.736	1	.736	.335	.564
	Error	162.504	74	2.196		
	Corrected Total	237.169	76			
Interest	Pre test(regression)	87.715	1	87.715	62.257	.000
	Groups(experiment/control)	16.405	1	16.405	11.643	.001*
	Error	104.260	74	1.409		
	Corrected Total	229.091	76			

Table 7 shows that when the pre-test scores are controlled, there appear significant differences between the post-test scores of the groups for two dimensions: positive attitude ($F_{(1,74)}$= 18.913, $p< .05$) and interest ($F_{(1,74)}$= 11.643, $p< .05$). More specifically, the experiment group had higher mean post-test scores for these dimensions than the control group. In addition, the experiment group had a higher mean post-test scores for the dimension of interest than the control group ($\boldsymbol{X}$=12.68 and $\boldsymbol{X}$=12.38, respectively). However, when the pre-test scores are controlled, it is found that this difference is not statistically significant ($F_{(1,74)}$= .642, p> .05). Similarly, the experiment group had a higher mean post-test scores for the dimension of importance than the control group ($\bar{X}$=12.63 and $\bar{X}$=12.43, respectively). However, when the pre-test scores are controlled, it is found that this difference is not statistically significant ($F_{(1,74)}$= .335, p> .05). These findings suggest that scientific argumentation based learning process has positive and significant effects on the student attitudes towards the course of science and technology.

Discussion and Conclusion

In the study it was found that scientific argumentation based learning process is much more efficient in improving student achievement than traditional and textbook based teaching methods. The finding of the study that scientific argumentation based learning process improves student achievement is consistent with previous findings (Yerrick, 2000; Zohar and Nemet, 2002; Kaya, 2005; Demirci, 2008; Sağır-Uluçınar, 2008; von Aufschnaiter et. al., 2008; Deveci, 2009; Köroğlu, 2009; Tekeli, 2009; Altun, 2010; Özkara, 2011; Ceylan, 2012; Okumuş, 2012; Uluay, 2012; Öğreten, 2014; Polat, 2014). For instance, Özkara (2011) analysed the effects of the scientific argumentation based learning process on the achievement of eighth graders in relation to the unit of pressure and concluded that this process has a significant effects on student achievement. Similarly, Polat (2014) compared the scientific argumentation based learning process and traditional teaching method on seventh graders and found that the former had positive effects on student achievement. On the other hand, this finding of the study is also consistent with the findings of the previous studies carried out on secondary students and student teachers (Yeşiloğlu, 2007; Özer, 2009; Demircioğlu and Uçar, 2015). However, Gümrah (2013) found no significant difference between the scientific argumentation based learning process and traditional methods on the ninth grade students' achievement. This inconsistency might have arised due to the use of different groups of participants.

Students who are taught through the scientific argumentation based learning process may experience several steps involved in the scientific process (Driver et. al., 2000). In the study it was found that the experiment group had higher mean post-test scores for five out of six dimensions of the nature of the scientific knowledge scale, namely ethics, creativity, development, simplicity and testability. On the other hand, although the difference is not statistically significant, the experiment group also had higher mean post-test score for the dimension of combination than the control group ($\bar{X}$=32.44 and $\bar{X}$=32.33, respectively). Therefore, it is safe to argue that the experiment students had much more developed understandings about the nature of scientific knowledge. This finding of the study is consistent with previous studies (Kaya, 2005; Uluçınar Sağır, 2008; von Aufschnaiter et. al., 2008; Tekeli, 2009; Altun, 2010). On the other hand, this finding of the study is also consistent with the findings of the previous studies carried out on secondary students and student teachers (Özer, 2009; Tümay and Köseoğlu, 2010; Gümrah, 2013; Boran, 2014). For instance, Gümrah (2013) found that the scientific argumentation based learning process has positive effects on student understandings about the nature of scientific knowledge. However, there are also studies which concluded that the scientific argumentation based learning process has no significant effects on student understandings about the nature of scientific knowledge (Yeşiloğlu, 2007, Ceylan, 2012, Şekerci, 2013). This inconsistency might have arised from the use of different groups of participants or the subject analysed.

The use of small groups in teaching scientific concepts makes it possible for students to perceive scientific concepts in a social pattern. In the study it was found that the experiment students had higher levels of willingness to take part in discussions than the control students. This finding is similar to those of the previous studies (Kaya, 2005; Uluçınar Sağır, 2008; Tekeli, 2009, Erdoğan, 2010; Yeh and She, 2010; Çınar, 2013). For instance, Çınar (2013) found that the experiment students who were taking the fifth grade science and technology course in a scientific argumentation based learning setting had higher levels of willingness to take part in discussions than the control students. On the other hand, this finding of the study is also consistent with the findings of the previous studies carried out on secondary students and student teachers (İşbilir, 2010; Şekerci, 2013; Demircioğlu et. al., 2015).

In the study it was also found that the scientific argumentation based learning process had positive effects in improving the student attitudes towrds the course of science and technology. More specifically, the experiment students had higher mean post-test scores for the dimensions of positive attitudes towards the course of science and technology and of interest in the course. It is thought that the reasons for these improved student attitudes are about the experience of a different teaching and learning process and intragroup interactions. The finding about the positive effects of the scientific argumentation based learning process on student attitudes is consistent with previous findings (Kaya, 2005; Tekeli, 2009; Erdoğan, 2010; Küçük, 2012). For instance, Küçük (2012) found the positive effects of the scientific argumentation based learning process on the attitudes of the seventh grade students towards the course of science and technology. Research suggests that student attitudes resist to change (Uluçınar Sağır, 2008; Altun, 2010; Özkara, 2011; Ceylan, 2012). On the other hand, Yeşiloğlu (2007) found that the scientific argumentation based learning process had no significant effect on the attitudes of the tenth grade students towards the chemistry course. This inconsistency can be stemmed from the use of different groups of participants and the analysis of different study subjects. In short, it is found that the scientific argumentation based learning process had significant and positive effects on student achievement, student understandings about the nature of scientific knowledge and their attitudes towards the course of science and technology.

Acknowledgements

This study is a version of the MA thesis under the supervision of Assoc. Prof. Dr. Nilgün YENİCE at Adnan Menderes University and was supported by the scientific research project directorate of Adnan Menderes University.

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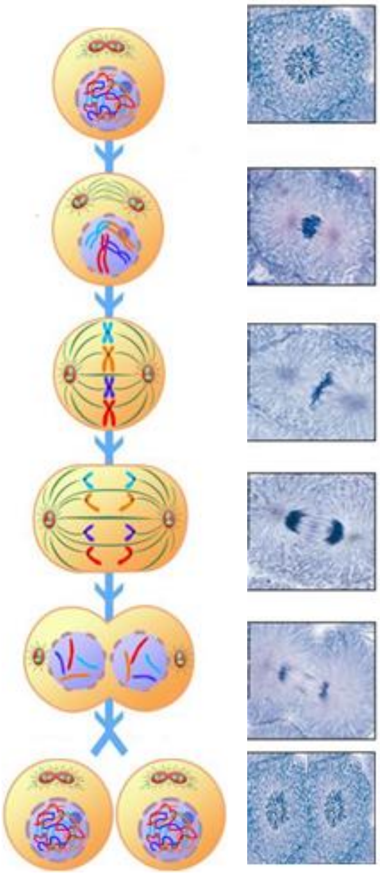
APPENDIX

Activity 2: Learning Mitosis

Please review the figures about the steps in mitosis. Tell what you have seen.

How many cells occur following the division?



What happens to parent cell following the division?

What is the relationship between parent cell and newly formed cells?

Compare the sizes of parent cell and daughter cells.

Why are newly formed daughter cells the same as parent cell?

My claim :

My justification:

Zooblast is responsible for cell division.

True ☐ False ☐

My claim :

My justification:

Rebuttal: If there was a group member who did not agree with your idea, how did you persuade him?

……
……
………

Chromosome can be seen with a microscope only during the cell division.

True ☐ False ☐

My claim	:
My justification	:

Chromosome exists in cystoblast.

True ☐ False ☐

My claim	:
My justification	:

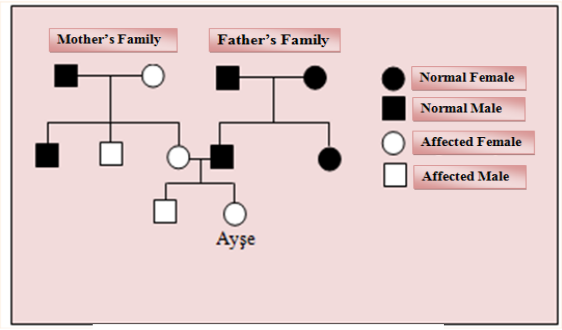
Chromosome can always be seen with a microscope.

True ☐ False ☐

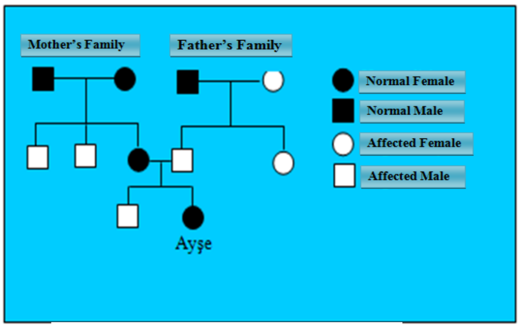
My claim	:
My justification :	

Activity 7: Let's draw İrem's family tree

Family tree is a schematic figure which makes it possible for us to see better the family relations. In family tree different signs are used for male members and female members of the family. Irem, an eighth grade student, was asked by her teacher to prepare a family tree focusing on a disease experienced in the family. She first makes a research about her family past. She learns that both grandfathers and one grandmother of her were color-blind and that her mother has gene for color-blindness. Based on this information Irem draws two family frees on cards with different colors. However, she is not sure about which one is correct.



The Pink Card



The Blue Card

Based on the information given above discuss which family tree is correct.

Theory 1: Family tree on pink card is correct.

Theory 2: Family tree on blue card is correct.

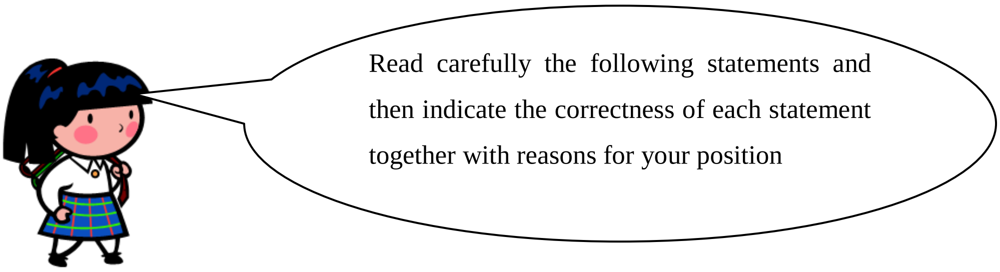
There should be at least one reason for your group to support for your argument.

<u>**Claims/ reasons**</u>

- Given that the mother of her father was color-blind, her father should also be color-blind.
- Gene for color-blindness can be transmitted to female members through their mothers or fathers.
- Given that her father is color-blind, she should also be color-blind.
- Her grandmother on her mother side is color-blindness carrier.
- Given that her mother has gene for color-blindness, she may also be color-blind.
- Color-blindness is a hereditary disease depending on X chromosome.
- Her sister does not get gene for color-blindness from her father.
- Given that the mother and father of her father were color-blind, her aunt is certainly color-blind.

If you have other reasons or evidence, please tell these.

Activity 9: Differences between mitosis and meiosis



Differences between mitosis and meiosis	True	False	Supporting reasons
Mitosis does not provide hereditary diversity.			
During mitosis homologous chromosomes seperate from each other.			
Meiosis provides diversity among living beings.			
Meiosis results in four cells.			
Mitosis consists of two consecutive steps.			
During mitosis parts are exchanged in homologous chromosomes.			
Mitosis results in reproduction in single-celled beings.			
Meiosis occurs in reproduction host cells.			
Sperm, egg and pollen cells are the results of mitosis.			
Mitosis results in two daughter cells which are the exact copies of parent cell.			