Argument Based Inquiry Approach Accompanied by Models in Primary Science Teaching

Serpil Kara
Necmettin Erbakan University, Turkey

Sevgi Kingir
Hacettepe University, Turkey

The follow-up of the scientific process steps that support scientific thinking is realized by questioning (Akben, 2015; Baxter and Kurtz, 2001). It is stated that when the argument-based inquiry approach and the model-based inquiry approach, which constitute the basis of scientific research and scientific literacy, are used together, the models formed by the student are actually student claims about a scientific concept. The ability of students to create, use and evaluate their own scientific models is expressed as an effective way of rendering thinking visible (Braaten and Windschitl, 2011). The aim of the model-supported inquiry is to make the students' objectives visible and to reach these goals by using models. As a class leader, a teacher should aim at ensuring that students present problem situations in which they can express and solve scientific terms. For this purpose, students should be ensured to make definitions and explanations by creating a model rather than individualized activities regarding the solution of a problem. In this case, students are given the opportunity to learn from each other and question themselves in a group. While the importance of using model and argumentation applications in order to contribute to the development of inquiry skills used in understanding the concepts of science and the production of scientific information and presentation of scientific explanations related to this situation are emphasized, it is also stated that they are related to each other (Mendonça and Justi, 2013; Passmore, Stewart and Cartier, 2009; Passmore and Svoboda, 2012). On the other hand, there are few studies that specifically investigate the relationship between model and argumentation (Mendonça and Justi, 2013).

Argument Based Inquiry Approach

Argument Based Inquiry (ABI) is a kind of inquiry-based learning approach where the processes of question, claim and evidence, which are the basic elements of argumentation, are brought to the forefront. Its original name is the Science Writing Heuristic, which was put forth by Keys, Hand, Prain ve Collins (1999) in order to integrate language activities, argumentation and inquiry for effective science instruction. When testing questions posed within ABI approach, it is essential to use scientific facts and evidence. The claim serves as an answer to a question determined for investigation. Evidence based on numerical data, observations and facts is used to support the claim (Yang and Wang, 2014). With the ABI approach, students construct information through inquiry by asking questions, conducting experiments and observations and creating claims and evidence. Additionally, it provides students with opportunities to define scientific events, organize and observe scientific concepts and to be able to explain the relations between events (Yang and Wang, 2014). In this context, the ABI approach includes two templates for teachers and students (Keys et al., 1999). The template recommended for teachers (See Table 1) is intended to be a guide that enables teachers to take into account the basic criteria of the ABI approach when preparing lesson plans. Student template (See Table 2) provides a framework for students to follow up both the inquiry activities within a scheme and to write research reports as a result of the activity.

Table 1. ABI Teacher Template

1. Revealing preliminary information through a concept map individually or as a group
2. Pre-laboratory activities where informal writing, observation, brainstorming and questioning techniques are used.
3. Participation in laboratory activities
4. I. Negotiation phase - Conducting personal writing events in laboratory activities (e.g. diary writing)
5. II. Negotiation phase - Sharing and comparing interpretations of data obtained from observations in small groups (e.g. drafting as a group)
6. III. Negotiation phase - Comparison of ideas with books or other sources (for example, taking group notes to answer initial questions)
7. IV. Negotiation phase - Conducting individual reflection and writing activities (for example, preparing presentations such as reports or posters for informants)
8. Finding out what is learned at the end of teaching through concept map

Table 2. ABI Student Template

1. Initial thoughts - What are my questions?
2. Tests - What did I do?
3. Observations- What did I see?
4. Claims- What can I claim?
5. Evidence - How did I understand? Why do I make these claims?
6. Reading - How do my thoughts compare to other thoughts?
7. Reflection- How have my thoughts changed?

Literacy activities in science subjects are proposed as a tool for improving students' scientific literacy (NRC, 1996). Many studies have emphasized that the template used for students helps students to improve meaningful learning (Hand, Wallance and Yang, 2004; Hohenshell and Hand, 2006; Keys et al., 1999). Students stated that they had difficulty in writing tasks rather than reading tasks due to lack of writing skills (McNeill, 2011). Therefore, the importance of having a template for full writing tasks is emphasized (Yang and Wang, 2014). A structured writing template improves students' argumentation skills better (Jang and Hand, 2017) and it provides a heuristic template to guide students' reasoning and scientific inquiry activities (Hand, 2008). Its most important difference from other inquiry-based learning approaches is that it provides peer negotiation while justifying scientific explanations. Learning by understanding is of great importance in the construction of knowledge. Negotiation is defined as the interaction between the students' own knowledge and their peers' knowledge; it supports meaningful learning and increases the knowledge retention (Keys et al., 1999; Norton-Meier, Hand, Hockenberry & Wise, 2008). Students' acquisition of scientific knowledge is one of the main objectives of science education.

In the ABI approach, which is a student-centered approach, at the beginning of the implementation process, the teacher should first design different activities that can reveal the students' prior knowledge. The rules that can increase the interaction in the classroom should be reminded and should be guiding the students toward listening to and understanding each other. Students should be helped in issues such as producing qualified questions on which they can conduct research within the scope of the implementation and the provision of materials that they want to use in order to find answers to the questions they produce. The course should support individual or group work that enables all students to be active. The teacher should be a guide, be able to test whether students understand or not and should encourage each student to present his/her opinion instead of giving the correct answer to the questions asked by the students (Keys et al., 1999).

In the implementation process of the ABI approach, students are required to determine questions that they want to investigate, to design activities in order to test their own questions. They record their observations and data which they collected during the activity process. At the end of this process, they construct claims and evidence based on their observations and data. They share their claims and evidence first in the group and then as a whole class in the negotiation process. In this process, they ask each other questions. They write their experiences in a reflective manner in accordance with ABI format as a result of the feedback they received from the negotiation process (Keys et al., 1999).

Writing, an essential part of ABI approach, is recommended as a good learning tool (Emig, 1977; Chen, 2013). Traditional writing (lecture notes, etc.) remains weak regarding students' construction of scientific knowledge (Yore, Bisanz and Hand, 2003). On the other hand, writing studies aimed at learning have been put forth by Emig (1977), who states that the acquisition of knowledge and skills is accomplished through the combination of listening, speaking, reading and writing processes. Writing activities aimed at learning provide contributions such as helping the students learn, increasing their existing knowledge and improving their skills such as remembering, commenting, reinforcing and communication (Hewson, 1981). The benefits of writing activities for learning purposes are summarized as follows in general (Daşdemir, Cengiz and Uzoğlu, 2015):

1. It improves conceptual understanding and communication skills of individuals by providing concept change.

2. It enables individuals to build meaningful connections between previous and new knowledge and build their existing knowledge on solid foundations.

3. It increases the retention of the knowledge by reinforcing the new information learned.

4. It facilitates the learning of complex concepts by processing them with the knowledge and links that exist in the mind.

Another essential part of ABI approach is argumentation. The contributions of using argumentation in science can be summarized as follows: (1) To support access to cognitive and metacognitive processes that characterize expert performance and to enable modeling for students. (2) To support the development of communicative competences, particularly critical thinking. (3) To support the achievement of scientific literacy and strengthen students' ability to speak and write scientific languages. (4) To promote the incorporation of science culture into practices and to develop epistemic criteria for knowledge evaluation. (5) To support the development of reasoning, in particular the selection of theories or positions based on rational criteria (Jiminéz-Aleixandre and Erduran, 2008, p.5).

Learning Through Models

In general, a model is defined as the representation of an event, an object or an idea (Gilbert, Boulter and Elmer, 2000; Mahr, 2011). In science, a model is defined as the visualization of a more familiar (source) object, natural phenomenon or idea (target) by way of representation (Gilbert, 1991; Tregidgo and Ratcliffe, 2000). According to Halloun (2004), the function of a model is to express a pattern that can correspond to the questions it can answer, to explain and to describe the problem. Models are external representations of mental concepts and can be in the form of diagrams, three-dimensional physical structures, computer simulations, mathematical formulas and analogies (Krajcik and Merritt, 2012).

The model provides individuals with the opportunity to question how a job is done and its outputs, to evaluate different situations, while, on the other hand, it supports the process of making arguments through negotiations by producing question-claim-evidence regarding the model formed, and contributes to individuals' understanding of science concepts and scientific writing skills (Chen, Benus and Yarker, 2016; Yarker, 2013). For students to understand the learning processes and products better, regarding science education, Hodson (1992) suggested three purposes being the learning of science, that is, understanding of ideas produced by science; learning about science, that is, understanding the important topics in the philosophy, history and methodology of science; and learning how to do science, that is, being able to take part in these activities which lead to the acquisition of scientific knowledge (cited in Justi and Gilbert, 2002b). In line with the purposes mentioned, it is explained that models and modelings have a central place in science education as follows (Justi and Gilbert, 2002b; Justi and van Driel, 2005; Reinisch and Krüger, 2018): (1) To learn science, students should know the nature, scope and limitations of certain scientific models. (2) To learn about science, students must learn the nature of models and recognize the role of models in the accreditation and dissemination of scientific inquiry products. (3) Students should be given the opportunity to create, express and test their own models in order to learn how to do science. The production and use of models play a central role in the growth of scientific knowledge. In understanding events, these objectives can be achieved through the creation of appropriate representations of the mental models that are formed or the actions of scientific modeling. For the development of mental models, first of all, it is necessary to have some direct or indirect, qualitative or quantitative experiences and observations about the phenomenon being modeled in consensus. Scientists expressed that consensus models can be formed by comparing and testing individual models (Justi and van Driel, 2005). The consensus models are the historical models of those currently used in research or those that are nowadays aimed at research (Justi and Gilbert, 2002b). Thinking and reasoning with models allow scientists to visualize abstract processes and beings they are investigating, make explanations to them and make predictions about them among other things (Justi and van Driel, 2005).

Models are external representations of mental concepts and are defined as thinking tools for both scientists and engineers to think and understand events and to provide possible solutions to problem situations (Duit and Glynn, 1996; NCR, 2011).

Scientists construct mental and conceptual models of phenomena and develop and use models to convey and criticize their ideas. Students are also expected to develop, use and revise their models to share and discuss ideas in the classroom (NRC, 2012; Nersessian, 2002; Passmore, Gouvea and Giere, 2014). In science education, although different types of models are used, it is in general possible to gather models under three headings as mental, conceptual and physical models. Mental models are psychological representations of real or imaginary situations, and they serve as a tool to think, predict, and build a sense of experience (Franco and Colinvaux, 2000; NRC, 2012). Individuals perceive and conceptualize situations in the world as they occur in their mind (Franco and Colinvaux, 2000). The quality of the mental models formed by students has an important role as an indicator of whether the concepts are understood or not, whether the information has been structured or not. At the same time, the most important feature of the mental models formed based on the analogy models is that they provide the opportunity to evaluate the extent to which an individual can improve his/her cognitive abilities (Ünal and Ergin, 2006). A conceptual model is an external representation created by teachers or scientists who facilitate the understanding or teaching of systems or situations around the world (Greca and Moreire, 2000). It also helps scientists visualize and understand the necessary solution to a problem (Greca and Moreire, 2000; NRC, 2012). These external representations may take place as mathematical formulations, analogies or concrete products. A representation illustrating the operation of a water pump, the similarity between Rutherford's atom and the solar system, or mathematical formulations of the shell model for nuclear physics are examples of conceptual models (Greca and Moreira, 2000). Since the drawings assessed in the conceptual model category are related to mental models, the use of student drawings in the teaching environment focuses on developing a spatial and causal/dynamic model rather than students' memorizing vocabulary (Clement, 2000). Therefore, drawings based on learning can be used as a record of easily accessible thoughts (Clement, 2000). Brooks (2009) stated the importance of children's drawings as: "When we see children's drawing as a form of communication and a means of producing meaning, the social, cultural and historical relationship with this process of gaining meaning requires careful consideration." It is also aimed to explore the engineering understanding of primary school students (Weber, Duncan, Dyehouse, Strobel and Diefes-Dux, 2011) and to assess their attitudes and misconceptions about scientists and engineers (Knight and Cunningham, 2004) by using drawings and writing approaches together.

Regarding physical models in science education, the model described as representation by Gilbert (2008) is defined as "internal representation" if it exists in the mind of the individual and "external representation" if it can easily be accessed physically by others. In teaching practices, models are considered as the heart of scientific research and are therefore emphasized as the cornerstones for developing knowledge about the nature of science (NRC, 2000). Regarding the teaching and application of concepts in science education, *in the framework program entitled "Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas"* (NRC, 2012) the importance of scientific methods has been emphasized and an understanding of moving away from uniformity through different methods and techniques has been adopted. On the other hand, modeling process is expressed as experimental testing of mental models (Justi and Gilbert, 2002a). Therefore, suggestions such as causal reasoning, evaluation, evidence, argumentation and model development-use were brought to the forefront. In the literature examined in this context, it is seen that science education advocates and supports the place of model based science education (Nersessian, 2002).

In the studies comprising the examination of modeling, model suggestion, evaluation and remodeling as a process, it is seen that the general focus is on analyzing the learning of concepts and sometimes emphasizing the collaborative aspect of conceptual development processes (Mendonça and Justi, 2013). In order to better understand the pedagogical functions of modeling teaching, in a compilation study of the last decade, one of the conclusions reached was that although conceptual understanding is the most common pedagogical element defined for modeling, it is rarely used in developing practices and understanding science (Campbell, Oh, Maughn, Kiriazis and Zuwallack, 2015). At the same time, a common finding of the previous studies was learning through modelling supports conceptual understanding (Hafner and Stewart, 1995; Sunyono, Leny and Muslimin, 2015; Thomson and Stewart, 2003). In teaching concepts, it is primarily aimed at questioning, putting forth arguments while questioning, and evaluating by forming a model based on this information. For this purpose, a model-based science teaching approach is an effective method for systematic teaching and learning of scientific concepts. With this approach, the design, construction, evaluation and development of models in the modelling process aimed at the understanding of the system, object or idea are thought to have an important place in the questioning, structuring and advancing of scientific knowledge (Mendonça and Justi, 2013; Passmore et al., 2009).

Campbell and Oh (2015) examined modeling pedagogy and their frequency of use in their studies. Pedagogical actions where models are frequently used are experimental modeling, evaluative modeling, and cyclic modeling. In experimental modeling, students construct hypotheses and predictions from models and test them by testing phenomena. At the same time, students review their mental models in accordance with new evidence obtained in practical or thought experiments. In evaluative modeling, students compare alternative models that address the same phenomenon or problem, evaluate their benefits and limitations, and select the most appropriate model/models to explain the phenomenon or solve the problem. In cyclic modelling, students are interested in model development, evaluation and development processes to complete long-standing science projects. It is seen that in the frequency table of these three pedagogical modeling actions, experimental modeling was reported to be the least used with 20% (Campbell and Oh, 2015). However, models can be seen as the center of scientific activities.

Model-based teaching and learning activities are seen to have a major impact on science education, not only in relation to scientific methods and perceptions, but also in designing curricula that are considered to be more concerned with teaching approaches and goals (Develaki, 2016). When the literature is examined, it is stated that some conclusions were reached such as the courses conducted with model based science education supporting students' conceptual development and facilitating understanding (Baek, Schwarz, Chen, Hokayem, and Zhan, 2011; White, 1993), ensuring that they act more courageously in understanding scientific methods and in applications (Hestenes, 1992; Hodson 1992; Lederman, 2007) and improving the development of their metacognitive abilities (Gilbert, 1995; Gobert, O'Dwyer, Horwitz, Buckley, Levy and Wilensky, 2011; White, 1993). In addition, it is stated that mentally modeling knowledge and contents (Schwarz and White, 2005; Oh and Oh, 2011), questioning and reasoning abilities (Böttcher and Meisert, 2011; Nersessian, 2008) develop together with model-based education. Another important point mentioned in the literature on this subject is the consensus on idea that models should be used by teachers and students in order to understand the scientific concepts and the nature of science, as stated by Gilbert (1991). Another common point that can be obtained from the studies on the model may be that neither teachers nor students have sufficient information about the model and therefore they have insufficiency in using it (Aktan, 2016; Langan, Dunleavy and Fielding, 2013; Nelson and Davis, 2012; Oh and Oh, 2011; Yenilmez Türkoğlu and Öztekin, 2016).

In addition, there are also studies regarding the empirical evaluation of how epistemological information of how students at various grade levels understand issues such as the nature and purpose of models representing the theoretical framework of various models, design and formation and testing of models (Grünkorn, Upmeier zu Belzen and Krüger, 2014; Gogolin and Krüger, 2018; Schwarz, 2002; Tasquier, Levrini and Dillon, 2016), and it is stated that this information ensures students to use models in science and conceptual understanding in the models used. The American Association for the Advancement of Science (AAAS) stated that students at grade 3 and 5 could see and evaluate the results of the changes made on a model on the corresponding entity. In addition, it is stated that geometric shapes, series of numbers, graphs, diagrams, maps and stories were used to show objects, events and processes in real life, but they were aware that they could not meet the truth in every detail (Project 2061, 1993, cited in *Ünal* and Ergin, 2006). It was stated that 3rd and 5th grade students began to make changes on the models in their hands and discuss their limitations within their natural games, started to create their own mental models regarding events they cannot directly observe and thus understand the science subjects (Ünal and Ergin, 2006). In addition, when the aim is a student's being able to make a successful scientific model, states such as understanding scientists' views on the nature of the model, the appropriate experience of the phenomenon represented, knowledge of why the model was originally built and why it should be learned, understanding how the model works, the information of the source on which the target model and/or the teaching model was established should be gained (Justi and Gilbert, 2002a).

In order to understand how knowledge is produced, analyzed, justified, evaluated and reflected in social practices, the process of inquiry is required. The findings obtained in this process can be criticized, discussed and reviewed by presenting them to the peer community. Discussion is a process that scientists' communities test, develop and accept temporarily. It is stated that participating in scientific debates (i.e. examining the relationship or connection with evidence and then accepting or rejecting it, and being able to associate theoretical ideas put forth in an explanation or evidence with theory) is defined as the process of constructing arguments, and scientific theories, modeling and argumentation are defined as dynamically intertwined and interdependent structures (Clark and Sengupta, 2013). The process of producing, testing, evaluating and reviewing models considering the permanence of scientific knowledge can be seen as the center for the development, critical evaluation and dissemination of scientific knowledge (Giere, 2001; Gilbert and Boulter, 1997; Nersessian, 2002).

Argument Based Inquiry Accompanied With Models (ABIAM)

Various approaches have been developed to analyze the structure and quality of the arguments, and the framework proposed by Toulmin (1958, 2003) for the structural analysis of the arguments is still widely introduced and used even today in research in the field of science education. While the diversity of these approaches also points to some theoretical and methodological problems related to the uncertainty of existing analysis methods, it is emphasized that while many frameworks are limited to explaining only parts of the controversial processes, there are several methodological difficulties that arise in the context of Toulmin's structural analysis of arguments (Böttcher and Meisert, 2011). Böttcher and Meisert (2011) argue that the inclusion of cognitive science results related to the role of mental modeling in discussion and problem solving processes and the use of a model-supported argumentation approach will help to overcome these difficulties.

Lehrer and Schauble (2006) proposed three important points for coordinating an effective approach: (1) using a model to identify evidence for information needs, (2) developing models using the argumentation process, and observing/revising them and reinterpreting new information; (3) using a set of models to represent ideas. Based on these three important points, Chen, Benus and Yarker (2016) developed a Science Negotiation Pedagogy framework, which combines arguments and model applications that can be used in science courses (See Figure 1). Based on the framework, Scientific Negotiation Pedagogy provides effective use of argumentation practices in science courses by supporting them with models.

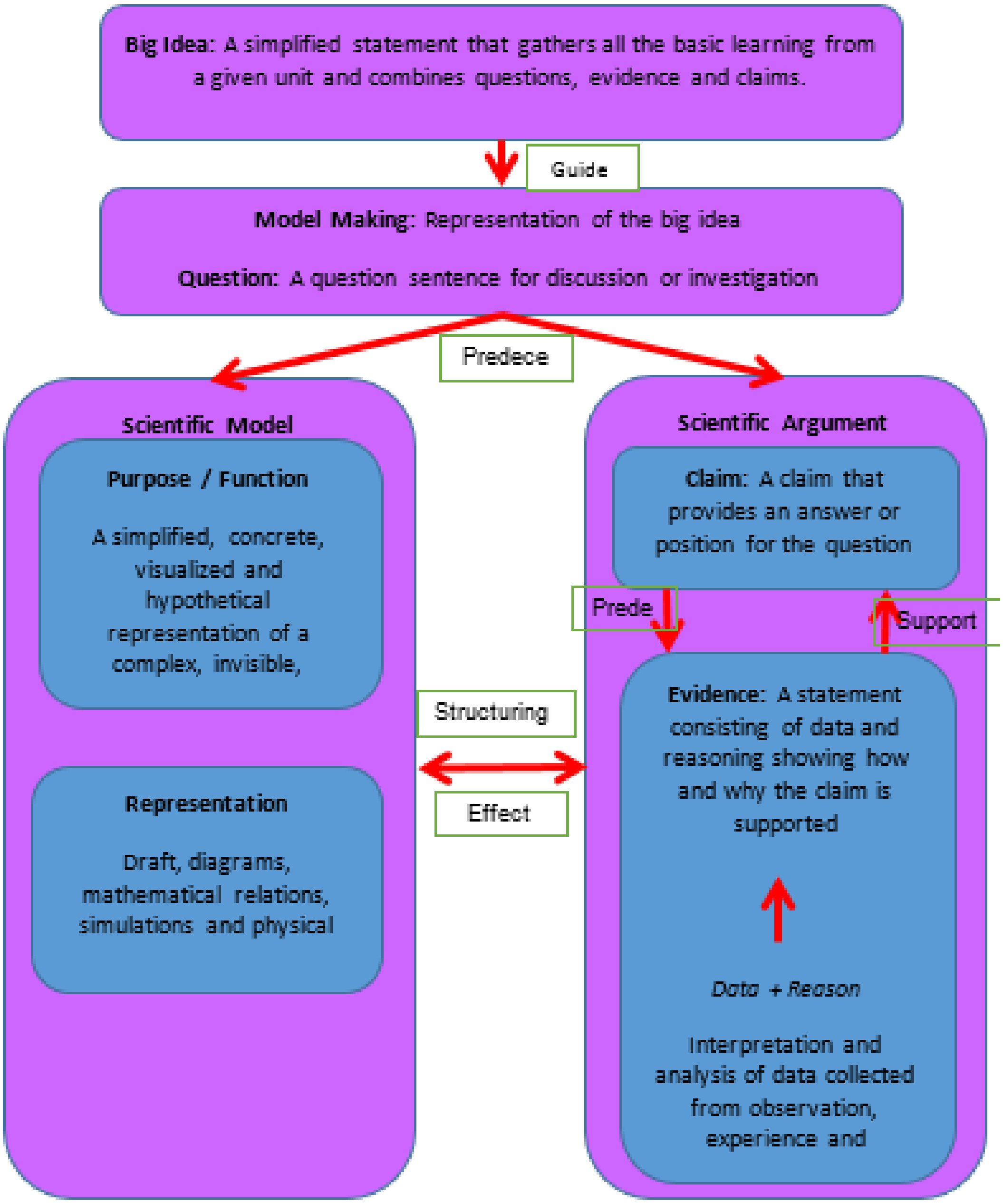

Figure 1. A framework for Scientific Arguments and Models in Science Subjects

This framework is based on Argument Based Inquiry Approach and includes six steps:

Step 1: Creating a beginning question that can be investigated. Students should be able to produce a good question in the first step of the application process of ABI approach. As a criterion for a good question, it should be a testable, researchable question, and should not contain short answers such as yes or no.

Step 2: Building a temporary model as a group. In order to answer the questions they form, students first design a mental model. They draw these models in their minds as conceptual models and then turn them into physical models. Thus, students have the opportunity to test their own negotiated ideas and the answers to the questions they have formed on their own models.

Step 3: Forming a temporary argument as a group. Using the models they have created in the previous step as a tool, the students construct a scientific argument including claims and evidence. The data includes not only quantitative information but also qualitative information. Students are ensured to form their written arguments in the framework of a form presented to them to write arguments.

Step 4: Discussing models and arguments through negotiation as a whole class. Students are provided to discuss and evaluate their models and arguments through negotiations as a whole class. At this step, activities are conducted for students to understand and discuss the big idea and to persuade and cooperate. Thus, students are ensured to recognize the strengths and weaknesses of their own ideas and to be able to revise their models and arguments.

Chen and Steenhoek (2013) define the cycle of negotiation that they propose to support argumentation on science issues as determination of a research question by the students, their conducting research on this research question as a group, presentation of an argument regarding the questions as a group, comparison of the arguments with books and other resources, learning-revising common concepts and reflecting what they have learned through individual writing.

Step 5: Consulting experts (internal and external resources: books, videos, all kinds of data that can be gathered in the classroom, Internet, newspapers, etc.). This step is designed to provide an opportunity for students to compare their current models and arguments with those of experts. It evaluates situations such as data, evidence, models, writing samples and videos that are formed by the student and can be described as internal resources; or as external sources, it utilizes situations such as textbooks, other books, Internet resources, newspapers and invited speakers.

Step 6: Reflecting the final arrangements through writing. In scientific research, students are encouraged to write a reflective individual text by reviewing their model and argument, similar to the methods by which scientists state how information progresses.

The purpose of using a model is to test ideas by representing connected transaction systems and to assess them with real-world evidence (Windschitl, Thompson and Braaten, 2008). Students need substantial experience to fully develop model practices that can be supported by social negotiation. At the same time, students can use and review models when working with experimental data from different sources, such as classroom experiments or authentic research data (Bielik, Damelin, Krajcik, 2019).

It is argued that regarding all contemporary education levels and science courses, a connection will be established with contemporary philosophy of science by in-depth analysis of model supported science education and research and innovation applications

(Adúriz-Bravo, 2011).

Conclusion

In conclusion, Argument Based Inquiry Accompanied With Models (ABIAM) successfully makes explicit modelling and argumentation within inquiry approach. It provides students to learn science concepts by creating models while constructing arguments in scientific investigations. In addition, elements of ABIAM approach -inquiry, argumentation, and designing/constructing models - were emphasized in Turkish Elementary Science Curriculum (MoNE, 2018). Therefore, it is concluded that teaching science with ABIAM approach is significant and important.

Acknowledgement

This study was produced from the literature review section of the PhD dissertation of Serpil KARA, conducted under the supervision of Assoc. Prof. Dr. Sevgi KINGIR.

References

Adúriz-Bravo, A. (2011). Fostering model-based school scientific argumentation among prospective science teachers. *US-China Education Review, 8*(5), 718-723.

Akben, N. (2015). Improving science process skills in science and technology course activities using the inquiry method. *Education and Science, 40*(179), 111-132.

Aktan, M. B. (2016). Pre-Service science teachers' prceptions and attitudesdes about the use of models. *Journal of Baltic Science Education, 15*(1), 7-17.

Baek, H., Schwarz, C. V., Chen, J., & Zhan, L. (2011). Engaging elementary students in scientific modeling: The models fifth-grade approach and findings. In Khine, M. S., & Saleh, I. M. (Eds.*), Models and modeling: cognitive tools for scientific enquiry (pp.195-218). Dordrecht: Springer.*

Bielik, T., Damelin, D., & Krajcik, J. S. (2019). Shifting the balance: Engaging students in using a modeling tool to learn about ocean acidification, *EURASIA Journal of Mathematics, Science and Technology Education, 15*(1), 1-17.

Braaten, M., & Windschitl, M. (2011). Working toward a stronger conceptualisation of scientific explanation for science education. *Science Education, 95*, 639-669.

Brooks, M. (2009). What Vygotsky can teach us about young children drawing. *International Art in Early Childhood Research Journal, 1*(1), 1-13.

Baxter, L. M., & Kurtz, M. J. (2001). When a hypothesis is not an educated guess. *Science & Children, 38*(7), 18-20.

Böttcher, F., & Meisert, A. (2011). Argumentation in science education: A model-based framework. *Science & Education, 20*, 103-140.

Campbell, T., & Oh, P. S. (2015). Engaging students in modeling as an epistemic practice of science: An introduction to the special issue of the journal of science education and technology. *Journal of Science Education and Technology, 24*(2-3), 125-131.

Campbell, T., Oh, P. S., Maughn, M., Kiriazis, N., & Zuwallack, R. (2015). A review of modeling pedagogies: Pedagogical functions, discursive acts, and technology in modeling instruction. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(1), 159-176.

Chen, Y. C. (2013). Constructing and critiquing arguments. *Science and Children, 50*(5), 40-45.

Chen, Y. C., Benus, M., & Yarker, M. B. (2016). Using models to support argumentation in the science classroom. *The American Biology Teacher, 78*(7), 548-559.

Chen, Y. C., & Steenhoek, J. (2013). A negotiation cycle to promote argumentation in science classrooms. *Science Scope, 36*(9), 41-50.

Clark, D. B., & Sengupta, P. (2013) Argumentation and modeling: Integrating the products and practices of science to improve science education. In Khine MS, Saleh IM (Eds.), *Approaches and strategies in next generation science learning* (pp. 85-105). IGI Global, Hershey, PA.

Clement, J. (2000). Model based learning as a key research area for science education. *International Journal of Science Education, 22*(9), 1041-1053.

Daşdemir, İ., Cengiz, E. & Uzoğlu, M. (2015). Öğrenme amaçlı yazma aktivitelerinden mektup yazmanın 7. sınıf ışık ünitesinde öğrencilerin akademik başarılarına ve bilimsel tutumlarına etkisi. *ODÜ Sosyal Bilimler Araştırmaları Dergisi (ODÜSOBİAD), 5*(11), 89-103.

Develaki, M. (2016). Key-aspects of scientific modeling exemplified by school science models: some units for teaching contextualized scientific methodology. *Interchange, 47*, 297-327.

Duit, R., & Glynn, S. (1996). Mental modelling. In G. Welford, J. Osborne, & P. Scott (Eds.), *Research in science education in Europe: Current issues and themes* (pp. 166-176). London: Falmer.

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication, 28*, 122-128.

Franco, C., & Colinvaux, D. (2000). Grasping mental models. In J. K. Gilbert & C. J. Boulter (Eds.)., *Developing models in science education* (pp.93-118). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Giere, R. N. (2001). A new framework for teaching scientific reasoning. *Argumentation, 15*, 21-33.

Greca, I. M., & Moreire, M. A. (2000). Mental models, conceptual models, and modeling. [Electronic version]. *International Journal of Science Education, 1*, 1-11.

Grünkorn, J., Upmeier zu Belzen, A., & Krüger, D. (2014). Assessing Students' Understandings of Biological Models and their Use in Science to Evaluate a Theoretical Framework, *International Journal of Science Education, 36*(10), 1651-1684.

Gilbert, J. K. (1995). *The role of models and modelling in some narratives of science education learning*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Gilbert, J. K. (2008). Visualization: An emergent field of practice and enquiry in science education. In Gilbert, J. K., Reiner, M., & Nakhleh, M. (Eds.), *Visualization: Theory and practice in science education* (pp. 3-24). Dordrecht: Springer.

Gilbert, J. K., & Boulter, C. J. (1997). Learning science through models and modelling. In B. J. F. K. Tobin (Eds.), *International handbook of science education* (pp. 53-66). Dordrecht: Kluwer.

Gilbert, J. K. Boulter, C. J., & Elmer, R. (2000). Positioning models in science education and in design and technology education. In J. K. Gilbert & C. J.Boulter (Eds.), *Developing models in science education* (pp.3-17). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Gilbert, S. W. (1991). Model building and a definition of science. *Journal of Research in Science Teaching, 28*(1), 73-78.

Gobert, J. D., O'Dwyer, L., Horwitz, P., Buckley, B. C., Levy, S. T., & Wilensky, U. (2011). Examining the relationship between students' understanding of the nature of models and conceptual learning in biology, physics, and chemistry. *International Journal of Science Education, 33*(5), 653-684.

Gogolin, S., & Krüger, D. (2018). Students' understanding of the nature and purpose of models. *Journal of Research Science Teaching, 55*, 1313-1338.

Hafner, R., & Stewart, J. (1995). Revising explanatory models to accommodate anomalous genetic phenomena: Problem solving in the "context of discovery". *Science Education, 79*(2), 111-146.

Halloun, I. A. (2004). *Modeling theory in science education*. Dordrecht: Kluwer Academic.

Hand, B. (Ed.). (2008). *Science inquiry, argument and language: A case for the science writing heuristic*. Rotterdam, The Netherlands: Sense.

Hand, B., Wallace, C. W., & Yang, E. (2004). Using a science writing heuristic to enhance learning outcomes from laboratory activities in seventh- grad science: quantitative and qualitative aspect. *Intenational Journal of Science Education, 26*(2), 131-149.

Hestenes, D. (1992). Modelling games in the Newtonian world. *American Journal of Physics, 60*(8), 732-748.

Hewson, P. W. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*(4), 383-396.

Hodson, D. (1992). In search of a meaningful relationship: An exploration of some issues relating to integration in science and science education. *International Journal of Science Education, 14*, 541-562.

Hohensell, L. M., & Hand, B. (2006). Writing-to-learn strategies in secondary school cell biology: a mixed method study. *International Journal of Science Education, 28*(2-3), 261-289.

Jang, J., & Hand, B. (2017). Examining the value of a scaffolded critique framework to promote argumentative and explanatory writings within an argument-based inquiry approach. *Research in Science Education, 47*(6), 1213-1231.

Jiménez- Aleixandre, M. P., & Erduran, S. (2008). Argumentation in science education: An overview. In S. Erduran & M. P. Jiménez- Aleixandre (Eds.)*, Argumentation in science education: Perspectives from classroom-based research*. Dordrecht: Springer.

Justi, R. S., & Gilbert, J. K. (2002a). Science teachers' knowledge about and attitudes towards the use of models and modelling in learning science. *International Journal of Science Education, 24*(12), 1273-1292.

Justi, R. S., & Gilbert, J. K. (2002b). Modelling, teachers' views on the natüre of modelling, and implications fort he education of modellers. *International Journal of Science Education, 24*(4), 369-387.

Justi, R. & van Driel, J. (2005). A case study of the development of a beginning chemistry teacher's knowledge about models and modelling. *Research in Science Education, 35*, 197-219.

Keys, C. W., Hand, B., Prain, V. & Collins, S. (1999). Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching, 36*(10), 1065-1084.

Krajcik, J., & Merritt, J. (2012). Engaging students in scientific practices: What does constructing and revising modelslook like in the science classroom? Understanding a framework for K-12 science education. *The Science Teacher, 79*(3), 38-41.

Knight, M., & Cunningham, C. M. (2004). *Draw an engineer test (DAET): Development of a tool to investigate student's ideas about engineers and engineering.* Paper presented at the ASEE Annual Conference and Exposition.

Langan, A. M., Dunleavy, P., & Fielding, A. (2013). Applying models to national surveys of undergraduate science students: What affects ratings of satisfaction?. *Education Sciences*, *3*, 193-207.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Ledreman (Eds.), *Handbook of research on science education* (pp. 831-879). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Lehrer, R., & Schauble, L. (2006). Cultivating model-based reasoning in science education. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences*. New York, NY: Cambridge University Press.

Mahr, B. (2011). On the epistemology of models. *Rethinking Epistemology, 1*, 301-352.

McNeill, K. L. (2011). Elementary students' views of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. *Journal of Research in Science Teahing, 48*(7), 793-823.

Mendonça, P. C. C., & Justi, R. (2013). The relationships between modelling and argumentation from the perspective of the model of modelling diagram. *International Journal of Science Education, 35*(14), 2407-2434.

National Research Council (NRC). (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press.

National Research Council (NRC). (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Nelson, M. M. & Davis, E. A. (2012). Preservice elementary teachers' evaluations of elementary students' scientific models: An aspect of pedagogical content knowledge for scientific modeling, *International Journal of Science Education, 34*(12), 1931-1959.

Nersessian, N. J. (2002). The cognitive basis of model-based reasoning in science. In P. Carruthers, S. Stich, & M. Siegal (Eds.), *The cognitive basis of science* (pp. 133-153). Cambridge: Cambridge niversity Press.

Nersessian, M. (2008). Model-based reasoning in scientific practice. In R. A. Duschl & R. E. Grandy (Eds.), *Teaching scientific inquiry. Recommendations for research and implementation* (pp. 57-79). Rotterdam: Sense Publishers.

Norton-Meier, L., Hand, B., Hockenberry, L., & Wise, K. (2008). *Ouestions, claims, and evidence: The important place of argument in children's science writing*. Portsmouth, NH: Heinemann.

Oh, P. S., & Oh, S. J. (2011). What teachers of science need to know about models. *International Journal of Science Education, 33*(8), 1109-1130.

Passmore, C., Stewart, J., & Cartier, J. (2009). Model-based inquiry and school science: creating connections. *School Science and Mathematics, 109*(7). 394-402.

Passmore, C. M., & Svoboda, J. (2012). Exploring opportunities for argumentation in modelling classrooms. *International Journal of Science Education*, *34*(10), 1535-1554.

Passmore, C., Gouvea, J. S., & Giere, R. (2014). Models in science and in learning science: Focusing scientific practice on sense-making. In M. R. Matthews (Eds.)., *International handbook of research in history, philosophy and science teaching* (pp. 1171-1202). Netherlands: Springer.

Reinisch, B. & Krüger, D. (2018). Preservice biology teachers' conceptions about the tentative nature of theories and models in biology. *Research in Science Education, 48*, 71-103.

Schwarz, C. V. (2002, April). *Using model-centered science instruction to foster students' epistemologies in learning with models*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Schwarz, C. V., & White, B. Y. (2005). Meta-modeling knowledge: Developing students' understanding of scientific modeling. *Cognition and Instruction, 23*(2), 165-205.

Sunyono, Leny, Y., & Muslimin, I. (2015). Supporting students in learning with multiple representation to improve student mental models on atomic structure concepts. *Science Education International, 26*(2), 104-125.

Tasquier, G., Levrini, O., & Dillon, J. (2016). Exploring students' epistemological knowledge of models and modelling in science: results from a teaching/learning experience on climate change. *International Journal of Science Education, 38*(4), 539-563.

Thomson, N., & Stewart, J. (2003). Genetics inquiry: strategies and knowledge geneticists use in solving transmission genetics problems. *Science Education, 87*(1), 161-180.

Tregidgo, D., & Ratcliffe, M. (2000). The use of modeling for improving pupils' learning about cells. *School Science Review, 81*, 53-59.

Ministry of Education (MoNE) (2018). Turkish Elementary Science Curriculum. Ankara: Education Board of Education. . [Online: http://mufredat.meb.gov.tr/Dosyalar], Date of access: 25.09.2018.

Ünal, G. & Ergin, Ö. (2006). Science education and models. *Millî Eğitim Dergisi (Journal of National Education), 171*, 188-196.

Weber, N., Duncan, D., Dyehouse, M., Strobel, J., & Diefes-Dux, H.A. (2011). The development of a systematic coding system for elemetary students' drawings of engineers. *Journal of Pre-College Engineering Education Research (J- PEER), 1*(1), 48-62.

White, B. Y. (1993). ThinkerTools: Causal models, conceptual change, and science education. *Cognition and Instruction, 10*(1), 1-100.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, *92*(5), 941-967.

Yang, H. T., & Wang, K. H. (2014). A teaching model for scaffolding 4th grade students' scientific explanation writing. *Research in Science Education, 44*, 531-548.

Yarker, Morgan Brown. (2013). *Teacher challenges, perceptions, and use of science models in middle school classrooms about climate, weather, and energy concepts* (Doctoral thesis). University of Iowa.

Yenilmez Türkoglu, A. & Öztekin, C. (2016) Science teacher candidates' perceptions about roles and nature of scientific models. *Research in Science & Technological Education, 34*(2), 219-236.

Yore, L., Bisanz, G.L., & Hand, B. M. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Science Education, 25*(6), 689-725.

Citation:
Kara, S. & Kingir, S. (2019). Argument based inquiry approach accompanied by models in primary science teaching. In M. Shelley & S.A. Kiray (Ed.). *Education Research Highlights in Mathematics, Science and Technology 2019* (pp. 144-162). ISRES Publishing, ISBN:978-605-698540-9.