AVRASYA Uluslararası Araştırmalar Dergisi
Cilt : 8 Sayı : 23 Sayfa: 409 - 427 Eylül 2020 Türkiye
Araştırma Makalesi

PRESENTATION OF SOCIO-SCIENTIFIC SUBJECTS TO STUDENTS BY USING ARGUMENTATION PROCESS

Dr. Öğr. Üye. Hamdi KARAKAŞ•

ABSTRACT

Real life problems in the socio-scientific structure are the issues that need to be considered and discussed from different perspectives in terms of their scientific aspect, the environment and the social structure that they affect. Individuals who gain experience with real-life knowledge can better adapt their knowledge to the problems they may encounter in daily life. The process of argumentation (scientific discussion) in the structuring of scientific knowledge and development of mental activities comes to the forefront in recent educational studies. This process begins with questioning of the claims made or defended by others and continues with the students' developing their own arguments, defending them and refuting counter claims. In this context, as the main aim of the study, the importance of presenting socio-scientific subjects to the students by utilizing argumentation process in science courses was investigated. The characteristic of the argumentation process is that individuals tend to support or refute arguments regarding the situations they are faced with. Thus, in the process of producing arguments, the socio-scientific situation is evaluated, examined and the problems encountered can be seen critically from someone else's point of view. Discussion of the dichotomous structure, inherent in socio-scientific topics, together with argumentation process will lead students to think actively, and they will interpret the events, develop arguments and produce applicable ideas.

Keywords: Socio-scientific issues, argumentation process, science literacy

FEN BİLİMLERİ DERSLERİNDE SOSYOBİLİMSEL KONULARIN ARGÜMANTASYON SÜRECİ KULLANILARAK ÖĞRENCİLERE SUNULMASI

ÖZ

Sosyobilimsel yapıdaki gerçek yaşam problemleri barındırdıkları bilimsel yönü, etkiledikleri çevre ve toplum yapısı itibariyle çok yönlü düşünülmesi ve tartışılması gereken konulardır. Gerçek yaşam bilgileriyle deneyim kazanan bireyler edindikleri bilgileri günlük hayatta karşılaşabilecekleri sorunlara daha rahat uyarlayabilirler. Bilimsel bilginin yapılandırılması ve zihinsel faaliyetlerin geliştirilmesinde argümantasyon (bilimsel tartışma) süreci son dönem eğitim çalışmalarında ön plana çıkmaktadır. Bu süreç başkalarınca ortaya atılan veya savunulan iddiaların sorgulaması ile başlar ve öğrencilerin kendi argümanlarını geliştirmeleri, onu savunmaları ve karşı iddiaları çürütmeleri ile devam eder. Bu bağlamda çalışmanın amacı fen bilimleri derslerinde sosyobilimsel konuların argümantasyon süreci kullanılarak öğrencilere sunulmasının önemi araştırılmıştır. Argüman sürecinin özelliği

•Sivas Cumhuriyet Üniversitesi, Eğitim Fakültesi, Eğitim Bilimleri Bölümü, hamdikarakas58@yahoo.com.tr, Orcıd ID: 0000-0001-9209-4128

Makalenin Dergiye Ulaşma Tarihi: 01.10.19 Yayın Kabul Tarihi: 25.06.2020

bireylerin karşılaştıkları durumlara yönelik argümanları destekleme ya da çürütme eğilimi içerisinde olmalarıdır. Böylece argümanlar üretme sürecinde sosyobilimsel durum değerlendirilir, incelenir ve karşılaşılan problemler başkasının bakış açısından eleştirel gözle görülebilir. Sosyobilimsel konularda var olan ikilemli yapının argümantasyon süreci ile tartışılması öğrencileri aktif düşünmeye yöneltecek, öğrenciler olayları yorumlayacak, argüman geliştirecek ve uygulamaya dönük fikirler üretecektir. Bu noktadan bakıldığında ilkokuldan öğretmen eğitimine kadar fen bilimleri derslerinde sosyobilimsel konuların argümantasyon süreci kullanılarak öğrencilere sunulması fen okuryazarı birey yetiştirmeye katkı sağlayacaktır.

Anahtar Kelimeler: Sosyobilimsel konular, argümantasyon süreci, fen okuryazarlığı

INTRODUCTION

One of the main objectives of education is to help individuals become aware of the problems they are faced with and understand the relationship between science, technology and society. Thus, they will be able to develop an awareness of responsibility regarding the solution of the problems they are faced with. Family, social environment, school and mass media are of great importance in developing this awareness (Sönmez, 1994). The school contributes to the development of this consciousness starting from childhood and allows individuals to grow up to be conscious citizens sensitive to the problems they are faced with from an early age (Dias et al., 2004). Within the framework of this awareness, science education can be thought of as a map used to teach the unknown or as a tool for students to find what they are looking for (Kurnaz, 2007). This is because science education allows students to understand the world they interact with, to create new concepts by experiencing, to learn how to organize these concepts in their minds, to apply and test the ideas they put forward (Harlen, 1985; ct: Yürüyozoğlu et al., 2009). The Ministry of National Education (MEB), determined its main vision as educating students as science literate individuals in Science Curriculum and adopted the goal of educating students who research, question and discuss for a lifetime (MEB, 2018). In this direction, MEB serves as the main guide for teachers in our country by setting concrete and guiding goals in reaching the set target.

Rather than directly transferring the existing knowledge to the students, contemporary education systems aim to provide the students with the skills of accessing information, to follow the developments in the field of science and technology and to interpret the effects of these developments on himself and his environment (Çavuş, 2013; Göcük and Şahin, 2016). When the student sees where and how the information s/he has learned theoretically is used, this accelerates his/her learning process, the data that students have the chance to experience themselves can be more permanent, and the knowledge may be transferred to other situations by being reshaped and reorganized (Kluger and Bell, 2000). When the knowledge that the students have formed through experience are combined with real-life problems, it becomes useful for them to solve the problems they are faced with. Learning real-life information is seen as an effective way to gain these experiences (Göcük and Şahin,

2016) because individuals who gain experience with real-life knowledge can better adapt their knowledge to the problems they may encounter in daily life.

Real life problems are issues that need to be considered and discussed from different perspectives with regard to their scientific aspect, the environment and the social structure that they impact. Some of these problems may even have a character on which all segments of the society may not reach a consensus, a single way out may not be found and there may be a dilemma of right and wrong. Real life problems comprise a dilemma because both social and scientific factors play a central role, and such issues are called socio-scientific issues (Sadler, 2003). Socio-scientific issues are issues that are intertwined with real life, have no single correct answers, are controversial and comprise dilemmas (Tüzün, 2013; Sağlam, 2016). For instance, should genetically modified organisms (GMOs) be consumed by humans? Are hydroelectric power plants (HEPP) necessary? Is cloning a cure for diseases? When we present such real life problems that unite science and society and that consist of dilemmas to students, most of them are not able to give the same answers. Through such subjects, the products generated by scientific knowledge and the problems they cause also emerge. Students are informed about these issues, question and discuss them and ultimately try to decide on this topic. Thus, important steps are taken towards raising science literate individuals. Likewise, among the main objectives of the MEB Science Education Program (2018) are to improve students' reasoning ability, scientific thinking habits and decision-making skills by utilizing socio-scientific topics and the use of socio-scientific topics in science courses is considered important.

In the structuring of scientific knowledge and the development of mental activities, argumentation (scientific discussion) process has come to the forefront in the studies conducted on education in recent years (Çınar, 2013). This process begins with the teacher or the students questioning the claims made or defended by others. The evidence and rationale that they present for their claims help students to develop a perspective. In this process, the students' developing their own arguments, putting forward their claims and joining debates to refute the counter-claims form the basis of the argumentation process (Lin and Mintzes, 2010). With the discussion process, students have the opportunity to study, support or refute both their own arguments and others' arguments by engaging in interactive dialogues. On the other hand, the teacher encourages students to share, evaluate and examine their arguments and to see the problems from others' point of view (Öztürk, 2013). Thus, in contrast to traditional teaching methods, the argumentation process puts students at the center of learning and provides opportunities for more meaningful learning. Based on this point, in this study, the importance of utilizing the argumentation process of socio-scientific topics suggested to be used in science courses and presenting them to students was emphasized. The researcher considered it important that the students could acquire knowledge aimed at socio-scientific issues concerning the society, develop analytical and critical thinking skills regarding these topics and gain decision-making and discussion skills with the 3rd and 4th grade science courses. In this context, as the main aim of the study, the importance of presenting socio-scientific subjects to the students by utilizing argumentation process in science courses was investigated. In the study, the content of the sociological subjects, the use of the argumentation process in

the learning-teaching environments and the discussion of the socio-scientific subjects using the argumentation process, the contributions of this process to students were described by the researcher and discussed and interpreted together with the previous researches in literature. It is also thought that this study will contribute to the literature due to the presentation of other research results compiled, guiding teachers' classroom practices and offering perspective to other researchers.

METHOD

Research Model

The study was conducted on the basis of a holistic multiple case study design, which is one of the qualitative research methods. The case determined in case studies is studied intensively, and the units such as an individual or school are examined in depth (Glesne, 2012; Simon, 2009). In case studies, data collection tools which include multiple sources such as observations, interviews, documents etc. are used (Creswell, 2017). The existing situation in the holistic multiple case design is examined in itself and the situations it includes are compared and interpreted (Yıldırım ve Şimşek, 2018). In this study, the multiple case examined, the presentation of socio-scientific topics using argumentation process, and the contributions of using this process in science courses to students were interpreted.

Data Collection

The data of the study were obtained by document analysis method. According to Merriam (2013), qualitative research is based on understanding and interpretation. The data in the basic qualitative research, which can be seen in all disciplinary and practical areas; interviews, observations and document analysis. While document analysis has traditionally been used by historians, anthropologists and linguists, sociologists, psychologists and educators have also contributed to the development of important theories by using document analysis (Şimşek, 2009). In this method, official documents, written rules and regulations, newspapers, magazines, books, press releases and the like are collected in accordance with the purpose of the study and then written and visual materials are examined in depth (Seydi, 2014; Turgut, 2012). In line with the purpose of the study, the researcher accessed sources such as published books, book chapters, theses, articles, papers, etc. and by forming a document pool.

Data Analysis

The documents collected by the researcher were examined by the researcher and the data were analyzed by descriptive analysis method. In the descriptive analysis method, the data are used without being changed, revealed, explained, depicted and illustrated to the readers (Sönmez and Alacapınar, 2018). In line with the obtained data, the concepts determined according to the purpose of the research were explained and interpreted under titles. According to the data obtained, the findings were determined and interpreted as "Socio-scientific Issues", "Argumentation Process is and Use in Learning-Teaching Processes" and "Discussion of Socio-Scientific Issues Using Argumentation Process".

FINDINGS AND INTERPRETATION

In this context, the importance of presenting socio-scientific subjects to the students by utilizing argumentation process in science courses was investigated. In this section, the content of socio-scientific subjects, the use of argumentation process in the learning-teaching environments, the discussion of socio-scientific subjects using the argumentation process and the contribution of this process to students were described and interpreted for the reader by titles in line with the data obtained from data collection tools.

Socio-scientific Issues

The fact that the current issues of the day, which directly concern the individual and the society such as the future of the world, human health and environmental problems, are included in the educational programs will change the students' behaviours positively and contribute to their becoming science literate. Emphasis on socio-scientific issues in science courses can serve as a tool to make this contribution. Kolsto (2006) defines socio-scientific subjects as issues that have a scientific aspect, are generally within the boundaries of scientific knowledge, involve observations and require decision making in individual or social terms; Sadler (2003), on the other hand, describes them as complex, open-ended, often controversial issues with no definite answers comprising dilemmas. Whereas socio-scientific subjects comprise moral and ethical dimensions, they contain important contradictions that have conceptual, methodological or technological ties with human life and that can create social effects (Lee et al., 2006; Sadler and Donnelly, 2006). These issues are accepted as controversial issues that concern the society with no definite answers as well as being scientific (Topçu, 2010). These issues, which can be evaluated from many perspectives, highlight the problematic situations that cannot be discussed with simple judgments and often include moral and ethical aspects (Akşit, 2011). While individuals evaluate socio-scientific issues, they compare the different dimensions of the subject and its related disciplines and this encourages them to think on a multidimensional level (Çavuş, 2013). The result of sociological issues evaluated in different disciplines includes the nature of the subject completely discussed, the basic information on this subject, the answers to be given in the light of these information and the decisions reached (Tüzün, 2013).

Many socio-scientific topics such as acid rain, ozone layer, greenhouse effect, fossil fuels, use of renewable energy, nuclear power plants, genetically modified organisms / foods (GMOs) can be presented to students as part of science education courses. Associating these subjects with science education lessons from the elementary school onward enables students to have knowledge on economic, political, social, health and ethical issues related to science, to approach them critically and to make more informed decisions about these issues (Gülhan, 2012; Yapıcıoğlu, 2016). Students who take this opportunity with socio-scientific issues make a connection between science and daily life and evaluate the information they have learned as a part of real life. Thus, they can develop more effective solutions to the real life problems they face.

In science topics, we expect the students to solve a problem or draw a conclusion based on the information currently accepted (Tüzün, 2013). Socio-scientific based teaching makes topics with scientific content, which students are not interested in and which may be deemed boring, more interesting and enjoyable (Dolan et al., 2009). In many research conducted, it was determined that in learning environments based on socio-scientific subjects and situations, students understood science concepts better, that such environments made the learning of boring scientific topics, which students show no interest in, more attractive, and that these environments increased motivation in learning and affected the attitudes of students towards science positively (Dolan et al., 2009; Aksit, 2011; Topcu et al., 2014, Yapicioglu, 2016). Klosterman and Sadler (2009) argued that socio-scientific subject-based education could be an effective tool in students' learning the science content, and stated that socio-scientific subject-based education content should be utilized in science courses. In their study, where they examined the relation between 5th grade students' scientific information regarding greenhouse effect and global warming and their awareness of social activism, Lester et al. (2006) found that educational status in socio-scientific topics contributed to the individuals' consciousness-raising in social aspect. In a study on energy literacy, which is a socio-scientific subject, problem-based learning method applied in the experimental group was found to be more effective in energy literacy than the activities in the current program. At the end of the study, the positive effects of socio-scientific issues on learning were discussed (Göcük and Şahin, 2016). Therefore, instead of directly transferring the subject, situation or problem that constitutes the objective of the course to the students with traditional teaching methods, creating a learning environment that enables students to discover and learn by themselves with socio-scientific based topics will enable them to better comprehend the knowledge (Akpınar and Ergin, 2005). The students will be able to discuss and interpret how science course and the scientific and technological developments affect the environment and the society with socio-scientific based teaching activities.

Although socio-scientific subjects are considered to be research subjects in fields such as science, medicine or biology, it should be known that such subjects also have political foundations or socio-political consequences (Çankaya, 2014: 297). The results of the studies on the environment and living things form the basis of developments that will significantly affect the social life not only in the technical sense but also in a sociological sense. The responsibility of the social sciences should be to follow these developments and associate them with social events and seek solutions to problems (Akar, 2010). The National Science Education Standards, published by the National Research Council (NRC) in 1996, emphasizes the need for students to discuss and analyze socio-scientific topics and the need for these topics to be in school programs. Klosterman and Sadler (2009) propose an interdisciplinary education model that includes socio-scientific subject-based concepts and compelling and problematic issues that drive these concepts and learned subjects into discussion, decision-making and critical thinking. Gray and Bryce (2006) argued that students should have the basic infrastructure and skills necessary to make informed judgments and decisions about the developments they face in the media or in daily life, and that social, moral and ethical issues should be included in all stages of science education. Many countries,

especially the USA, recognized the importance of socio-scientific subjects for science education and placed socio-scientific subjects in their school curricula (Topçu, 2015; MEB, 2018).

Argumentation Process is and Use in Learning-Teaching Processes

Today, science education is not expected to equip students with memorization-based information; the aim of this course is to educate individuals who question the information they obtain and who can use this information in different situations and problem solutions in a functional way (Aktaş, 2017). The Ministry of National Education has defined the ideal student role in the education programs it has published and emphasized the importance of their being individuals who investigate the source of information, question, explain and discuss the events and situations (MEB, 2013; 2018). In order to raise this student model, the methods and strategies, where they can research, question and discuss, feeling the need to explore the natural and physical world that surrounds them and form the knowledge in their own minds by acting, living and thinking like a scientist, should be included in the learning-teaching processes (Babacan, 2017). Appropriate discussion activities can be used to achieve this goal in science courses because if a situation or event is presented and evaluated in discussion activities, it is easier for students to make appropriate claims and to understand the nature of science (Driver et al., 2000). In this way, while learning becomes more meaningful and permanent, students will grasp the social aspect of scientific knowledge as they will interact socially with their friends (Çınar, 2013). At the same time, in-class scientific discussions lead students and teachers to think and reason scientifically (Erduran et al., 2004).

In the context of scientific discussion activities in the teaching and learning processes of science courses, argumentation activities are frequently used in recent years. An argument is defined as claims, data, justifications and supporters that contribute to a discussion process (Erduran et al., 2004); it includes statements put forward to present the strengths of a situation or issue and to convince others of this idea (Güzel et al., 2009). Thus, the individual participates both in a cognitive and social argumentation process throughout the course of scientific discussion by analyzing his explanations and evidence in an organized way in his own thinking process (Duschl and Osborne, 2002). Argumentation is defined as a mental activity and refers to the process in which mental activities and evidence are used to support claims through verbal and written activities (McNeill and Pimentel, 2010). Argumentation has been described as a process that allows individuals to be curious and active, helps meaningful and permanent learning, and gives students and teachers the opportunity to express their thoughts (Aydın and Kaptan, 2014).

Toulmin (1958) stated that individuals produce arguments by presenting reason or rationale to justify their behaviors, beliefs, attitudes and values to convince others. However, he argued that the arguments created by individuals about the same situation, problem or subject may be different from each other. With the argumentation model that he formed, he defined the formation of data, claim and justification against the event, situation or problems as the main components of the argument and included supportive, qualitative (restrictive) and refuting components in this model for more

complex arguments (Aldağ, 2006). The Toulmin Argumentation Model is presented in Figure 1.

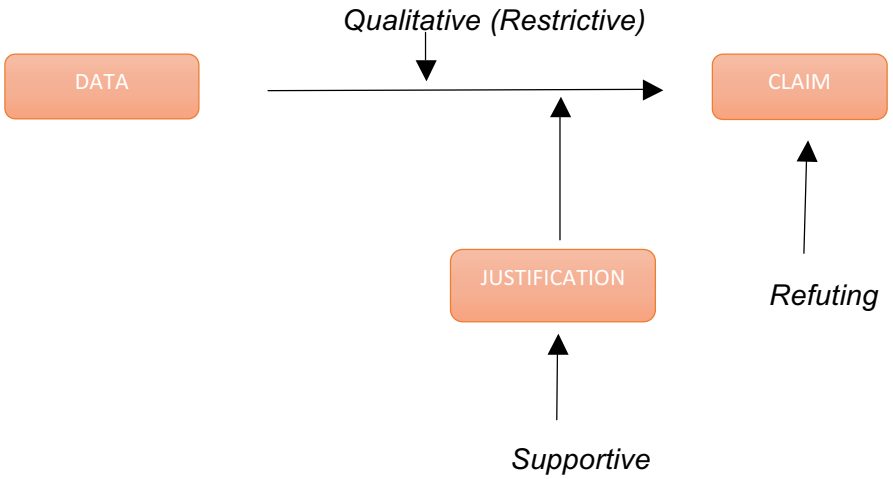

Figure 1. Toulmin Argumentation Model

This model, developed by Toulmin, combined the daily use of argumentation with critical thinking skills and paved the way for the use of the argumentation process with classroom practices. Öztürk (2013), while describing the argumentation process using the Tolumin Model, emphasized that it is a process that includes both mental and social dimensions including written and verbal activities where students' ideas are put forward, their claims are supported with evidence and ideas are mutually evaluated. In the argumentation process, which is used as a teaching method, students are asked to produce arguments about their views, support their claims with data and provide justification for their claims. In order to produce higher-level, complex arguments, their use of rebuttal, restriction or support is encouraged (Cross et al., 2008). The use of Tolumin Argumentation Model in learning-teaching environments brought together theory and learning models in a special field, and the students expressed themselves in relation to the problems posed using claims, data, or real-world experiences. Thus, the argumentation process is used as a social activity that enables them to find solutions to possible problems (Andrews, 2010).

In the discussions that are traditionally applied in science classes, while preparing an environment that basically supports the teacher-learner interaction, it starts with a question directed by the teacher and ends with the evaluation of the answers from the students. On the other hand, since classroom discussions where the argumentation is included in the learning process is based on producing ideas, evaluating the different ideas obtained in line with evidence and choosing the argumentation, which uncovers the best idea, the course process becomes more efficient (Aktaş, 2017). Argumentation-based activities should be organized as group or whole class discussions, and the opportunity to form a group argument with data usage and interpretation skills should be encouraged, thus contributing to the development of students' argumentation skills (Jan, 2009). This is because argumentation-based learning environments require the collaboration of everyone in the classroom, and instead of accepting information as it is, there are questions, discussions, evaluations, criticisms, and finding a middle ground (Angün and Atalay, 2016). The argumentation

process thus becomes a structure where students can gain different perspectives and develop their communication skills when they interact (Chen and She, 2012). At the same time, when students participate in the argumentation process and encounter different views, they can reflect their own ideas, recognize misconceptions and learn better (Cross et al., 2008).

Students who personally participate in the argumentation process will question the scientific knowledge, put forward their arguments, support them with data and enter into the discussion process. They start to refute or interpret the allegations against them. In this way, while students argue with their peers during the argumentation process, they build their new knowledge on the old ones. Thus, the opportunity is given for knowledge to be structured in minds, and the way is opened for meaningful learning. In addition, students may experience frustration and surrender rather than success and trust throughout the argumentation process, where they have to deal with difficult ideas (Hudson, 2010). While providing an environment where students can discuss based on the argumentation process, a classroom environment should be created in which they will not move with the sense of competition, will not experience the ambition to win or fear of losing and where they may feel comfortable. Otherwise, instead of evaluating the relationship between ideas and events from a scientific point of view, students may exhibit a dominant personality for the sake of justification throughout this process (Torun, 2017). In this context, teachers should take the necessary precautions and place emphasis on the discussion of scientific knowledge by preparing activities based on argumentation.

The argumentation process enables the subjects to be taught in a more interesting way, to remember the learned knowledge, to make the learning of knowledge more permanent, to make analysis and synthesis; but it is also an important teaching method for students in terms of improving reading, writing and speaking skills (Schmoker and Graff, 2011). In the argumentation process, students make an effort to reach a common idea based on data among different ideas (Furtak, 2006). Through the argumentation process, students can be critical thinkers who are open-minded, attentive while researching the data regarding the topic, focused on questioning it, honest in confronting their personal prejudices, meticulous in decision making and willing to reconsider their decisions (Facione, 2011). By creating an interactive discussion environment based on argumentation in classrooms, students are ensured to ask questions to each other, to evaluate their results scientifically, to be able to comment on the ideas suggested and to analyze explanations (Çınar, 2016). Considering these important contributions, the argumentation process that will enable them to understand not only conceptual knowledge but also critical thinking skills and scientific issues should be emphasized during science education (Driver et al., 2000).

Discussion of Socio-Scientific Issues Using Argumentation Process

Socio-scientific issues are open-ended, unresolved problems due to their structure. These issues, which are contradictory and comprise dilemmas, are evaluated by individuals with different thinking structures (Levinson, 2006). Socio-scientific issues allow students to look at the issue from different perspectives and evaluate the possible moral consequences of their decisions, and offer many ideas regarding the impact of

the issue on the environment and society (Akşit, 2011). The characteristic of the argumentation process is that individuals tend to support or refute arguments regarding the situations they are faced with. Thus, in the process of producing arguments, the socio-scientific situation is evaluated, examined and the problems encountered can be seen critically from someone else's point of view (Öztürk, 2013). Since the evaluation of socio-scientific topics throughout the argumentation process leads to decision making concerning topics defined as comprising dilemmas and to develop new ways of solution, it may not enable students to look critically. Babacan (2017) asked secondary school students to produce arguments on socio-scientific issues and concluded that the students improved their critical thinking skills at the end of the activities. In another study related to nuclear energy, which is a socio-scientific subject, it was found that the reasoning levels of teacher candidates producing arguments increased (Demircioğlu and Uçar, 2014). In the study, which Çelik et al. (2017) designed for mathematics teachers and examined the critical reading levels through the online argumentation process, at the end of eight weeks of practice, it was found that online argument creation environment increased students' critical thinking skill scores significantly in statistical terms. Tal and Kedmi (2006), in their study, where they brought out the relation between high school students' ability to produce arguments in socio-scientific subjects and to think critically, found that students' argumentation skills increased over time and that students whose argumentation skills increased also improved their critical thinking skills. Therefore, discussion of socio-scientific issues with argumentation based teaching process provides students with scientific thinking skills, changes students' perspective on the world and events, and develops their critical thinking skills. Thus, it makes important contributions regarding individuals' being science literate.

Due to the nature of socio-scientific issues, there are some studies, which conclude that students develop their argument levels by using the components necessary for a scientific discussion more comfortably. Lina and Mintenz (2010) concluded that socio-scientific practices improved 6th grade students' argumentation skills and that it led to the improvement of their skills such as argument, justification and counter argument. Öztürk (2013), in his research with 8th grade students, concluded that socio-scientific subject-based practices led to improvement in students' argument skills and that students produce better quality arguments as the process progresses. Zengin et al. (2012) found a significant difference between pre-test and post-test mean scores in their experimental study with primary school students on nuclear power plants, a socio-scientific subject, and found that students produced better quality arguments as the weeks progressed. Topçu (2015) stated that as the content of socio-scientific subjects presented to prospective teachers changed, the qualities of the arguments they formed also changed, and revealed that socio-scientific subjects could significantly change the argumentation abilities of science teacher candidates. Zeidler and Sadler (2008) argued that the students who gained the skill of argument should be democratic, participatory and knowledgeable students and that the argumentation process could be used for citizenship education. Thus, with science education, students can be helped to be active, knowledgeable, thinking, responsible and democratic participants and it can also be aimed to develop their ethical and moral decision making skills (Kolsto, 2001; Waghid, 2005). Socio-scientific issues are multi-

faceted with their moral, ethical, social, political and economic characteristics and are difficult to solve and cannot be solved alone. Discussion of these situations develops the ability of individuals to make decisions as world citizens and paves the way for decisions to be the product of common sense (Karakaya, 2017). Thus, discussion of socio-scientific issues by using argumentation process contributes to the development of active individuals who research, think, question and can make decisions.

With the argumentation applications based on socio-scientific issues, students' interest towards the course may increase, their information deficiencies and misconceptions may decrease and academic achievements may increase. Özdemir (2010), in his study, stated that students may comprehend the Science-Technology-Society-Environment relation in general but can not understand the intellectual background in technological developments, and justified it with their superficial knowledge regarding current phenomena, concepts and principles in terms of science literacy. The fact that socio-scientific issues are intrinsically frequently encountered and thought provoking subjects as part of daily and social life and that these situations are discussed in individual or group discussions with the argumentation process may positively increase learners' motivations throughout the learning process. Because, in this process, the individual will be actively involved in the center of learning by going beyond traditional teaching methods. Demirel (2017) found that combining the argumentation process with real-life problems was more effective in increasing the success and motivation of secondary school students compared to current curriculum practices. He stated that the information learned was thus more permanent, the lessons were more remarkable and fun, and the applications had a facilitating effect on learning. Çınar (2016) taught the unit "energy in our lives" to 5th grade students using argumentation based teaching process and found that the academic success and conceptual understanding of students increased in comparison to the use of the current program. In another study, the use of the argumentation process on the subjects “sun, moon and earth” increased the 5th year students' desire for learning, their effective learning levels increased and misconceptions were minimized (Kuzzu, 2018). Akkaş et al. (2018), in their studies, where they used argumentation based teaching approach in socio-scientific situations aimed at 5th grade students, applied a unit-based achievement test to the experimental and control groups and found a significant difference in favor of the experimental group in the mean academic achievement scores following the process.

CONCLUSION AND RECOMMENDATIONS

When individuals make decisions about socio-scientific issues; they can be affected by religious judgments, age level, teacher's position, lack of field knowledge, limited environment, family perspective, emotional state and economic factors (Yapıcıoğlu and Kaptan, 2016). But, discussion of the dilemma bearing structure, inherent in socio-scientific topics, together with argumentation process will lead students to think actively, and thus students will interpret the events, develop arguments and produce applicable ideas. In this process, the students will justify their claims with the data they have obtained using Toulmin Argumentation Model, and they will be directed to refute or accept them by using qualifiers and supporters against counter claims. Smith (1992) presented a model based on argumentation, which

includes the bio-ethical process, a socio-scientific subject. This model can be administered by teachers and practitioners in science teaching and learning environments as shown in Figure 2.

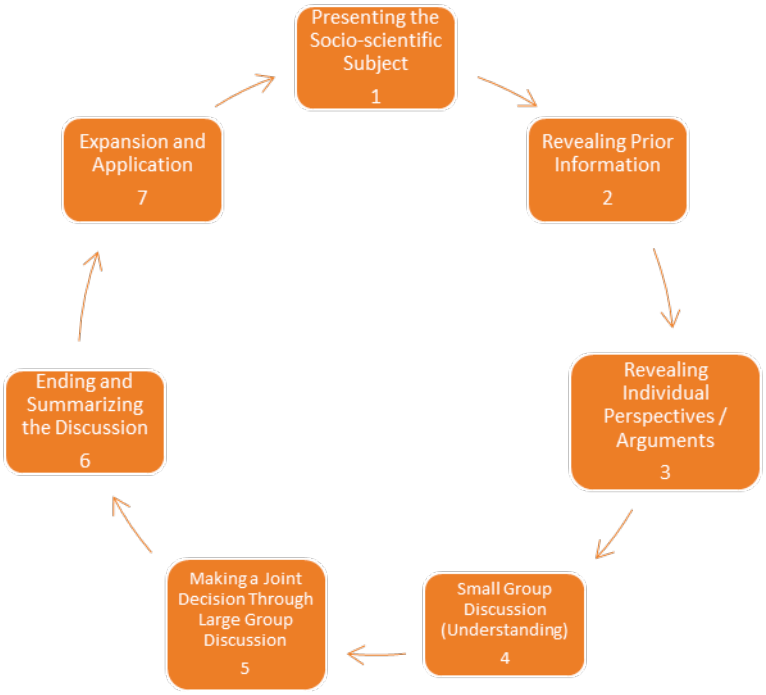

Figure 2. Socio-Scientific Topic Based Education Process Built on Argumentation According to Smith (1992)

In this model, a connection is established between the dilemma situation created by the socio-scientific subject and the scientific / theoretical preliminary knowledge that students have learned at school. The students are expected to form arguments, where they will reveal their personal viewpoints regarding the socio-scientific topic presented. At this stage, the main argument components of the Toulmin Argumentation Model can be taken as a basis. The guidance of the teacher or practitioner is seen as important in the process, and students are encouraged to make decisions by discussing their individual arguments in small and large groups. At the same time, Mason (2001); Karakaş and Sarıkaya (2020) argumentation method is effective in learning students' concepts of science has reached the conclusion that small group discussions. Individual arguments formed in small and large group discussions can be strengthened or changed. It can also produce a higher quality argument because it involves a small and large group interaction process. The arguments formed at the end of the activity may be evaluated, deepened and adapted to different situations and the students are allowed to question socio-scientific real life problems in a multidimensional way. What is fundamental in the implementation of this model is not that individuals are in different positions; to solve the problem they face, to understand the issue and to make decisions about the different perspectives, the possible solutions are to examine and evaluate (Aldağ, 2005).

Many different socio-scientific issues such as industrial development, acid rain, ozone destruction, global climate change, use of fossil fuels, renewable energy and environmental impact, nuclear power plants, in vitro fertilization, stem cell therapy, gene therapy, genetically modified organisms (GMO), cloning can be presented to the students at different levels (primary, secondary and high school) in the argumentation process as part of the science courses. Different topics may allow primary school students to become accustomed to this method and to use arguments effectively. Lazarou (2009) has shown that the use of the argumentation method creates positive improvements over the time for primary school students to produce better quality arguments. Hasançebi (2014) emphasized that argumentation-based learning approach contributes to the development of written argumentation skills of elementary school students and as a result of this approach, there is a positive development in the individual characteristics of students such as self-confidence, self-expression and communication. At the same time, combining experimental activities with argumentation process in science courses improves both scientific process skills and critical thinking skills (Çınar, 2016). Because, by presenting socio-scientific issues by using argumentation process, the necessity of a multi-faceted scientific discussion process between students and teachers will be inevitable and a social dialectic process will be revealed in the scientific discussion process. Ulu (2018) used the argumentation-based science learning approach as a discussion process in laboratory activities in experimental processes. He stated that this method increases students' level of concept learning and the argumentation process is useful in observing the cause-effect relationship.

Prospective teachers who will train students at primary level can be included in the applications where they can use socio-scientific issues during the discussion process. Associating these types of subjects with science courses may enable students to be informed about economic, political, social, health and ethical issues related to science, to look at the issues critically and to make more informed decisions, to increase their academic level and reduce their misconceptions. At the same time, it can raise curiosity since socio-scientific issues are often encountered as part of everyday and social life, thus increasing learners' motivation positively throughout the learning process. From this point of view, presentation of socio-scientific subjects to students by using argumentation process in science classes will contribute to the education of science literate individuals.

REFERENCE

AKAR, B. (2010). ***Tıp fakültesi öğrencilerinin insan genetiği uygulamalarına yönelik risk algıları ve etik inançları arasındaki ilişkinin incelenmesi.*** Yayınlanmış yüksek lisans tezi, Ankara Üniversitesi Biyoteknoloji Enstitüsü, Ankara.

AKKAŞ, B. N. Ç., ÖZ, M. ve MEMİŞ, E. K. (2018). ***Argümantasyon tabanlı bilim öğrenme (atbö) yaklaşımının 5. Sınıf öğrencilerinin başarılarına ve başarının***

kalıcılığına etkisi. 17. Uluslararası Sınıf Öğretmenliği Sempozyumu'nda sunulmuş bildiri, Ankara.

AKPINAR, E. ve ERGİN, Ö. (2005). Yapılandırmacı kurama dayalı fen öğretimine yönelik bir uygulama. ***Hacettepe Üniversitesi Eğitim Fakültesi Dergisi***, 29, 9-17.

AKŞİT, A. C. A. (2011). ***Sınıf öğretmeni adaylarının sosyobilimsel konularla ve bu konuların öğretimiyle ilgili görüşleri***. Yayınlanmamış yüksek lisans tezi, Ege Üniversitesi Sosyal Bilimler Enstitüsü İlköğretim Anabilim Dalı Sınıf Öğretmenliği Bilim Dalı, İzmir.

AKTAŞ, T. (2017). ***Argümana dayalı sorgulama öğretiminin 7. Sınıf öğrencilerinin kuvvet ve enerji ünitesindeki akademik başarılarına ve argümantasyon seviyelerine etkisi.*** Yüksek lisans tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

ALDAĞ, H. (2006). Toulmin tartışma modeli. ***Ç.Ü. Sosyal Bilimler Enstitüsü Dergisi,*** *15*(1), 13-34.

ANAGÜN, Ş. S. ve ATALAY, N. (2016). Laboratuvarda deneylerle ilişkilendirilmiş öykülerin kullanımının sınıf öğretmeni adaylarının argümantasyon becerilerine etkisi. ***Eğitim ve Öğretim Araştırmaları Dergisi,*** 5, 158-168.

ANDREWS, R. (2010). ***Argumentation in higher education improving practice through theory and research.*** Newyork and London: Routledge.

AYDIN, Ö. ve KAPTAN, F. (2014). Fen-teknoloji öğretmen adaylarının eğitiminde argümantasyonun biliş üstü ve mantıksal düşünme becerilerine etkisi ve argümantasyona ilişkin görüşler. ***Eğitim Bilimleri Araştırmaları Dergisi,*** *2*(4), 164-188.

BABACAN, M. A. (2017). ***Sosyobilimsel konulardaki etkinliklerin yedinci sınıf öğrencilerinin eleştirel düşünme becerilerine etkisi***. Yüksek lisans tezi, Ömer Halisdemir Üniversitesi Eğitim Bilimleri Enstitüsü, Niğde.

CHEN, C. H. ve SHE, H.C. (2012). The impact of recurrent on-line synchronous scientific argumentation on students' argumentation and conceptual change. ***Educational Technology ve Society****,15*(1), 197–210.

CRESWELL, J. W. (2017). ***Araştırma deseni*** **(S. B. Demir, Çev., 3. Baskı).** Ankara: Eğiten Kitap.

CROSS, D., TAASOOBSHIRAZI, G., HENDRICKS S. ve HICKEY, T. D. (2008). Argumentation: A strategy for improving achievement and revealing scientific identities. ***International Journal of Science Education****,30*(6), 837-861.

ÇANKAYA, H. (2014). Dünyanın düzeltilmesi üzerine bir araştırma: Genetizm ve insan hakları. ***Memleket Siyaset Yönetim (MSY),*** *9*(22), 295-326.

ÇAVUŞ, R. (2013). ***Farklı epistemolojik inanışlara sahip 8. Sınıf öğrencilerinin sosyobilimsel konulara bakış açıları***. Yayınlanmamış yüksek lisans tezi, Sakarya Üniversitesi Eğitim Bilimleri Enstitüsü İlköğretim Anabilim Dalı Fen Bilgisi Eğitimi Bilim Dalı, Sakarya.

ÇELİK, T., GÖKÇE, S, YENMEZ, A. A. ve ÖZPINAR, İ. (2017). Online argümantasyon: eleştirel okuma özyeterlik algısı. ***Dil Eğitimi ve Araştırmaları Dergisi****, 3*(2), 117-134.

ÇINAR, D. (2013). ***Argümantasyon temelli fen öğretiminin 5. Sınıf öğrencilerinin öğrenme ürünlerine etkisi.*** Doktora tezi, Necmettin Erbakan Üniversitesi Eğitim Bilimleri Enstitüsü, Konya

ÇINAR, B. T. (2016). ***Argümantasyona dayalı öğretimin ilköğretim öğrencilerinin başarıları kavramsal anlamaları ve eleştirel düşünme becerileri üzerine etkisi: Yaşamımızdaki Elektrik ünitesi****.* Doktora Tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul

DEMİRCİOĞLU, T. ve UÇAR, S. (2014). Akkuyu nükleer santrali konusunda üretilen yazılı argümanların incelenmesi. ***İlköğretim Online,*** *13*(4), 1373-1386.

DEMİREL, T. (2017). ***Argümantasyon yöntemi destekli artırılmış gerçeklik uygulamalarının akademik başarı, eleştirel düşünme becerisi, fen ve teknoloji dersine yönelik güdülenme ve argümantasyon becerisi üzerindeki etkisinin incelenmesi.*** Doktora tezi, Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Eğitim Bilimleri Anabilim Dalı, Adana

DIAS R. A., MATTOS C.R. ve BALESTIERI J.A.P. (2004). Energy education: Breaking up the rational energy use barriers. ***Energy Policy****,* 31, 1339–1347.

DOLAN, T. J., NICHOLS, B. H. ve ZEIDLER, D. L. (2009). Using socioscientific issues in primary classrooms. ***Journal of Elementary Science Education****,* 21(3), 1-12.

DRIVER, R., NEWTON, P. ve OSBORNE, J. (2000). Establishing the norms of scientific argumentation in classrooms. ***Science Education****, 84*(3), 287–312.

DUSCHL, R. A. ve OSBORNE, J. (2002). Supporting and promoting argumentation discourse ın science education, ***Studies in Science Education***, *38*(1), 39-72.

ERDURAN, S., SİMON, S. ve OSBORNE, J. (2004). TAPping into argumentation: Developments in the application of toulmin‟s argument pattern for studying science discourse. ***Science Education****, 88*(6), 915-933.

FACIONE, P. (2011). Critical thinking: What ıt is and why ıt counts*.* ***Insight Assesment,*** 1-28.

FURTAK, E. M. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. ***Science Education****, 90*(3), 453-467.

GÖCÜK, A. ve ŞAHİN, F. (2016). Probleme dayalı öğrenme yaklaşımının 5. Sınıf öğrencilerinin enerji okuryazarlıkları üzerine etkisi. ***Journal of Human Sciences***, 13 (2), 3446-3468.

GRAY, D.S. ve BRYCE, T. (2006). Socio-Scientific issues in science education: Implications for the professional development of teachers. ***Cambridge Journal of Education***, 36(2), 171-192.

GÜLHAN, F. (2012). ***Sosyo-bilimsel konularda bilimsel tartışmanın 8. Sınıf öğrencilerinin fen okuryazarlığı, bilimsel tartışmaya eğilim, karar verme becerileri***

ve bilim-toplum sorunlarına duyarlılıklarına etkisinin araştırılması. Yüksek lisans tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

GÜZEL, B. Y., ERDURAN, S. ve ARDAÇ, D. (2009). Aday kimya öğretmenlerinin kimya derslerinde bilimsel tartışma (argümantasyon) tekniğini kullanımları. ***Boğaziçi Üniversitesi Eğitim Dergisi****, 26*(2), 33-49.

HASANÇEBİ, F. (2014). **Argümantasyon tabanlı bilim öğrenme yaklaşımının (atbö) öğrencilerin fen başarıları, argüman oluşturma becerileri ve bireysel gelişimleri üzerine etkisi**. Doktora Tezi, Atatürk Üniversitesi Eğitim Bilimleri Enstitüsü, Erzurum

HUDSON, R. A. (2010). ***Statistical argumentation in project-based learning environments*****.** Doctoral dissertation, Indiana University, USA

JAN, M. (2009). ***Desiging an augmented reality game-based curriculum for argumentation*****.** Doctoral dissertation, University of Wisconsin, USA

KARAKAŞ, H. ve SARIKAYA R. (2020). Çevre-enerji konularına yönelik gerçekleştirilen argümantasyon temelli öğretimin sınıf öğretmeni adaylarının argüman oluşturabilmelerine etkisi. ***Pamukkale Üniversitesi Eğitim Fakültesi Dergisi***, 48, 346-373.

KARAKAYA, E. (2015). ***bilimsel bilginin doğasını anlama ve sosyo-bilimsel konularda akıl yürütme.*** Yüksek lisans tezi, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul

KLOSTERMAN, M. L. ve SADLER, T. D. (2009). Multi-level assessment of scientific content knowledge gains associated with socioscientific ıssues-based ınstruction. ***International Journal Of Science Education***, 1–27.

KLUGER, B. ve BELL, B. (2000). Recognizing inquiry: Comparing three hands-on teaching techniques. ***National Science Foundation, Inquiry Thoughts, Views, and Strategies For The K-5 Classroom****,* 2, 39-50.

KOLSTO, S. O. (2010). Patterns in students' argumentation confronted with a riskfocused socio-scientific issue. ***International Journal of Science Education****, 28*(14), 1689-1716.

KURNAZ, M. A. (2007). ***Enerji kavramının üniversite 1. Sınıf seviyesinde öğrenim durumlarının analizi*****.** Yüksek lisans tezi, Karadeniz Teknik Üniversitesi Fen Bilimleri Enstitüsü Ortaöğretim Fen ve Matematik Alanları Eğitimi Anabilim Dalı, Trabzon.

KUZZU, E. P. (2018). *5.****sınıf fen bilimleri dersinde güneş, dünya ve ay ünitesinde oluşabilecek kavram yanılgılarının argümantasyon yöntemi ile giderilmesi****.* 27. Uluslararası Eğitim Bilimleri Kongresi'nde sunulmuş bildiri, Antalya

LAZAROU, D. (2009). ***Learnıng to tap: An effort to scaffold students' argumentation in science.*** In G. Cakmakci & M. F. Taşar (Eds.) Contemporary Science Education Research: Scientifıc Literacy And Social Aspects Of Science (pp: 43-50), Ankara, Turkey: Pegem Akademi

LEE, H., ABD-EL-KHALICK, F. ve CHOI, K. (2006). Korean science teachers' perceptions of the introduction of socio-scientific issues into the science curriculum.

Canadian Journal of Science, Mathematics and Technology Education*, 6*(2), 97-117

LESTER, B. T., MA, L. ,OKHEE ve L., LAMBERT, J. (2006). Social activism in elementary science education: a science, technology and society approach to teach global warming. ***International Journal of Science Education****,* 28(4), 315-339.

LEVINSON, R. (2006). Towards a theoretical framework for teaching controversial socioscientific issues. ***International Journal of Science Education***, *28*(11), 1267-1287.

LIN, S. S. ve MINTZES, J. J. (2010). Learning argumentation skills through instruction in socioscientific issues: The effect of ability level. ***International Journal of Science and Mathematics Education***, *8*, 993-1017.

MASON, L. (2001). Introducing talk and writing for conceptual change: A classroom study. ***Learning and Instruction***, 11, 305-329.

MCNEILL, K. L. ve PIMENTEL, D. S. (2010). Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation. ***Science Education***, *94*(2), 203-229.

MERRIAM, S. B. (2013). **Nitel araştırma: Desen ve uygulama için bir rehber**. İçinde S. Turan (Çev. Ed.). Ankara: Nobel Yayınevi.

MEB (2013). ***İlköğretim Kurumları Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. Sınıflar) Öğretim Programı*****.** Ankara: MEB Talim ve Terbiye Kurulu Başkanlığı.

MEB (2018). ***İlköğretim Kurumları Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. Sınıflar) Öğretim Programı.*** Ankara: MEB Talim ve Terbiye Kurulu Başkanlığı.

ÖZDEMİR, O. (2010). fen ve teknoloji öğretmen adaylarının fen okuryazarlığının durumu. ***Türk Fen Eğitim Dergisi***, 3, 42-56.

ÖZTÜRK, A. (2013). ***Sosyo-bilimsel konularla argümantasyon becerisi ve insan haklarına karşı tutum geliştirmeye yönelik bir eylem araştırması***. Doktora tezi, Çukurova Üniversitesi Sosyal Bilimler Enstitüsü, Adana

SADLER, T. D. (2003). ***Informal reasoning regarding SSI: The influence of morality and content knowledge*****.** Doctoral dissertation, ProQuest Dissertations And Theses; Thesis (Ph.D.), University of South Florida

SADLER, T. D. ve DONNELLY, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. ***International Journal Of Science Education***, 28(12), 1463–1488.

SAĞLAM, H. İ. (2016). ***Öğretmen adaylarının nükleer enerji kullanımına yönelik informal muhakemeleri üzerine karma yöntem araştırması***. Yüksek lisans tezi, Aksaray Üniversitesi Sosyal Bilimler Enstitüsü İlköğretim Anabilim Dalı, Aksaray.

SEYDİ, A. R. (2014). Türkiye'nin Suriyeli sığınmacıların eğitim sorununun çözümüne yönelik izlediği politikalar. ***Süleyman Demirel Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi,*** 31, 267-305.

SCHMOKER, M. ve GRAFF, G. (2011). More argument, fewer standards. ***Education Week****, 30*(28), 31-33.

SMITH, W. (1992). ***A process: Framework for teaching bioethics*****.** Woodrow Wilson Biology Institute.

SÖNMEZ, V. (1994). ***Program geliştirmede öğretmen el kitabı***. Ankara: Pegema Yayınları.

SÖNMEZ, V. ve ALACAPINAR, G. F. (2018). **Örneklendirilmiş bilimsel araştırma yöntemleri (6. Baskı).** Ankara: Anı Yayıncılık.

Şimşek, H. (2009). Methodical problem in the researches of educational history. **Journal of Faculty of Educational Sciences,** 42(1) 33-51.

TAL, T. ve KEDMI, Y. (2006). Teaching socioscientific issues: Classroom culture and students' performances. ***Cultural Studies of Science Education,*** *1*(4), 615–644.

TOPÇU, M. S. (2010). Development of attitudes towards socioscientific issues scale for undergraduate students. ***Evaluation ve Research in Education***, 23(1), 51-67.

TOPÇU, M. S. (2015). ***Sosyobilimsel Konular ve Öğretimi***. Ankara: Pagem Akademi.

TOPÇU, M. S., MUĞALOĞLU, E. Z. V. ve GÜVEN, D. (2014). Fen eğitiminde sosyobilimsel konular: Türkiye örneği. ***Kuram ve Uygulamada Eğitim Bilimleri***, 14(6) s. 1-22.

TORUN, F. (2017). ***Sosyal bilgiler öğretiminde argümantasyon yönteminin kullanımı***. İçinde R. Turan ve H. Akdağ (Ed), Sosyal Bilgiler Öğretiminde Yeni Yaklaşımlar III, (ss: 150-166). Ankara: Pegem Akademi

TOULMIN, S. (1958). ***The uses of argument***. Cambridge: Cambridge University Press

TURGUT, Y. (2012). **Verilerin kaydedilmesi, analizi, yorumlanası: Nicel ve nitel.** İçinde A. Tanrıöğen (Ed), Bilimsel Araştırma Yöntemleri (ss: 193-247). Ankara: Anı Yayıncılık.

TÜZÜN, Y. Ö. (2013). Fen derslerinde sosyobilimsel konuların işlenişine yönelik kuramsal ve uygulamalı yaklaşımlar. ***Cito Eğitim: Kuram ve Uygulama***, 22, 9-20.

ULU, C. (2018). **Argümantasyon tabanlı bilim öğrenme yaklaşımının kavram öğrenmeye etkisinin iki aşamalı teşhis testiyle incelenmesi**. 27. Uluslararası Eğitim Bilimleri Kongresi'nde sunulmuş bildiri, Antalya

WAGHID, Y. (2005). Action as educational virtue: Toward a different understanding of democratic citizeship ecucation. ***Educational Theory,*** *55*(3), 323-243

YAPICIOĞLU, A. E. (2016). Fen bilimleri öğretmen adaylarının sosyobilimsel durum temelli öğretim yaklaşımı uygulamalarına yönelik görüşleri ve çalışmalarına yansıtmaları. ***Hacettepe Üniversitesi Eğitim Bilimleri Enstitüsü Eğitim Araştırmaları Dergisi (HÜNER),*** 2 (2), 132-151

YAPICIOĞLU, A. E., ve KAPTAN, F. (2018). Sosyobilimsel durum temelli öğretim yaklaşımının argümantasyon becerilerinin gelişimine katkısı: Bir karma yöntem araştırması. ***Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi***, *37*(1), 39-61.

YILDIRIM, A. ve ŞİMŞEK, H. (2018). **Sosyal bilimlerde nitel araştırma yöntemleri (11. Baskı).** Ankara: Seçkin Yayıncılık.

YÜRÜMEZOĞLU, K., AYAZ, S. ve ÇÖKELEZ, A. (2009). İlköğretim ikinci kademe öğrencilerinin enerji ve enerji ile ilgili kavramları algılamaları. ***Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*****,** 3(2), 52-73.

ZEIDLER, D. L. ve SADLER, T. D. (2008). ***The rol of moral reasoning in argumentation: Conscience character and care****.* In S.Erduran ve M.P. Jimenez-Aleixandre (Eds), Argumentation in science education: Perspectives from classroom-based research (201-216). Dordrecht Nerherlands: Springer Press.

ZENGİN, F., KEÇECİ, G. ve KIRILMAZKAYA, G. (2012). İlköğretim öğrencilerinin nükleer enerji sosyobilimsel konusu online argümantasyon yöntemi ile öğrenmesi. ***New World Sciences Academy – Education Sciences****, 7*(2), 647-654.