Synthesis Study on Argumentation in Science Education

Yurdagül Boğar[1]

[1] Faculty of Education, Hakkari University, Hakkari, Turkey

Correspondence: Yurdagül Boğar, Faculty of Education, Hakkari University, Hakkari, Turkey.

Abstract

In current educational research, there is an increasing acceptance among researchers to emphasize that students must be educated on scientific ways of thinking. Simultaneously, science education practice has focused on the development of scientific thinking skills which are associated with scientific inquiry rather than memorization skills. When it comes to scientific practices, educational reforms highly emphasize scientific practices such as argumentation in science education. Therefore, the purpose of this study is to conduct a synthesis study on argumentation in science education. In order to achieve this purpose, this topic will be reviewed under seven main headings within the current study. These are development of argumentation theory, argumentation approaches, argumentation models used in science education, student's role in argumentation, teacher's role in argumentation, activities that create an argumentation environment, difficulties associated with the implementation of the argumentation in the learning environment and scientific argumentation respectively. In addition, some sub-headings will follow the main headings.

Keywords: argumentation, literature review, science education

1. Development of Argumentation Theory

According to Bricker and Bell (2008), argument is a core practice for scientific discourse. Scientific data are vetted and eventually accepted as a theory. As a theory, argumentation went through a progressive process starting from the time of Aristotle to the 21st century. However, in Aristotle's argumentation theory, some factors were not taken into consideration. The next was Toulmin's (1958) argumentation pattern. It was developed to investigate argumentations of individuals and to consider contextual factors in argumentation rather than the formal argumentation structure (Sampson & Clark, 2008). However, Toulmin's argumentation pattern did bring about some methodological challenges (Driver, Newton, & Osborne, 2000). Consequently, other argumentation frameworks were developed such as Johnson and Blair's (1994) non-formal argumentation and Walton's (1996) presumptive reasoning. In these frameworks, it was emphasized that the relationship between the premises of arguments and conclusions were important in the evaluation of argument quality (Greenwell, Knight, Holloway, & Pease, 2005). In summary, these argumentation frameworks established the foundations of the argumentation theory.

1.1 Definitions of Argumentation

In the educational context, Sampson and Clark (2008) argued that the term argument identifies an element used in constructing a claim, whereas argumentation identifies the process and discourse. There are different definitions about argumentation that are made by lots of scientists. Giving the definitions made about argumentation in the field literature chronologically would be significant in the sense that it would enable us to see the different definitions and changes that happened to the concept over time. Toulmin's (1990) argumentation was defined as the process of using data, justifications, contributions and disproving in order to convince people about the validity of a certain claim. In another definition on argumentation argued by Kuhn (1993), she stated that argumentation is fundamental to science activity because science education researchers construct arguments, evaluate evidence, form warrants to endorse their hypotheses, and discuss alternative explanations. Mason and Santi's (1994) argumentation was defined as a way of communication that is 'epistemic' which deals with the social composition of knowledge, 'analytic' which deals with structure, consistency and getting to a conclusion, and 'critical' which deals with current situations and possibilities of the conditions. According to Driver and his colleagues (2000), argumentation is a reasonable process. Reason is an academic discipline that exposes significant rules in order to reach results from related foundations. In this sense, argumentation can be thought of as a social activity within a

special group in a social environment and as an individual activity through writing, thinking and speaking. According to Nussbaum and Bendixen's (2003) definition, argumentation is creating justifications that aim to solve a problem or answer a question and criticize.

In general, when we look at the definitions about the concept of argumentation above, we see different ideas about whether this process has been created by a community or by the processes in the mind of an individual. In literature, it is known that as a common opinion, argumentation process is both an individual and social activity. The individual creates specific arguments, designs and evaluates them in her/his mind. In social processes, two or more individuals create different arguments on a specific topic, and they argue about the validity of these arguments for evaluation.

When we look at all the definitions in the literature, we see that argumentation is an approach that came to existence to define the logical problems in daily life. However, argumentation and reason are terms that should not be mixed with each other because argumentation and logic (reason) are two different disciplines. Each has a different field of work and each serve a different purpose when practiced in the classroom. In classroom practices, argumentation works on the activity of arguing and aims to teach 'how to argue better' to students. Logic (reason), however, works on the process of reasoning and aims to teach the students 'how to make a better reasoning' (Binkley, 1995; Driver et al., 2000).

2. Argumentation Approaches

Van Eemeren et al. (1996) divided argumentation into three different groups - analytic, dialectic and rhetoric - and then defined them as:

Analytic argumentation is based on the theory of logic and may include hints (periphrases), material practices, comparisons and incorrect thoughts. In such arguments, a conclusion is reached by induction or deduction.

Dialectic discussions include finding a reason which is not accepted as truth and are part of daily life. The idea of reaching new ideas through argument and reasoning about our present ideas lies in the basis of such discussions.

Rhetoric discussions are used for explaining the strength of a claimed idea to others and convincing them. Therefore, making someone accept an idea or showing an effort to convince others is at the heart of these discussions. Because of its effect on convincing opponents, foundation is the most important part of rhetoric discussions, and in argumentation, presenting proof is superiority (Driver et al., 2000; Jiménez-Aleixandre et al., 2000; Van Eemeren, Grootendorst, Henkemas, Blair, Johnson, Krabbe, & Zarefsky, 1996).

Aristo's three argumentation types (analytic, dialectic and rhetoric discussions) are given below and their characteristics are compared (Van Eemeren et al., 1996):

Table 1. Characteristics of analytic, dialectic and rhetoric argumentations

Argumentation	Analytic	Dialectic	Rhetoric
Purpose	Accurate	Acceptable	Convincing
Foundation	Correct as obvious	Acceptable	Convincing the audience
Result	Reasonable	Reasonable	Convincing the audience
Theory	Reasonable	Dialectic	Rhetoric

3. Argumentation Models Used in Science Education

Toulmin model is the most common and first used argumentation model in science education (e.g., Driver et al., 2000; Erduran, Simon, & Osborne, 2004; Erduran & Jiménez-Aleixandre, 2007; Kutluca, 2012; Özkara, 2011; Simon, Erduran, & Osborne, 2006). Later, some models of science education were introduced due to some disadvantages of this model (e.g., Kelly & Takao, 2002; Lawson, 2003; Sampson & Clark, 2008; Schwarz, Neuman, Gil, & İlya, 2003). Sampson and Clark (2008) collected these models under two headings: Domain-General and Domain-Specific.

3.1 Domain-General (Independent) Models

Models created under this title allow not only a single field but also the evaluation of the generated arguments in other fields. Domain-general models are explained in Table 2.

Table 2. Domain-general models

Toulmin Argumentation Model (1990)	Argumentation as a reasoning process in the Toulmin (1958) model is defined as the main component of data, claim, warrant and backings in order to examine the structure of the arguments in a context-free manner. In the Toulmin (1990) model, qualifiers and rebuttal components have been added to the basic components of data, claim, warrant and backings, and to analyze more complex and advanced arguments (Aktamış & Hiğde, 2015; Sampson & Clark, 2008).
Schwarz, Neuman, Gil and İlya Model (2003)	Schwarz and colleagues (2003) focused on the arguments, structure and acceptability in a model they designed as domain-general, rather than a set of arguments, and formed a model in this context. This model focuses more on acceptance and justification of the model (Erduran & Jiménez-Aleixandre, 2007; Sampson & Clark, 2008). The hierarchy of the argument structure of Schwarz and his colleagues is quite simple, with an assertion only ordered by a compound argument. Assertion only is a result that is not supported by any justification. One-sided arguments contain only one conclusion and one or more reasons. Two-sided arguments contain reasoning that support or object to the conclusion. On the other hand, compound arguments open up this type of analysis with expressions such as "depends, if, but, only if." (Aktamış & Hiğde, 2015; Erduran & Jiménez-Aleixandre, 2007).

3.1.1 Toulmin's Argumentation Model

In his model, Toulmin defined argumentation as a pattern which has related components as *Data, Claim, Warrant and Backings*, and for more complex arguments as *Qualifiers and Rebuttals* (Toulmin, 1958). Moreover, in his book entitled *the Uses of Argument*, he analyzed many arguments to explain everyday argumentation and presented a model, which included the elements of an argumentation and showed the relationships between them (Figure 1).

The main components of this model are:

- Data: These are the facts, the evidences, or observations that support the claim.

- Claim: The conclusion drawn from the merits to be built.

- Warrants: These are the causes such as principles that show the connection between the data and claim.

- Backings: These are defined as generalizations that support particular warrants.

Driver, Newton, and Osborne (2000) formulated these main components of an argument in a sentence like: "because (data).... since (warrant).... on account of (backing)... therefore (claim)" (p. 293).

In addition to the main components above, Toulmin (1958) identified two more components included in complex arguments:

- Qualifiers: The limitations on the claim when the claim is accepted as true.

- Rebuttals: These are the conditions when the claim is not accepted as true. They may be in contradiction with any other basic component of the argument.
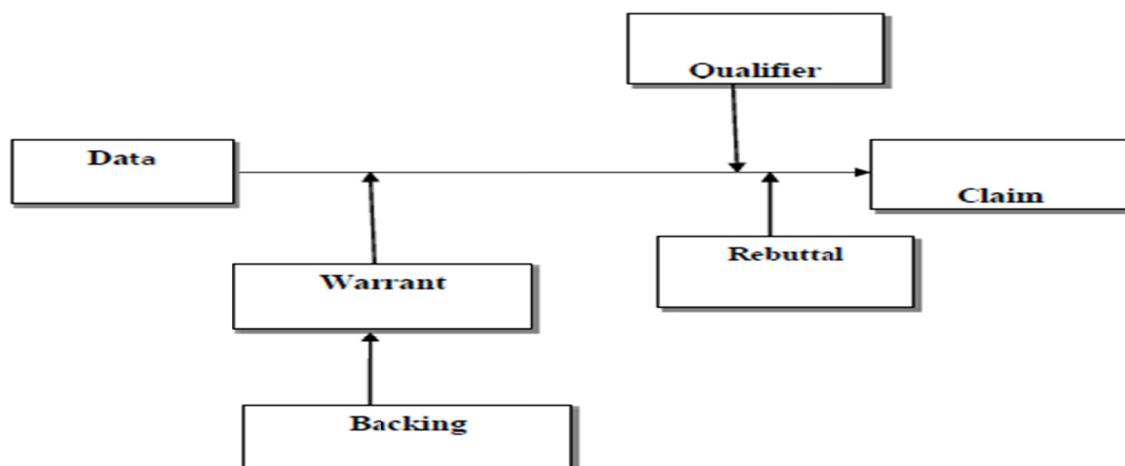

Figure 1. Toulmin's Argument Pattern. Adapted from Argumentation in Science Education: *Perspectives from classroom-based research* (p. 57, by Erduran, 2008, Dordrecht, London: Springer)

Toulmin's argumentation model has a major contribution to the literature on the explanation of the argument concept (Erduran et al., 2004; Osborne, Erduran, & Simon, 2004a). According to Aldağ (2005), instead of just witnessing the process, students get involved and become a part of that process, thanks to Toulmin's argumentation model. This method also improves the students' ability to ask questions and makes them learn when it would be proper to ask a specific question. Thanks to this model, students learn to be able to change their claims, to be open to criticism and to revise their claims according to criticisms. It gives the opportunity to understand that sometimes people cannot agree on human relationships and that they can solve these disputes by making discussions. Additionally, Toulmin's argumentation model slows down the course-teaching process and makes it easier for students to understand (Leeman, 1987).

In Toulmin's argumentation, claim is the ground for all arguments. For a good argument, the claim must be justified by providing a warrant and a backing. However, Driver, Newton, and Osborne (2000) argue that Toulmin's argumentation has mainly three limitations. These limitations are stated below:

1) It only gives idea about the structure of the arguments but does not evaluate their correctness.

2) It does not consider the dialogic structure of the argumentation, that is, recognition is given to interactional ways of the argumentation.

3) Toulmin's scheme is decontextualized, that is linguistics and situational contexts are not emphasized (Driver, Newton, & Osborne, 2000, p. 294).

In order to construct argumentation, it is required to present the validity of claims, evaluate the alternatives and proofs and with all these, texts are supposed to be interpreted. However, since the method of argumentation in schools is not entirely in classroom culture, problems can arise in the formation of general strategies that will allow students to participate in the argumentation process. Osborne, Erduran, and Simon (2004b) have pointed out that the Toulmin argument model poses difficulties in the implementation of class-based verbal data, although the argument is used as a structure for identification. They have emphasized that the main difficulty is what the claim, data, justification and supporting are to be considered as. Erduran (2008) stated that one other major difficulty about the Toulmin model was the coding of arguments. The researcher emphasized that the questions "If the components of an argument repeat, should we consider the new argument as another argument?" and "Can we determine the role and function of such repetition in speech?" must be answered, and researchers should determine the rules and the boundaries for such situations.

In their compilation study on the structures of argument analysis, Sampson and Clark (2008) have studied many structures of argument analysis in literature. As a result of the review, they have identified two difficulties regarding the Toulmin model. First, some of the expressions correspond to more than one argument component at the same time, and secondly, when the arguments are long, expressions can lead to contradictions about analysis as they can be thought as a new claim or as a justification for a claim. They have emphasized that a researcher commenting on what is to be counted as a claim, data or justification according to his/her personal point of view would adversely affect the internal reliability of the argument analysis. Researchers who stated that importance is given to whether data, justifications and supporting in Toulmin's analytic structure exist or not instead of whether they are true or not, have suggested that those who want to examine the content of an argument should support the Toulmin argument model with other measurements. Additionally, due to the fact that Toulmin's argumentation model is suitable for short discussion and that some concepts are not explicitly expressed, it leads to uncertainty in discussion and creates a limited schema (Niaz, Alguilera, Maza, & Liendo, 2002; Zeidler, 1997).

3.2 Domain-Specific (Dependent) Models

Models developed under this heading are used only in the evaluation of the arguments produced in science or in any branch of science. There are four different models that are evaluated in the domain-specific context. Domain-specific models are explained in Table 3.

Table 3. Domain-specific models

Giere Model (1991)	In this model of Giere (1991), scientists generate data after the process of observing and experimenting with the real-world situations. This process is then entered into the forecasting process by calculation and reasoning. By comparing the data and the predictions, the competing theories are controlled. In fact, the process that is important for the scientists is to arrive at the most acceptable scientific explanations by determining the theory and the model that best fits what is available. The model used here is essentially aimed at achieving what is most convincing by comparing the theoretical world with the actual world (Aktamış & Hiğde, 2015; Ceylan, 2012; Driver et al., 2000).
Zohar and Nemet Model (2002)	This model makes it possible to evaluate the quality of written arguments produced by students in the context of 'the content of the justification for an argument'. Zohar and Nemet (2002) state that the argument consists both of assertions or conclusions, as well as their justifications, and that they consist of reasons or supporters (Aktamış & Hiğde, 2015). Strong arguments in this model have multiple full justifications for supporting the results that combine relevant, specific, precise scientific concepts and facts (Erduran, 2008). Weak arguments consist of irrelevant justifications (Duschl, 2008).
Kelly and Takao Model (2002)	The most important factor determining the quality of an argument in the model developed by Kelly and Takao (2002) is the epistemological level that the argument has. In this model, researchers first find the arguments and classify them according to 6 epistemic levels (Kelly & Takao, 2002). These epistemic levels are defined by disciplinary special structures and reflect a general difference between the lower level definitions of the data and the epistemologically higher levels that are related to the theories of a particular field (Sampson & Clark, 2008). After making these definitions, the researchers define how these propositions are related to each other, and then they use this knowledge to prepare the diagram that shows the graphical structure of the argument. Through this graphical representation, it is examined how one associates and coordinates his/her suggestions (Aktamış & Hiğde, 2015).
Lawson Model (2003)	Lawson (2003) focuses on the hypothetical-deductive validity of an argument. Lawson (2003) argues that science educators need to help students understand how arguments are created and how they are evaluated by scientists, instead of solely explaining the arguments in general terms. In this model, argumentation begins with a perplexing observation, which leads to a number of explanations that may change and cause a question. It must then be tested in order to ensure the validity of the statements and the statement to be subjected to this test is deemed to be correct first. Tests are designed to obtain observable results. Words such as "if," and "after" are used to associate the test designed to make predictions with explanations. When this planned test is applied, multiple observable results are obtained and they constitute evidence. The evidence is compared with the prediction, and the validity of the disclosure is determined as a result of the predicted verification or the disapproval of the evidence (Aktamış & Hiğde, 2015; Sampson & Clark, 2008).
Sandoval Model (2003)	Sandoval (2003) presented a model considering that scientific approaches and approaches based on the evaluation of these arguments should not be deprived of epistemological and conceptual qualities (Aktamış & Hiğde, 2015; Sampson & Clark, 2008). This model is a discipline and domain-specific model. Sandoval measures the quality of the arguments by how well students explain their causal claims in a domain-specific theoretical framework, and how well-justified these claims are by using existing evidence (Sandoval & Millwood, 2005). The students' justification of a claim is determined with as much data as possible, the coherent causal explanation for an event, and the combination of appropriate rhetorical references while giving a reference to a verse defining the epistemological quality of the arguments (Aktamış & Hiğde, 2015; Sandoval, 2003; Sandoval & Millwood, 2005).
McNeill, Lizotte, Krajcik and Marx Model (2006)	In this model, scientific argumentation is evaluated in three components as claim, evidence and reasoning. Claim is a statement or a conclusion sentence which students try to answer or that answers the original problem. This component is the easiest component for students. Evidence is the scientific evidence supporting the claim. Evidence can also come from studies completed by students or from secondhand sources such as newspapers, books or the internet. The evidence should be adequate and appropriate. It is meant to be relevant to the current question and to help students express their direct claims (McNeill et al., 2006; McNeill & Martin, 2011). Adequacy means that students consider and use multiple pieces of evidence to support the claim rather than relying on a single piece of data (McNeill et al., 2006). Reasoning is justification of why data is accepted as evidence in order to support the claim which needs the use of scientific principles (McNeill et al., 2006; McNeill & Martin, 2011; Sampson & Clark, 2008).

4. Student's Role in Argumentation

Researchers are stressing that argumentation should be used as a tool for improving through scientific explanations in science education. Andriessen (2006) characterizes this form of argumentation as "discussing for learning" created by the collaboration of groups studying the same subject. From this point of view, solving a dispute is a way of explaining a scientific phenomenon by the collaboration of individuals which is accomplished by working to determine the explanations that give the best evidences and comparing supporting explanations with

disagreements (Berland, 2008). From this point of view, argumentation improves the reasoning skills of students and enables them to reveal their ideas. When students believe in the benefits of their discussions, the discussions they make will be of higher quality, and their personal and social development will be positively affected. As Erduran and her colleagues (2006) expressed, responsibility belongs to the student in argumentation. It is the student who makes the claim. Also, they stressed that making students think about the link between the argument that they create during the argumentation process and the evidence put forth as a support for that argument would improve their critical thinking skills. Argumentation is seen as an effective approach that can be used in science education for students to work collaboratively in the problem-solving process, to learn their responsibilities, to be able to think the way scientists do and to understand the nature of science (Eichinger et al., 1991).

5. Teacher's Role in Argumentation

It is also the duty of the teacher to apply the argumentation activities in the specified manner. Teachers have a very significant role in practicing argumentation in classrooms. If argumentation activities are to be carried out in a class, the class must first be prepared for discussion. The teacher has an important position in providing students with reliable environments where they can express their ideas and opinions comfortably, to encourage the class to work in collaboration and to make students support the arguments they create with claims, backings and justifications (Jiménez-Aleixandre et al., 2000). At the same time, with the argumentation practices, the teacher helps the students to develop such higher cognitive skills as analysis, synthesis and evaluation (Duschl & Osborne, 2002). Throughout the argumentation process, the teacher should support students with writing activities as well as oral activities and should be able to give them instructions (Driver, Asoko, Leach, Scott, & Mortimer, 1994; Duschl & Osborne, 2002; Kuhn, Shaw, & Felton, 1997).

6. Activities that Create an Argumentation Environment

The activities used to create an argumentation environment in science classes are as follows (Osborne, Erduran, & Simon, 2004b):

6.1 Expressions Table

In this activity, a table that carries expressions of a certain science course subject is given to students. Students are then asked to tell if they agree or not on the given expressions and to discuss the expressions that they choose.

6.2 Concept Map of Students' Ideas

Based on the research done in literature, a concept map about science that includes expressions is given to students. Students are then asked to discuss the concepts on the map and on the links between concepts and to make decisions about whether they are scientifically right or wrong, and to suggest reasons and arguments for their decisions both individually and in groups.

6.3 Experiment Report Prepared by Students

Students are given another student's experiment report and results. The experiment report includes misconceptions or deficiencies. Thus, students are directed to object. They are asked to express their thoughts about the experiment and how in their opinions the results of the experiment could be fixed.

6.4 Theories Competing in the Form of Concept Cartoons

Students are presented with two or more competing theories in the form of cartoons. They are asked to express the theory they believe and to discuss why they think the theory that they choose is true.

6.5 Theories Competing in the Form of a Story

Competing theories are given to students in the form of a story. Students are asked to tell which theory they believe is true and to put forth evidences for why they believe that theory.

6.6 Theories Competing with Ideas and Evidences

In this activity, a physical phenomenon is introduced to the students and then two or more competing explanations are given about that phenomenon. Additionally, students are provided with a series of evidences that are supporting one, the other, both or neither of these explanations. After that, the students are asked to form small groups and to think about evidence in order to find and evaluate the role and importance of the evidence. Therefore, with this activity, the students have to use evidence when discussing the ideas.

6.7 Structuring an Argument

Students are given the explanation of a physical phenomenon and many data expressions about this situation. Then they are asked to discuss which data expression gives the most powerful explanation for this phenomenon by

structuring an argument on why it gives the most powerful explanation.

6.8 Predict-Observe-Explain

In this activity, a phenomenon is introduced without showing and students are asked to discuss what will happen when the phenomenon is started and to justify their reasons. After that, the phenomenon is shown to them. If the result occurs to be different from what is expected, students are asked to rethink and re-evaluate their arguments in the beginning.

6.9 An Experiment Design

Students are asked to work in pairs to design an experiment in order to test a hypothesis. Then pairs come together to discuss their designs, suggesting alternative procedures and to discuss their relative evaluations.

7. Difficulties with the Implementation of the Argumentation in the Learning Environment

Advantages of argumentation, which is the process of reaching the most accurate knowledge among different arguments, cannot be ignored. However, the approach of learning with argumentation and the cultural background that comes with this approach are not completely flawless (Krajcik et al., 1998). Studies on the subject of argumentation clarify various difficulties faced by students during the process such as students' inability to behave naturally and simply. For example, not sharing the epistemological goals of the implementation that is being done and not fully understanding what they are doing are shown as reasons for students' not entering the argumentation process. Although research on argumentation in science education has continued intensely over the past years, it is thought that such problems in the performances of students occur due to the short periods of education time such as a couple of days or weeks (Gümrah, 2013).

Studies indicate that argumentation learning covers certain cognitive skills. This could be improved through practice, but it is usually hard to learn. Some possible cognitive problems during argumentation can be mentioned: not being able to form cause-result relations, not being able to give meaning to phenomenon leveled knowledge in context, not being able to show evidences, not being able to determine shifts in themes, not being able to identify the elements related to the discussion, not being able to create alternative thoughts and common epistemic views (Hogan, 2000; Jiménez et al., 2000; Kuhn, 1991).

Traditional science education, which is widely adopted in schools, is causing difficulties as a positivist science understanding that includes clear truths and unquestionably accepted results are reached from data. Because of this apprehension, students generally tend to see science as a whole absolute truth about the world instead of a process of creating theories/models and testing them (Driver et., 1994). In connection with this, students' tendency to not understand how scientific knowledge is structured and limited, their tendency to not think that the same data can be interpreted in different ways, and their tendency to not understand that the knowledge put forth are not real discovered facts but claims that need to be supported by justifications are some important problems that can make it difficult to implement argumentation.

Faults and false attitudes present in the argument construction process are also problems in argumentation. Some problems related to attitudes towards argumentation are verbal rudeness, not listening to others, withdrawal from discussion, trying to impose views to another group without considering relativeness of those views to the subject and insisting on a piece of knowledge that has the possibility of being incorrect (Infante, 1987; Infante et al., 1984).

Ryu and Sandoval (2012) listed some of the hardships faced by students when structuring an argument:

- Students are challenged to procure data that is suitable for their arguments.

- They are not able to request data from each other.

- Similarly, students are not successful in rebutting an argument and presenting a counterargument when needed.

- Rebuttals are usually ignored. Although arguments progress in a way that mutual claims are spoken of, no effort is being made by students in order to truly contribute to the competing arguments or stating the supports for their arguments.

- When students procure data, they are challenged to make the connection between the data and their argument. In other words, they are challenged to justify their arguments. This appears to be the hardest part of developing argumentation throughout learning (Clark & Sampson, 2008; Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Sandoval, 2003; Sandoval & Millwood, 2005).

8. Scientific Argumentation

Scientific argumentation can be defined as a social activity in which the persuasion process is experienced through

justification of ideas to explain different points of view and thoughts with a positive critical perspective to overcome the mutual "ambiguity" arising from different points of view and arguments submitted about a subject; to try and uncover the facts and the unknowns in a complete way, and while doing that using not only language but also visuals and texts to produce a solution to problems (Driver et al., 2000; Simon, Erduran, & Osborne, 2006). In other words, scientific argumentation can be explained as a process containing social and mental activities in which individuals exchange ideas among themselves, and by presenting written scientific facts or via conversing about those facts, and trying to persuade each other about their ideas being correct and factual (Hakyolu, 2010; Kitcher, 1998).

Scientific argumentation is not an evaluation of the individual. On the contrary, it is a communication process that can be conducted individually or in groups to change the opinions of the individuals in order to eliminate different points of view (Van Eemeren & Grootendorst, 2004). The concept of scientific argumentation should not be confused with the concept of debate. While debates are arguments with both a losing side and a winning side, scientific argumentation is defined as a process of sharing ideas by using scientific evidences between the individuals (Driver et al., 2000; Kuhn, 1993). Scientific argumentation does not have competitive individuals; it has individuals who exchange ideas with available data and by putting forward evidences (Hakyolu, 2010). Scientific argumentation takes place in an environment where arguments are being created. For that reason, realistic arguments are needed in order to convince the individuals and to increase the semantic level of the discussion (Yeşiloğlu, 2007). While arguments are statements made in the light of claims, data, reasons and backings; scientific argumentation is a process in which these are combined and conversed (Simon, Erduran, & Osborne, 2006). On the other hand, scientific argumentation is a community idea where there are no direct answers to questions between a teacher and students, with students in the center of it, sharing the rich and acceptable criteria of knowledge (Deveci, 2009). At the heart of scientific argumentation lies the idea of in-group or individual interactions based on persuading the other by presenting valid and acceptable alternative ideas (Clark & Sampson, 2008).

Van Eemeren et al., (1996) express the characteristic aspects of the scientific argumentation as follows:

- An activity of judging in which the speaker explains her/his ideas on a certain subject.
- An oral activity which is executed with a simple language.
- A social activity conducted with other individuals.
- It is always about a specific idea on a certain subject. Scientific argumentation is needed when an opposing idea is present, or considered to be present.
- The goal is to increase the acceptability of an important point for the speaker or the audience.

Scientific argumentation is generally an oral and social reasoning activity. A person in this process asks questions, specifies conditions, opposes ideas, and answers questions while using a certain vocabulary for all those actions. Presenting an idea is not enough on its own, arguments must be open to other points of view too. Consequently, the point of scientific argumentation is to verify or to refute an idea (Van Eemeren et al., 1996).

Studies show that scientific argumentation may have an important impact on literacy if it is integrated into education (Driver et al., 2000; Duschl & Osborne, 2002). Erduran (2008) points out in a broader way that scientific argumentation is an important goal for science education. It is one of the focuses of science education to have the students active in field-specific events. Also, in arguments held in order to acquire scientific knowledge, the usage of evidence and the validity of the evidence depends on the evaluation of the claimed idea (Kaya & Kılıç, 2008). Ford (2008) points out that scientific argumentation helps students in building knowledge. If the students do not question the knowledge they gain in their cultural environment in debates, they will be obligated to accept the ideas of another individual who can defend their ideas reasonably and strongly. Therefore, scientific argumentation has an important role in scientific education to configure scientific knowledge. Cross, Taasoobshirazi, Hendricks, and Hickey (2008) explain that when students are learning scientific terms, it is necessary for them to interact with their peers and the best way to achieve that is through argumentation. Berland and Reiser (2009) tell that scientific argumentation is a questioning practice which is gaining importance for the science students.

8.1 The Role of Scientific Argumentation in Science Education

A great lot of research has been done by researchers in order to find out which educational technique is more efficient and what environmental conditions and what circumstances are needed for science courses to be more effective and fruitful for students (Khine, 2012; Kuhn, 1993b; Osborne, Erduran, & Simon, 2004a; Zohar & Nemet, 2002). As a result of such research, it has been observed that teaching methods and techniques for science teaching have been revised in the social context in the recent years (Kuhn, 1992; Osborne, Erduran, & Simon,

2004a). By re-interpreting science teaching from a social constructivist perspective, it is now understood that science is not only an experimental activity that uses scientific processes, but also a social activity that includes debates, rejections and objections, and questions the nature of scientific knowledge by talking and debating (Erduran & Jiménez-Aleixandre, 2007). In this context, argumentation in science teaching is a very significant method since it broadens visions of the students, enables them to understand the nature of science and to configure and develop the concepts of science (Herrenkohl & Guerra, 1999). The main aim of argumentation in the context of science teaching consists of improving the abilities of students to support their claims by using evidences (Hodson, 2003; Kelly, Regev, & Prothero, 2008; Sandoval & Millwood, 2008; Yore et al., 2006). In other words, during the process of science education, using activities based on argumentation would enable the students to produce scientific knowledge since students would defend their claims by using the evidences and the data they obtained during the process (Duschl & Ellenbogen, 1999).

Researchers have made clear that for young students who are learning science, an active participation in both writing and talking processes is necessary in order to make them think about scientific cases, experiments and explanations that are given to them (Driver et al. 1994; Simon & Johnson, 2008). According to the principles of constructivist approach, argumentation activities are the primary activity during these writing and talking processes (Driver et al., 2000; Newton, Driver, & Osborne, 1999) because students can clearly express the causes that are supporting their views and strive to prove them by making use of their preliminary knowledge thanks to the argumentation technique. Other students also express their opposite views clearly, explain their doubts and present alternative ideas. Therefore, students work like scientists; they come up with support and reason in order to prove their claims (Driver et al., 1994; Newton et al., 1999; Siegel, 1995). Students who think deeply on the arguments and counter arguments activate their metacognitive skills and this creates a conceptual change (Dole & Sinatra, 1998). Therefore, in that context, it can be said that argumentation enables the individuals to see and evaluate each perspective at the same time and makes them see different perspectives and create deeper knowledge (Yeh & She, 2010). Thus, students can realize how they get to know a piece of knowledge and consolidate their scientific knowledge. Additionally, on the one hand, students are being directed to think the way scientists do and they are made to learn permanently, and on the other hand, their quality of living is much better.

In science literature, it has been frequently emphasized in many studies that one of the main aims of argumentation practices for students is to increase their ability to think critically (Erduran et al., 2006; Kuhn, 1993; Simon, Erduran, & Osborne, 2006), make them understand how scientific mechanisms work and how scientific studies are materialized (Driver et al., 2000; Duschl, 2008). It also makes them good citizens (Kolstø, 2001). These qualities point out to the attributes that are needed to be gained by students in order to make them democratic participants. However, for students to be well informed participants in democratic societies, improving the use of argumentation abilities is shown as a necessity (American Association for the Advancement of Science [AAAS], 1990, 1993; Organisation for Economic Cooperation and Development [OECD], 1998).

Making students have a better understanding of scientists and making them see what scientific processes are used by scientists in order to get scientific knowledge is seen as an essential component of science literacy. One way of developing science literacy is making students develop abilities of meaningful and effective understanding of science course subjects. Argumentation is at the center of methods that help students in the development of science literacy based on scientific reasoning skills (AAAS, 1993; National Research Council [NRC], 2000). Explanations given during the process of argumentation enables students to realize what the data mean and what conclusions can be reached by students from the data, and the data are provided for students to criticize, argue and revise (Driver et al., 2000; Sandoval & Reiser, 2004). Thus, participating in an efficient argumentation and effectively actualizing this process is evaluated as an indicator of science literacy (Driver et al., 1994; Driver et al., 2000; Erduran et al., 2004; Jiménez-Aleixandre et al., 2000, Kuhn, 1993).

From a cognitive point of view, argumentation in science education includes the individuals' ability of reasoning. Expressing ideas in the classroom makes the student steer from inner psychological area (mind) to outer psychological area (classroom). Students, as a result of their agreement on the benefits of a discussion, improve both themselves and their friends by making quality discussions. The interaction of students in personal and social areas enables them to develop their common knowledge, values and beliefs (Erduran et al., 2006; Simon, Erduran, & Osborne, 2006). Also, significant abilities of problem solving and decision making can be developed by making such discussions on scientific issues in daily life or social problems (Kuhn, 1993).

One other reason for promoting argumentation in science education with special emphasis is the potential it has for assisting students in understanding the epistemic views of science in argumentation (Driver et al., 2000; Duschl, 2008; Kuhn, 1993). For example, Duschl (2008) argues that making argumentation forms a bridge between science education from epistemic and conceptual aspects and creating scientific meanings from social

aspects. Although argumentation helps the epistemic views of science to be understood, it has been studied by a very few numbers of researchers (McDonald & McRobbie, 2012).

According to Erduran and Jiménez-Aleixandre (2007), argumentation method used in science education is helpful in the sense that it;

a) Enables the pre-knowledge to appear and teachers to evaluate what students understand,

b) Helps students to create scientific arguments and logical deductions by using the methods such as big group discussions,

c) Enables students to talk about their ideas, to get involved in groups and to base their thoughts on scientific facts,

d) Enables students to feel the differences and similarities between their thoughts and the thoughts of others (including scientists),

e) Supports scientific thinking,

f) Increases motivation of students who now see similar claims made by their peers (Erduran & Jiménez-Aleixandre, 2007).

8.2 Scientific Argumentation and Epistemological Orientations

Argumentation at the same time is a discursive activity, so it has a special significance in terms of reflecting the judgments that individuals have. It has been observed that because of this quality of argumentation, it is being used as both a written (Kelly & Takao, 2002) and spoken (Jiménez-Aleixandre, Rodriguez, & Duschl, 2000; Kuhn, 1993) tool for revealing the epistemological features of individuals. During argumentation, it has been observed that most individuals get involved in the process according to their epistemological beliefs when they are given data and evidences about an event (Kuhn, 1993). This is also parallel with Posner et al.'s (1982) conceptual change model. According to Posner and friends, one side of the individuals' conceptual ecology is the epistemological features and metaphysical beliefs. For an individual to adopt a new concept, the individual must be reasonable and causative. In this context, it has been put forth that there are similarities between an individual's structure of belief and cognitive structure.

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