



## Effectiveness of the argumentation method: A meta-analysis<sup>1</sup>

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### Abstract

In this age of rapidly developing science and technology and with all the ease of access to information regardless of time and location, it is an indispensable component of every country's educational policy to educate individuals who can think, defend their ideas and make innovations. The purpose of this research is to determine the effect of the argumentation method on the students' academic achievement. To achieve this purposes, Meta-analysis, also known as the analysis of other analyses, is employed in this study. All the experimental studies in Turkey have been reviewed and examined by means of national and international electronic database searching for this research, and 25 of them have been found to meet our criteria so that we could examine them through meta-analysis. As a result of these analyses, calculated effect size is found to be large. Consequently, the argumentation method has been determined to have a significantly positive effect on the academic achievement ( $ES=0,997$ ;  $p<0,05$ ). Considering the population of Turkey, this result indicates that the argumentation method proves itself to be more effective on students' academic achievement than the traditional education.

**Keywords:** Argumentation; meta-analysis; effect size; academic achievement; effective

### Introduction

In this age of rapidly developing science and technology and with all the ease of access to information regardless of time and location, it is an indispensable component of every country's educational policy to educate individuals who can think, come up with ideas, defend them and make innovations. Starting from the year 2005 in our country, some radical changes in the educational programs have been made with the aim of educating individuals who can meet the requirements of this competitive age. In such educational programs, the use of more contemporary

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teaching methods and active participation of students in the learning process are promoted through methods and techniques that allow students to integrate their existing knowledge with the new ones which increase at an ever-accelerating pace. In this way, education is not considered to be merely a direct lecture of an instructor. Instead, it is constructed within an environment which makes it possible for the students to question and research about the information presented to them (Yıldırım, 2013).

It is aimed that students educated with these methods become more inclined to question, research and synthesize by generating ideas to attain their goals and in turn become scientifically literate individuals. In order to attain these qualities, special emphasis has been placed on the properties of various educational methods in the renewed educational programs. One of these methods is the argumentation method. Some essential properties of the argumentation method were emphasized in the National Education policy document: Students should be able to: "Understand that science has a structure that is based on evidence and that allows questioning and falsification [...]", "explain the role of evidence, theories and/or paradigms on how scientific knowledge changes [...]", "realize that when new evidence appears, current scientific knowledge is tested, limited, corrected or renewed" (MNE, 2005).

Andriessen, Baker, and Suthers (2003 ) define argumentation as "putting forward an opinion together with its reasons and trying to convince those who have different opinions", and Erduran & Jiménez-Aleixandre (2008) define it as "a scientific discussion and social interaction process in which scientific claims are supported and evaluated with experimental or theoretical evidence". Through the implementation of this process, students are expected to disprove the opposing arguments or defend their own arguments against those of their peers by presenting reasons from different perspectives in the scientific or socio-scientific issues, and finally construct scientifically solid explanations (Driver, Newton, & Osborne, 2000).

Toulmin (1958) describes the elements of argumentation patterns (claim, data, warrant, backing, rebuttal and qualifier) and the relation between them, as shown in the figure below (Figure - 1). While claim, data and warrant are the most basic elements of an argument, backing, rebuttal and qualifier are more complex elements.

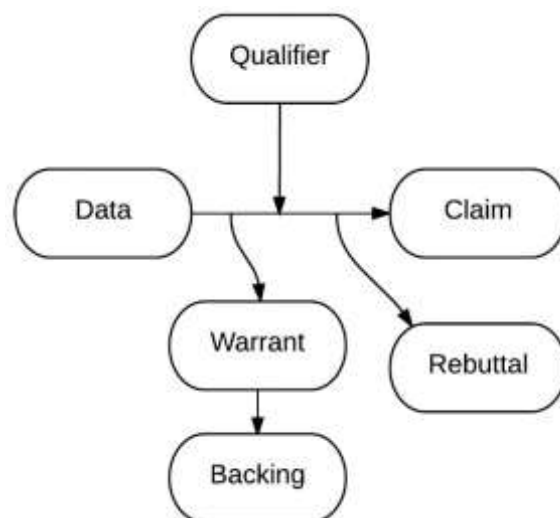


Fig. 1. The Basic Elements of Argumentation patterns (Toulmin, 1958).

As mentioned in the model, claim is generally the statement of an assertion or an opinion. Data is the information, evidence or an occasion used to support the claim. Warrant is the statement of how and in which way the data supports the claim. Backing is the information, which backs up the warrant and the reliability or acceptability of the claim and helps the audience understand the rationale behind the argument. Qualifier comprises the statements such as “maybe”, “possibly” or “certainly” that limit the scope of the argument or refer to the conditions under which the claim holds true. Rebuttal is a statement that shows under which conditions the arguments are not true and the claims are not valid, or it is a counter-argument (Simon, Erduran, & Osborne, 2006; Toulmin, 1958; Van Eemeren, 1995).

Anderiessen (2006) illustrates the definitions given above through the Kyoto Protocol as follows: Kyoto Protocol is necessary to reduce the global warming (claim). The global temperature has been rising for the last century along with the increase in greenhouse gases (data). Scientists maintain that this increase in the temperature is not attributed to another reason (warrant). Scientists define atmospheric mechanisms as the greenhouse gases causing the Earth’s surface to heat (backing). They have also discovered that in some cases the Earth’s temperature may rise and fall with no apparent cause (Qualifier). If all the countries voluntarily decrease the production of the greenhouse gases, then the Kyoto Protocol will be redundant (rebuttal). If an argument includes all the elements as in the example above, it is accepted as a strong argument; on the contrary, the fewer of these elements and argument contains, the weaker it becomes. A well-constructed and strong argumentation can make the students take part in the classroom discussions and encourages them to defend their ideas, which has a critical role in forming an environment which is conducive to learning and providing active participation in the lesson on the part of the student. In such a

learning environment students get the chance to test their current knowledge and to engage in meaningful learning through reconstructing the new information they just acquired from the interaction within the classroom. Erduran and Jiménez-Aleixandre (2008) note the primary benefits of argumentation for science education as follows:

- It helps develop the cognitive and the metacognitive processes in science education.
- It develops communication and critical thinking abilities.
- It encourages the students to speak and write in scientific language and to develop scientific literacy.
- It helps develop scientific reasoning and gather logical criteria.
- It helps students internalize the scientific culture and develop their epistemology.

Studies on argumentation date back to the 1950s, attracting more attention in the 1970s with Perelman and Toulmin entering the field, and since the 1990s the studies especially in the field of education have been steadily increasing in number. Duschl and Osborne (2002) stated that students' conceptual understanding gets better through constructing argument activities and having scientific discussions about the subjects. Cross, Taasooobshirazi, Hendricks and Hickey (2008) identified that argumentation helps students to integrate their newly-acquired and existing knowledge, to learn concepts more thoroughly (Albe, 2008; Sadler, 2004), and to reduce misconceptions and become academically more successful. In addition, according to many experimental study results, students in argumentation group maintain better academic achievement than those in the traditional group (Ceylan, 2010; Deveci, 2009; Eryilmaz, 2002; Teichert & Stacy, 2002; Yeşiloğlu, 2007; Sağır and Kılıç, 2012; Kaya, 2005; Çelik, 2010; Özkara, 2011; Ceylan, 2010).

In a 9th grade biology course, during the instruction of genetics unit in Zohar and Nemet (2002) taught the experimental group with the argumentation method, and the control group in the traditional method in order to find out the effectiveness of the argumentation method. As a result, the experimental group proved to be more successful in constructing an argument and conceptual understanding than the control group. In 2010, Dawson and Venville studied the effect of argumentation on students' conceptual understanding in genetics and found similar results to Zohar and Nemet's, stating that students taught with the argumentation method are more successful. Teichert and Stacy (2002) also stated that throughout the courses on chemical bonds and spontaneity, students taught with the argumentation method had better conceptual understanding and academic achievement than the others. In another study carried out with 10th grade students in the subjects of chemical reactions, gases and states of the matter, it has been

stated that the students taught with the argumentation method are more successful than the ones taught in the traditional method (Driver et al., 2000).

In the study conducted by Kaya (2005), there were 7th grade students and 8th grade students. 7th grade students were taught the subject of “a journey to the internal structure of matter” and 8th grade students were taught the subject of “changes of matter and energy”. Experimental groups used the argumentation method while the control groups were taught in the traditional method. The achievement tests conducted at the end of the instruction indicated that the students taught with argumentation method did significantly better than the students in the control group in terms of both academic achievement and understanding the concepts related to the nature of science. Aydeniz, Pabuccu, Cetin, and Kaya (2012) carried out a study on the gasses with undergraduate students in order to find out to what extent the traditional instruction method and the argumentation-based method affect the conceptual understanding. It is determined that the students taught with argumentation method scored significantly higher in the posttest than the students taught with the traditional method. Also it is determined that students’ pre-existed misconceptions decreased by %50, students dispelled their misconceptions and lack of knowledge about the subject through the argumentation method, they listened to the lesson more eagerly in order to remove their inadequacies and they formed a favorable opinion about the courses covered through the use of the argumentation method, thinking that they were more enjoyable and informative. In Yeşiloğlu’s study (2007) related to the effectiveness of argumentation method on the 10th grade students’ conceptual change and academic achievement on the subject of gases, it was observed that students who received instruction based on argumentation method proved to be of higher level than the students of the control group, both in gases unit achievement tests and in conceptual understanding tests, and the difference was statistically significant. Çinici et al. (2014) examined the effects of 8th grade students’ argumentation based concept cartoons activities on “Cell Division and Heredity” unit academic achievements and argument developing levels. Students in the control group received a traditional instruction, while the experimental group students received argumentation based-concept-cartoons activities instruction. At the end of the study, the academic achievement of the students in the experimental group indicated more improvement than the academic achievement of the control group students. Also, it is determined that the students especially focused on the second level in terms of the argument developing quality and they enjoyed argument developing process, although they could not develop arguments at the higher levels.

## Research Question

After surveying the related literature on the subject, no record of any publication which determines the effect size of the argumentation method on academic achievement has been found in our country. As a result, it is necessary to carry out a meta-analytical effect analysis in the light of the researches conducted in our country so far in order to get a clear picture of the effect of the argumentation method on academic achievement.

Toward this end, the main objective of the study is to uncover the whole picture through finding the effect size of the argumentation method on the academic achievement. In order to reach this objective, the experimental studies carried out in Turkey were gathered according to the criteria of meta-analysis method and an answer was sought to the question “Does the argumentation method affect the academic achievement of the students compared to the traditional teaching method?”

## Method

One of the methods of literature review, meta-analysis, also known as the analysis of other analyses, is employed in this study (Glass, McGaw, & Smith, 1981). Meta-analysis is the use of statistical analysis on the data of discrete but similar experimental studies. Meta-analysis is an approach to estimate how much one treatment differs from another over a large set of similar studies and the variability associated with it. It is the method of combining the results of many independent studies on a subject and making a statistical analysis of the data gathered (Mann, 1990). It is the standardization of the results of various studies on a specific subject by gathering them in a single metric and summarization of the calculations by using quantitative research synthesis methods (Cook et al., 1992). On the surface, it resembles a literature review, but while ordinary reviews provide a qualitative evaluation for the studies, meta-analysis, ensures a quantitative analysis of all available data from experimental studies (Mann, 1990). An additional advantage of meta-analysis is that moderator variables can be investigated to explore more detailed relationships that may exist in the data (Means, Toyama, Murphy, Bakia, & Jones, 2009). In order to make a meta-analysis, it is necessary to form hypotheses and gather data and carry out analyses to test these hypotheses. Unlike experimental studies, the data of the previous studies are used rather than collecting data from the study groups (Şahin, 2005).

The steps of meta-analysis can be defined as following (Cook et al., 1992; Egger, Smith, & Phillips, 1997):

- Defining the research problem
- Defining the aims and goals
- Reviewing the literature
- Coding the data by a coding chart
- Calculating the effect size
- Conducting the statistical analysis
- Reporting the findings and offering a discussion

### **Data Collection**

The literature review covered national and international databases for studies on argumentation such as published and unpublished dissertations, all articles published in journals with referee, the theses catalogue of YÖK, the electronic catalogue of the universities in Turkey, presentation documents of conferences, Google's academic search engine, ERIC, EBSCO, PROQUEST, Ulakbim and ASOS served as reference. Keywords like "scientific discussion", "argumentation" and "argument" were used in this context and 82 studies were found. Some of the studies in the research were excluded from the study since they lacked experimental pattern or were not suitable for the objective of the study. Some others were discovered to be presented both as theses and presentation documents, and in such cases theses were selected for the study. According to the criteria of meta-analysis, only the experimental studies with control groups were included in this study. Finally 17 postgraduate dissertations and 8 articles, totally 25 experimental researches were found to be related to the topic and compatible with the criteria laid out in our study.

### **Criteria of Inclusion**

The criteria for the material to be included in this study are as follows (Camnalbur & Erdoğan, 2008; Özcan & Bakioğlu, 2010; Okursoy, 2009): (i) Time: Only the studies of the last twenty years; (ii) Sources: All published and unpublished postgraduate dissertations, all articles published in journals, and documents presented in congresses and symposiums; (iii) Research Method: Experimental studies that have control groups and experimental group that will help measure the standardized effect size in meta-analytic studies; (iv) Teaching Method: Studies that contain argumentation method as the teaching method; (v) Sufficient Quantitative Data: Studies that give the values of sample size (N), mean (M), standard deviation (SD) which will help to calculate the effect size of the studies included.

### **Coding Method**

A coding chart is prepared in order to determine whether the studies included in meta-analysis fit the criteria. This chart was designed to be wide enough to contain all the studies and distinct enough to reflect specific differences between studies. The coding used in this research consists of three main titles and 11 questions. The first section “research identity” consists of 4 questions. The title of the research, authors, year and city are recorded to identify the researches. The second section “research content” consists of 4 questions. The course, time, education level and the criteria of inclusion are provided in this section. The third section is “research data”. It contains the descriptive statistics such as sample size, the mean and the standard deviation of the control and experimental groups.

### **Variables**

Effect size of the argumentation method used in the studies included in the meta-analysis is defined as dependent variable. The effect size is the standardized value for various measuring devices for each study (Hedge, 1982). The independent variables are defined as research characteristics. (i) the level of education of the students were included in the experiment, (ii) the courses in which the experiment was carried out, (iii) the research places, (iv) the sample volume (v) and study year of the studies have been recorded in the code paper and used in data analysis as variables in order to evaluate the relations between the research characteristics and the effect sizes in this study.

### **Data Analysis**

Depending on the choice of model, various statistical combination methods are devised in order to combine the results of the studies carried out by different researchers, at different times and places on the same topic. In this study, the study effect meta-analysis was employed. This method is used when none of the studies included in the meta-analysis is gathered from different scales (Özcan, 2008). The main purpose in this method is to calculate the difference between the averages of the experimental groups and the control groups, represented as  $d = (X_e - X_c) / SD$  in experimental studies. The result value,  $d$ , also mentioned as the occurrence frequency of the term in the society, represents the effect size and forms the basis of meta-analysis (Cohen, 2013; Cooper, 1989). In order to combine different studies as a whole, it is necessary to convert the data gathered into a single unit, which is the effect size. “Hedge’s  $d$ ” is used in this study to calculate the effect size, and the significance level of the analyses is determined as 0.05.



The model of meta-analysis is also important while combining different sizes of effect. The choice of statistical method can vary according to the research results (Raudenbush, 1994). The inferences rely on two statistical models: the constant effects model and the random effects model. While choosing the model in the meta-analysis, it is possible to test the homogeneity of the size effect distribution (Cohen, 2013). In this research, in cases of homogeneity the constant effects model is used, and in other cases the random effects model is used. While calculating the effect sizes which rely on arithmetic averages, level classification is used for more detailed classification (Cohen, 2013; Thalheimer & Cook, 2002):

- $0,15 \leq \text{effect size} < 0,40$  Small
- $0,40 \leq \text{effect size} < 0,75$  Medium
- $0,75 \leq \text{effect size} < 1,10$  Large
- $1,10 \leq \text{effect size} < 1,45$  Very Large
- $1,45 \leq$  Huge

To calculate the effect size and variance values for each study and to compare specific groups in this study CMA (Comprehensive Meta-Analysis), MetaWin statistical programs and Microsoft Excel 2013 were used.

## Results

### Descriptive Data of Studies

Concerning the effect of argumentation method on students' academic achievement, 25 studies have been analyzed in this research and their sample size, mean and standard deviation values are used to determine general characteristics and effect sizes of the studies. Considering all of the 25 studies, the total number of students in the experimental group and in the control group is 768 and 749, respectively. Statistics of the percentage and frequency of the studies are given in Table 1.

**Table 1. Frequency and percentage of the studies according to variables**

Variables	f	%
<b>Level of Education</b>		
Primary school	17	68,0
Secondary school	5	20,0
Higher Education	3	12,0
<b>Courses</b>		
Biology	2	8,0
Science	17	68,0

Chemistry	6	24,0
<b>Years of the studies</b>		
2007	1	4,0
2008	1	4,0
2009	5	20,0
2010	4	16,0
2011	5	20,0
2012	4	16,0
2013	4	16,0
2014	1	4,0
<b>Publication Types</b>		
Article	7	28,0
Thesis	18	72,0

As seen in Table 1, the largest percentage of studies is in primary level (%68), and next comes the secondary level (%20), and the least is in college (%12). The course, which has the largest share, is Science courses with 17 studies (%68). It is also worth noting that all of the 25 studies found are related to science, chemistry and biology. Unfortunately, we did not come across any experimental study carried out in the field of social sciences.

Experimental studies of argumentation started in the year 2007, and 4 to 5 studies were carried out each year from 2009 until 2013. 7 articles (%28) and 18 theses (%72) have been included in the research.

Sample size, sample volume, effect size, standard deviation and variance values are presented in Figure 2. There is also a meta-analysis diagram to study the uncombined effect sizes of the studies included in the research.

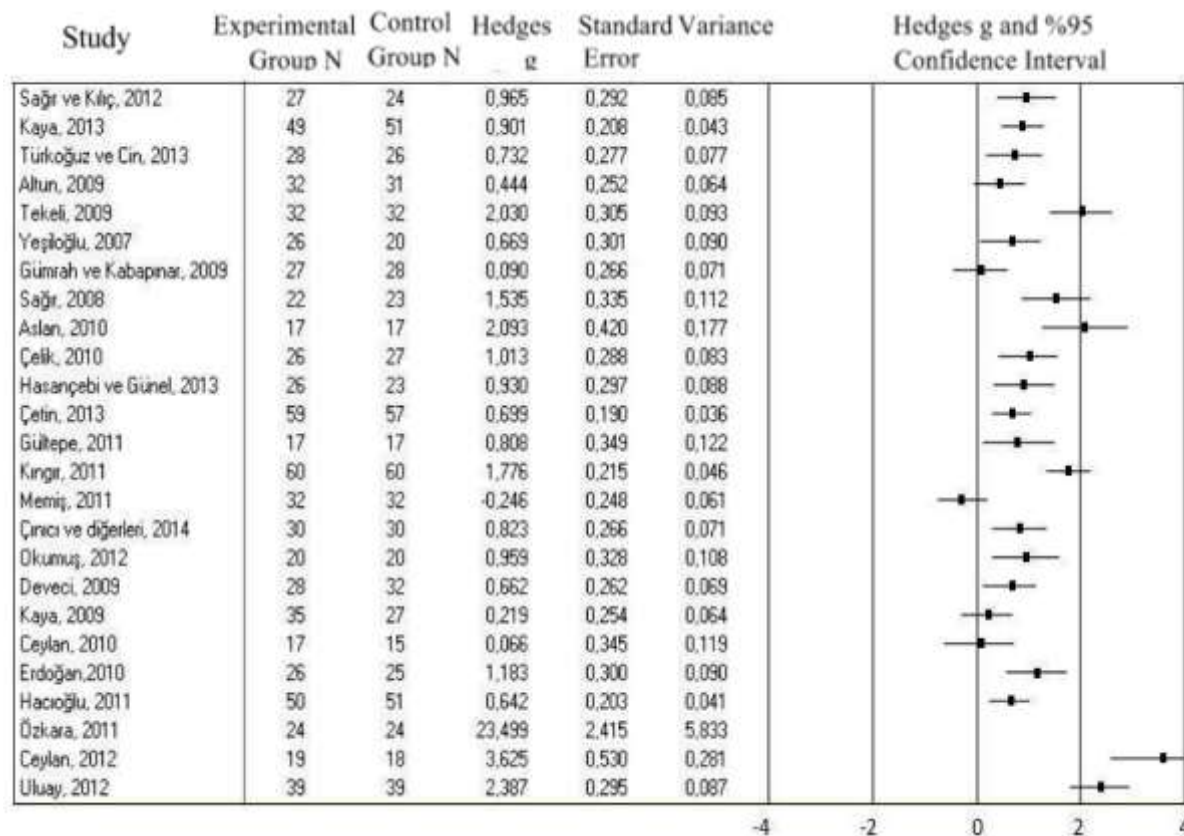


Figure 2: Effect Sizes for Contrasts in Meta-Analysis

According to the forest plot in Figure 2, the study with the biggest effect size belongs to Özkara (2011) and the one with the smallest effect size is (Ceylan, 2010). Four studies have small effect sizes, six studies have medium effect sizes and the remaining 15 studies have large effect sizes. These findings prove that the argumentation method has a positive effect on achievement.

The effect sizes of the studies are shown with black squares in the meta-analysis diagram, and the horizontal lines within each square reflect the trust range of that study. The longer the horizontal line is, the wider the confidence interval of that study is. Arrows reflect the trust range continuing beyond the diagram (Gözüyeşil & Dikici, 2014, s.633). The directions of the studies according to their effect size are presented in Table 2.

**Table 2. Frequency and percentage of the studies' effect sizes**

Effect Size	Frequency	Percentage
0 (zero)	0	0,0
+ (positive)	24	96,0
- (negative)	1	4,0

Considering the effect size direction of the studies, 25 studies (96,0%) have positive effect sizes, while only 1 study (4%) has negative effect size. The majority of the effect size values being single means that the academic achievement performance is in favor of the experimental group.

It is necessary that the effect size differences of the studies included in the study be kept at a reasonable level so that they can be studied statistically. Therefore, effect size distribution homogeneity should be tested (Hedges, 1982). The normal distribution Q-Q graph of the studies included in the research are given in Figure 3 (created with the software MetaWin 2.0) to demonstrate whether it is suitable to combine these studies or not.

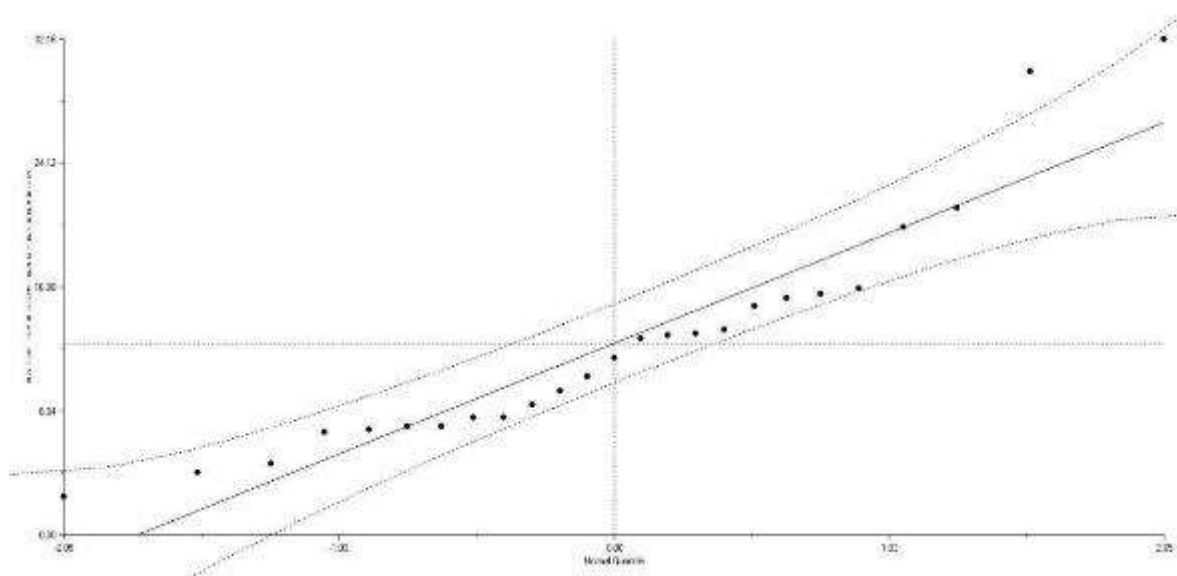


Figure 3. Normal distribution Q-Q graphs of effect size

If the general effect size distribution of the studies combined is within the trust range along the line  $X=Y$ , then it is close to the normal distribution (Rosenberg, Adams, & Gurevitch, 2000). According to the Figure 3, there are no significant deviations in the studies included in the research. However, Özkara's study (2011) falls outside of the  $\pm 1,96$  range. Therefore, this study was excluded from the meta-analytic process.

### Investigating the Efficiency of the Argumentation Method

Table 3. The average effect size and homogeneity values according to the constant effects model

N	ES	z	p	Q	%95 Confidence Interval (Lower – Upper)
24	0,900	16,185	0,000	146,661	0,791 - 1,008

The average effect size and homogeneity values according to the constant effects model are given in Table 3. As a result of the meta-analysis of 24 studies, the lowest limit of the %95 trust range is 0,801 and the top limit is 1,022; the average effect size is 0,900. It can be concluded from these results that the argumentation method has positive effects on the student's success (ES=0,900;  $z=16,185$ ;  $p<0,05$ ). According to the classification made Thalheimer & Cook (2002), the effect size value is on a large level.

The statistical Q value is calculated as  $Q=146,661$  in the homogeneity test. 23 degree of freedom value on %95 significance level is calculated as 35,17 on the  $X^2$  chart. Q (146,661) statistical value is observed over 35,17. In the light of these findings, the effect size distribution of the studies appears to be heterogeneous according to the constant effects model. Therefore, the random-effects model to synthesize the findings was employed (Raudenbush, 1994).

**Table 4. The average effect size and homogeneity values according to the random effects model**

N	ES	z	p	%95 Confidence Interval (Lower – Upper)
24	0,997	6,933	0,000	0,717 - 1,276

Average effect size values according to the random effects model are presented in Table 4. According to this, the lowest limit of the %95 trust range is 0,717 and the top limit is 1,276 and the average being 0,997. According to this result, the argumentation method has a positive effect on the students' academic achievement (ES=0,997;  $z=6,933$ ;  $p<0,05$ ). According to the classification made Thalheimer & Cook (2002), the effect size value is on a large level.

## Discussion

Academic achievement is one of the key elements in the education process. Various education methods have been developed to increase the academic achievement and to make learning more efficient. One of these methods is the argumentation method. In this research, experimental studies about the effect of the argumentation method on the academic achievement are combined by meta-analysis. As a result, the value and direction of the effect size of the argumentation method on the academic achievement is calculated. In order to discover the effect of the argumentation method on students' academic achievement, first 24 studies were analyzed based on the constant effects model. According to the homogeneity tests, the effect distributions of the studies are found to be heterogeneous; therefore the analyses were carried out according to the random effects model.

According to the results based on both models, the argumentation method has a significant positive effect on the academic achievement of the students. According to the classification made by Thalheimer & Cook (2002), the effect size value is on a large level.

The argumentation method is found to be significantly effective on the academic achievement in the national and international studies on the effect of the argumentation method on the academic achievement (Teichert & Stacy, 2002; Yeşiloğlu, 2007; Sağır and Kılıç, 2012; Deveci, 2009; Gümrah ve Kabapınar, 2010; Kaya, 2005; Ceylan, 2010; Çelik, 2010; Özkara, 2011; Çinici et al. 2014). Some have also discovered significant relations between the academic achievement and the argumentation method (Aydeniz et al., 2012; Norris & Phillips, 2003; Tsaparlis, Hartzavalos, & Nakiboğlu, 2013; Sadler, 2006).

In addition, it is also discovered that the argumentation method increases the conceptual understanding of the students (Albe, 2008; Sadler, 2004), creates a better environment for education and for conceptual change, provides the students with the ability to better understand the structuring and evaluation of scientific knowledge (Bell, 2000; Dawson & Venville, 2010; Erduran & Jiménez-Aleixandre, 2008; Zohar & Nemet, 2002), and correct misconceptions in this way (Eryılmaz, 2002).

It is also stated that by means of the argumentation process, the discussion and argument constructing abilities of the students were developed (Asterhan & Schwarz, 2009; Driver et al., 2000; Nussbaum & Sinatra, 2003; Patronis, Potari, & Spiliotopoulou, 1999; Yıldırım & Nakiboğlu, 2014; Sadler, 2004).

Also the ability of scientific process and critical thinking, reasoning, decision making were improved (Lawson, 2003; Zhou, 2010; Yeşiloğlu, 2007) and the students had a better understanding of the nature of science (Sandoval & Wilwood, 2008; Simon et al., 2010). Additionally, it is also reported that students had a more positive attitude towards the lessons with the argumentation method (Kaya, 2005; Osborne, Simon, & Collins, 2003; Çelik, 2010).

Küçük and Aycan (2014) stated after reviewing the literature for argumentation studies, it is found that since their mind is conducive to acquiring skills more easily and efficiently, students at the secondary level can sharpen their higher level cognitive skills such as reasoning, critical thinking, and decision making ability and accordingly more studies at this level should be conducted.

As for the other two grades, the preponderance of the studies, %68, conducted to examine the effects of argumentation method on academic achievement are carried out in primary schools, while only %12 of the studies are done at colleges, which is a rather small percentage. However, it is

stated in the study of Küçük and Aycan (2014) which compiled all the quantitative, qualitative and mixed studies done on argumentation in Turkey that the bulk of studies were carried out at college level. This finding seems to be in contradiction with the findings of previous research. Yet this situation possibly stems from the fact that at the college level usually more qualitative and mixed approach studies are carried out than the qualitative experimental ones.

Concerning the courses upon which the studies examining the effects of the argumentation method were carried out, it is observed that all the studies are within the scope of science subjects, such as biology and chemistry; however, there is no study on the physics course. In the examination made by Küçük and Aycan (2014), science courses are found to be the primary focus of studies, too. Taking into account all these findings, it is interesting to note that there is no study in the social branches which fall within the scope of meta-analysis. As a result, it is recommended that studies be made on such social branches.

In this meta-analytic research; only the effect of the argumentation method on the academic achievement is studied and other effects of the method are excluded from the scope of this study. Other researchers can carry out researches concerning the effects of the argumentation method on conceptual understanding, scientific process abilities and the effect of gender and socio-economic differences on the argumentation method. They can also carry out more comprehensive studies which also include qualitative studies.

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