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The Efficiency of Argument-Based Inquiry Practices in Science Teacher Candidate Education[*]

Argümantasyona Dayalı Araştırma-Sorgulamaya Uygulamalarının Fen Öğretmen Adayı Eğitimindeki Etkililiği

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ABSTRACT: This study aimed to develop, implement, and evaluate argumentation-based inquiry teaching practices to train qualified science teachers. In this context, first, practices in argument-based inquiry were developed to have highly qualified individuals with cognitive flexibility; the ability to look at happening from divergent perspectives and consider them in alternate ways is an essential skill for the 21st century. Second, the designed argument-based inquiry practices were applied for 14 weeks in the "Science Literacy" elective course. Teacher candidates' scientific process skills, high-level thinking skills, and consideration of the nature of science were researched to evaluate the effect of the implementation. A "concurrent triangulation design" was utilized in this mixed methods research. The study group comprised 38 science teacher candidates. Quantitative data were collected utilizing a scientific process skills test, critical thinking disposition instruments, a metacognitive awareness inventory, and a nature of science views test. Qualitative data were collected through a semi-structured interview and documents (reflective learning diaries, reflective evaluation notes). The results show that the quantitative and qualitative findings support each other. It was found that the practices carried out during the 14 weeks contributed to the science teacher candidates' development of scientific process skills, critical thinking tendencies, metacognitive awareness, and views about the nature of science.

Keywords: Argumentation, inquiry-based learning, science teacher education, science process skills, higher-order thinking skills, nature of the science.

ÖZ: Bu araştırmada, nitelikli fen öğretmenleri yetiştirilmesi için argümantasyona dayalı araştırma-sorgulama uygulamalarının tasarlanması, uygulanması ve etkisinin ortaya konulması hedeflenmiştir. Bu kapsamda, öncelikle mental esnekliğe sahip, eleştirel, yaratıcı ve yenilikçi düşünebilien, yaşanılan çağa uyum sağlayabilen öğrenciler yetiştirilmesi için argümantasyona dayalı araştırma-sorgulama uygulamaları tasarlanmıştır. Daha sonra, tasarlanan argümana dayalı araştırma-sorgulama etkinlikleri Fen Eğitimi bölümü "Fen Okuryazarlığı" dersinde 14 hafta boyunca uygulanmıştır. Bu etkinliklerin öğretmen adayları üzerindeki etkisini ortaya koymak amacıyla, fen öğretmen adaylarının bilimsel süreç becerileri, üst düzey düşünme becerileri ve bilimin doğası anlayışlarındaki gelişimleri araştırılmıştır. Araştırmada karma yöntemlerden "eş zamanlı üçgenleme deseni" kullanılmıştır. Araştırmanın çalışma grubunu 38 fen öğretmen adayı oluşturmaktadır. Nicel veri toplama araçları; bilimsel süreç becerileri testi, eleştirel düşünme eğilimi ölçeği, üstbiliş farkındalık envanteri, bilim doğası görüşleri testi; nitel veri toplama araçları ise yarı yapılandırılmış görüşme formu ve dokümanlardır. Yapılan uygulamaların öğretmen adaylarının bilimsel süreç becerilerinin, eleştirel düşünme eğilimlerinin, üst biliş farkındalık düzeylerinin, bilimin doğası hakkındaki görüşlerinin gelişmesine yol açtığı belirlenmiştir.

Anahtar kelimeler: Argümantasyon, araştırma-sorgulamaya dayalı öğrenme, fen öğretmen eğitimi, bilimsel süreç becerileri, eleştirel düşünme, üstbilişsel düşünme, bilimin doğası anlayışları.

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Developed and developing countries have started to give more importance to science education to continue the leadership race with each other in the economic field since the second half of the 20th century (Barrow, 2006). Today the fourth industrial revolution is taking place, and one way to show progress and development as a country is to train qualified science teachers. The targeted teacher profile for the 21st century is the ability to be competent in many areas with the knowledge, skills (cognitive skills, internal skills, social skills, research skills, learning-teaching skills), and values that have the needs of the age.

Science education is of vital importance in developing 21st-century skills, namely life skills. Students build their cognitive and psychomotor skills in science education while working on specific science subjects and concepts (Bybee, 2009). Providing students with authentic learning environments enable life skills, so 21st-century skills to develop (Larson & Miller, 2011). The National Science Teacher Association [NSTA] emphasizes that science practices that appeal to the nature of science offer a rich context for developing many skills, such as critical thinking, problem-solving, and science literacy (NSTA, 2011). According to Bybee (2009), inquiry-based learning environments have great potential to develop 21st-century skills. In this age of technological and scientific developments, 21st-century skills can be developed with scientific process skills, especially in science lessons. Students' use of scientific process skills in science classes requires higher-order thinking skills. Thanks to quality science education, it can be possible for students' 21st-century life skills can be improved (Turiman et al., 2012).

Theoretical Background and Literature Review

Science Teaching Curriculum in Turkey

In the 21st century, where scientific knowledge has grown day by day and technology is developing rapidly, to be among the developed countries, the importance given to science education is increasing day by day. Reform documents published in the field of science education focus on promoting scientific literacy for all students (Ministry of National Education [MoNE], 2018; National Research Council [NRC], 2000). To improve the quality of science education in Turkey, many national and international research and projects have been carried out (Ex: MASCIL, PATHWAY, PRIMAS, PROFILES, SAILS, S-TEAM, STING, etc.). In Turkey, since the declaration of the Republic in 1926, 1936, 1948, 1968, 1972, 1974, 1992, 2000, 2005, 2013, 2017, and 2018, the science teaching curriculum has been changed and updated to improve science learning and teaching (MoNE, 2005, 2013, 2018; Yılmaz & Morgil, 1992). Until 2004, with the effect of behavioral learning theory, a teacher-centered approach called the 'traditional learning approach' was adopted. In this approach, the student is the receiver and storage of knowledge; the teacher is the server of scientific knowledge. Considering the reforms in science education, it was realized that it is important for the students to evaluate the ever-changing information in a questioning and critical manner and to make logical decisions (NRC, 2000). In line with this, the science teaching curriculum has been updated to train students who will produce new knowledge and sign important discoveries and inventions. The vision of the Science and Technology Teaching Curriculum in 2005 was defined as "Regardless of individual differences, all students are educated as science and technology literate." There has been a radical change based on the 'constructivist learning approach, which requires the student's active participation (MoNE, 2005). In this context, it is proposed to organize teaching-learning environments. In 2013, the vision of the science teaching curriculum was updated as 'To educate all students as science-literate individuals.' To educate science-literate students, it is recommended to use the 'inquiry-based learning approach' in the science teaching curriculum (MoNE, 2013). The inquiry learning process is considered not only as a "discovery and experiment" but also as an "explanation and argument" creation process (MoNE, 2013). In 2018, the science teaching curriculum was again updated, as in the 2013 curriculum; it aims to train science-literate individuals. It is recommended to use the "inquiry-based learning and argumentation-based learning approach with STEM (Science, Technology, Engineering, and Mathematics) integrated perspective (MoNE, 2018). In the science teaching curriculum (2018), the acquisitions for the areas of "knowledge" (earth and universe, physical events, matter and its nature, creatures, and life), "skill" (scientific process skills, life skills; high-level thinking skills, engineering, and design skills) and "science, engineering, technology, society, environment" (views of nature of science) learning areas are included. MoNE (2018) suggested that these acquisitions should be realized through inquiry-based learning and argumentation-based learning environments.

Literature Review for Needs Analysis

Despite the studies and arrangements in the field of science education, it has been revealed that the students (Gonzales et al., 2008; Nwosu & Ibe, 2014; OECD, 2013; Özdem et al., 2010), teacher candidates (Özdemir, 2010; Yetişir & Kaptan, 2007), and even teachers (Özdemir, 2011; Sülün et al., 2009) have not a sufficient level of science literacy.

Although there are positive developments in science education and teaching programs to improve education quality, some problems in the science teaching-learning process prevent students from becoming science-literate individuals. Some problems arise from the teacher. Capps et al. (2010) stated that teachers did not sufficiently apply the inquiry-based learning approach in their classrooms. Küçüköner (2011) determined that teachers could not adopt constructivist teachers' roles. Şimşek et al. (2012) determined that science teachers continue to use traditional teaching methods such as lecture, question, and answer. In the study conducted by Erişti and Tunca (2012), it was found that teachers were insufficient in teaching affective skills. A study conducted by Geçer and Özel (2012) found that teachers continued to use teacher-centered learning methods in their classrooms for various reasons. As Korkmaz and Kaptan (2002) stated, the student model, who takes the knowledge from the teacher, has to leave the place to a student model, who can access the knowledge, select and remove the knowledge from the complex knowledge network and solve the problems by using this knowledge. In a study conducted by Aydın and Çakıroğlu (2010), teachers stated that in-service training for the new program is insufficient. Akıncı et al. (2015) reported that in-service teacher training does not provide professional development and experience. Kaya and Böyük (2011) found that teachers were insufficient in many subjects during laboratory studies. Yoon et al. (2012) determined that teachers experienced problems in the practices of the inquiry-based learning approach in their classes. Newton et al. (1999) determined that the dialogues in the science classes are teacher-centered, and that the student is not interactive. Besides, it was found that the students are not allowed to explain and share their views, are not considered from different perspectives, and are given almost no opportunity to reason based on the evidence (Newton et al., 1999). It is emphasized that teachers do not have sufficient knowledge and experience in the argumentation-based learning approach, and as a result, they are insufficient to implement the argumentation-based learning approach (Driver et al., 2000; Erduran & Jiménez-Aleixandre, 2007). Although the inquiry-based learning approach is recommended in Turkey's Science Teaching Curriculum, in the study conducted by Feyzioğlu (2019), it was found that this approach was not used at the specified level. Zeidler (1997) stated that teachers should participate in this process as students to conduct the argumentation process well. In addition, it is stated in the research (Driver et al., 2000; Jiménez-Aleixandre et al., 2000; Newton et al., 1999; Simon & Johnson, 2008) that argumentation and inquiry-based implementations are insufficient and teacher education is needed in this subject.

When the results of the research in the literature are evaluated with a holistic evaluation, it can be said that most teachers have difficulties due to their education with a teacher-centered approach, and they have difficulty changing their teaching routines. It is challenging to change the image of the teacher. NRC (1996), *"...If reform is to be accomplished, professional development must include experiences that engage prospectively and practicing teachers in active learning that builds their knowledge, understanding, and ability. The vision of science and how it is learned as described in the Standards will be impossible to convey to students in schools if the teachers themselves have never experienced it*." (p. 56).

Furthermore, it is emphasized that teachers play an essential role in developing science-literate individuals and that teachers should have knowledge skills, attitudes, and values related to science to educate students as science-literate individuals (NRC, 1996). Therefore, to contribute to the professional development of teachers, the implementation of pre-service and in-service education should include practices that will contribute to the development of knowledge, skills, and practical learning areas of teachers (Driver et al., 2000). Otherwise, no matter how functional the Science Teaching Curriculum is prepared, it is seen that if the teachers are not equipped with appropriate features, it is challenging for the program to be successful (Demirel, 2005).

Importance of the Science Teacher Education in Turkey

In these days of the fourth industrial revolution, a way to show progress and progress as a country is to educate qualified teachers. The teacher professional development program is an essential factor that will affect the next generations of education, determining teacher qualifications, what to teach, and what to value and how to behave (Özcan, 2011). It can be said that this is the teaching-learning approach that science teachers adopt while teaching science is the most necessary feature that determines the quality of science teachers in the 21st century. The goal of the Turkey Science Teaching Program is to hope that teachers will have the knowledge, skills (cognitive skills, internal skills, social skills, research skills, teaching-learning skills), and values that will adapt to the era's needs and be competent in many areas (MoNE, 2013, 2018). Science lessons improve the cognitive, affective, social, and psychomotor skills of 21st-century students. To educate individuals with qualified science literate, Science Teaching Program was reformed (MoNE, 2013, 2018). Because the common trend is still a more teacher-centered learning approach, more importance should be attached to the education of science teachers so that the changing teaching program (student-centered learning approach) can be implemented as targeted and reveal the targeted learning outcomes. For the science teachers to implement argumentation and inquiry-based learning, long-term professional development programs should be attended. Only in this way do they adopt the learning environment based on inquiry and argumentation.

Significance of the Study

As can be seen, argumentation and inquiry-based learning emphasize life skills such as scientific process skills and critical thinking skills. This study aimed to develop, implement, and evaluate argumentation-based inquiry teaching practices in this context. The practices based on argumentation-based inquiry teaching have been developed to educate teachers/teacher candidates/students with mental flexibility, an ability to look at events from different perspectives, think alternatively, and have the necessary skills for the 21st century. The approach that constitutes the theoretical foundation of the developed implementations is the open inquiry and argumentation-based learning process. In the literature, it is seen that there are various argumentation and inquiry-based learning stages, cycles, and models, but there is no consensus on specific components (Pedaste et al., 2015). In line with the objectives of the study (the development of 21st-century skills), a teaching model named "argumentation-based inquiry teaching model" was designed as a result of its synthesis of various inquiry and argumentation models (Bybee et al., 2006; Keys et al., 1999; Minner et al., 2010; NRC, 2012; Pedaste et al., 2015; Toulmin, 1958; Walton, 2006; White & Frederiksen, 1998). This designed model is described in the method section. The planned argumentation-based inquiry teaching practices were applied for 14 weeks in the "Science Literacy" elective course in the undergraduate program of science education. The following questions were investigated in the study to examine the effect of argumentation-based inquiry teaching practices on science teacher education.

Sub-problems:

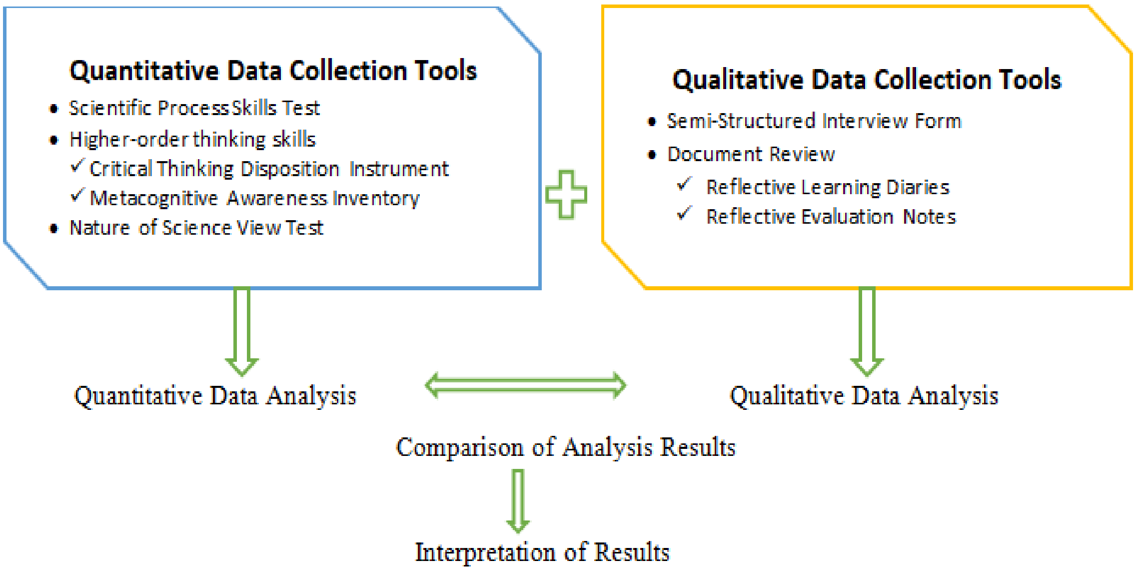
1. What impact do argumentation-based inquiry practices have on improving science teacher candidates' *scientific process skills*? What are the views of teacher candidates' on improved scientific process skills?
2. What impact do argumentation-based inquiry practices have on improving science teacher candidates' *higher-order thinking skills* (*critical thinking, metacognitive awareness*)? What are the views of teacher candidates' on improved higher-order thinking skills?
3. What impact do argumentation-based inquiry practices have on improving science teacher candidates' *views of the nature of science*? What are the views of teacher candidates' on an improved view of the nature of science?

Method

In this study, which investigated the efficacy of "*argument-based inquiry*" activities in training science teacher candidates' education, "*Convergent parallel design*" was used as mixed-method research (Creswell, 2009).

Figure 1

Research Method: Convergent Parallel Design, Mixed Method



The convergent parallel design combines qualitative and quantitative methods' differentiating strengths and non-overlapping weaknesses. It allows triangulation of methods to compare and strengthen quantitative and qualitative findings (Creswell & Plano-Clark, 2007). The quantitative section of the study was designed as a "*one group pretest-posttest poor experimental design*" (Fraenkel et al., 2012). The absence of the control group in the study is among the study's limitations. The qualitative part of the study was structured as a *"phenomenology design"* (Merriam, 2009) to reveal the opinions and perceptions that individuals developed based on their experiences.

Study Group

In this study, a convenient sampling method was used. The study group comprised 38 science teacher candidates who enrolled in the elective course "*Science Literacy"* in the science teaching program of a public university in Ankara. 4 of the teacher candidates are male, and 34 are female. The average score of academic achievement of science teacher candidates was calculated as 2.83 out of 4.0.

Interview Group

Interviews were conducted with 14 teacher candidates from the study group. Voluntary participation in the study group was considered to determine the teacher candidates who would participate in the interview. Eleven of them are female teacher candidates, and 3 of them are male teacher candidates. Three of them are in 2nd grade, six are in 3rd grade, and five are in 4th grade.

Data Collection Tools

The most significant advantage of mixed-method research is that more reliable results can be achieved by integrating qualitative and quantitative data collection instruments. It is possible to make a comparative evaluation by ensuring the consistency and complementarity of the quantitative and qualitative findings obtained (Creswell, 2009).

Quantitative Data Collection Tools

The scientific Process Skills Test. It was adapted to Turkish by Geban et al. (1992) from Okey et al. (1985) and was used to measure the improvement of scientific process skills. This test is preferred and reliable in order to measure teacher candidates' scientific process skills (Arı et al., 2017; Bahtiyar & Can, 2017; Kanlı & Temiz, 2006; Karapınar & Şaşmaz Ören, 2015; Sezek et al., 2015; Temel & Morgil, 2007; Yurdatapan, 2013). The Cronbach Alpha reliability coefficient calculated by Geban et al. (1992) was calculated as (Alpha) .81. Karapınar and Şaşmaz Ören (2015) have tested the reliability of the test with 247 teacher candidates. They calculated the reliability coefficient as .79. For the current study, the KR-20 reliability coefficient value was .76. The scientific process skills test consists of 36 multiple-choice questions. Five sub-dimensions consist of identifying and stating hypotheses, identifying variables, investigations designing, operationally defining, graphing, and interpreting data consists of 5 sub-dimensions. The correct score of the scientific process skills test is '1 point,' and if it is false and empty, it is evaluated as '0 points'. Usually, the lowest score received due to scoring is '0' while the highest score is '36'. However, since the number of items in the sub-dimensions is not equal, the maximum score is 100 for facilitating comparisons and increasing intelligibility. It was applied as a pre-test and post-test.

Critical Thinking Disposition Instrument UF/EMI Critical Thinking Disposition Instrument. It was developed by Irani et al. (2007). The instrument used to measure the development of critical thinking tendencies of teacher candidates was adapted to Turkish by Ertaş Kılıç and Şen (2014). This scale consists of 25 items in a 5-Likert type format and has three sub-dimensions: Engagement, Cognitive Maturity, and Innovativeness. In Likert-type scale is coded as follows: *"I strongly agree (5 points), I agree (4 points), I am undecided (3 points), I disagree (2 points), I strongly disagree (1 point)"*. The dimension of engagement is 11 items, the cognitive maturity dimension is seven items, and the innovativeness dimension consists of 7 items. Ertaş Kılıç and Şen (2014) determined the internal consistency coefficient of the whole scale as .91; the internal consistency coefficient of the engagement dimension as .88, the internal consistency coefficient of the Cognitive Maturity dimension as .70; and the internal consistency coefficient of the Innovativeness dimension as .80. Instrument's reliability, this study was applied to 140 teacher candidates**.** As a result of the present study, the internal consistency coefficient for the whole instrument was calculated as .96; the internal consistency coefficient for the engagement dimension was obtained at .91; the internal consistency coefficient for the cognitive maturity dimension was obtained at .89; the internal consistency coefficient for the innovativeness was 0,88. It was applied as a pre-test and post-test.

Metacognitive Awareness Inventory. It was developed by Schraw and Dennison (1994) and adapted to Turkish by Akın et al. (2007). It was used to determine the development of metacognitive awareness levels of teacher candidates. This inventory composes of 52 items in a 5-Likert type format. In Likert-type inventory, it is coded as follows: *"always (5 points), usually (4 points), frequently (3 points), rarely (2 points), never (1 point)"*. The scale has two sub-dimensions: The Structure of Cognition and Regulation of Knowledge. The dimension of the structure of cognition is 17 items, and the regulation of knowledge dimension consists of 35 items. Akın et al. (2007) determined the internal consistency coefficient of the whole scale as .95; the internal consistency coefficient of the structure of cognition dimension as .88; the internal consistency coefficient of the regulation of knowledge dimension as .93. The present study was applied to 140 teacher candidates to test the instrument's reliability. As a result of the present study, the internal consistency coefficient for the whole inventory was calculated as .96; the internal consistency coefficient of the structure of cognition dimension as .91; the internal consistency coefficient of the regulation of knowledge dimension .89. It was applied as a pre-test and post-test.

Nature of Science Views Test. It developed by Yalaki et al. (2014), was used to determine the development of views on the nature of science. This test consists of 24 questions in multiple choices. The internal consistency coefficient of the test was determined as .74 by the researchers. The present study was applied to 140 teacher candidates to test the instrument's reliability. As a result of the present study, the internal consistency coefficient for the whole inventory was calculated as .63. Although this value was low, it was decided to use the test within the present study since qualitative data were also used. It was applied as a pre-test and post-test.

Qualitative Data Collection Tools

Semi-Structured Interview Form. Within the present study, semi-structured interviews were carried out at the end of the implementation to determine the views of science teacher candidates on the effectiveness of argument-based inquiry practices. Firstly, the researcher prepared the semi-structured interview form as a draft form. The interview form includes open-ended and easy-to-understand questions. After the interview form was prepared, qualitative research and science education experts were consulted, and after taking feedback and making corrections, a pilot study was conducted with two teacher candidates. At the end of the semester, teacher candidates were informed about the interview. Semi-structured interviews were managed with fourteen volunteer teacher candidates. Each interview continued for about 20 minutes. Interview questions are presented in Appendix 1.

Reflective Evaluation Notes. A reflective evaluation form was prepared to find out the opinions of the teacher candidates about the practices. The prepared form consists of 5 open-ended questions. (*-what are your thoughts on the teaching of this course? -What do you think were the strengths and weaknesses of the course? -What was the contribution of this course in terms of science teaching to you? -How would you explain the content of this course to your friends who want to take this course next year? -what aspects of this course do you intend to use when you become a teacher? in terms of target, content, measurement, evaluation method, and science teaching approach.)* This form was applied to thirty-eight teacher candidates at the end of the semester.

Reflective Learning Diaries. from all teacher candidates in the study group were called to keep a reflective learning diary to improve their metacognitive awareness after each lesson. Learning diaries include the experiences of teacher candidates about the knowledge, skills, and practical learning areas that were learned as a result of the practice and also the problem encountered in the practice process, and the solution suggestions. Moreover, the learning diaries include the reflective evaluations of teacher candidates to determine what they need to change, what they can do differently, and what kind of equipment and materials they need to be more successful. In addition, teacher candidates were called to write their emotions and opinions about argument-based inquiry practices. In this way, it aimed to define teacher candidates' opinions about the practices.

Implementation Process

The implementation was carried out in the *"Science Literacy"* elective course in a public university's undergraduate science education program in Ankara during the fall semester of the 2016-2017 academic years. An implementation process was prepared, including argument-based inquiry activities in which teacher candidates designed their experiments. The activities were developed and implemented by the researcher. Activity plans, including detailed process steps for each activity, were prepared. Activity plans consist of the activity's goal, concepts, principles, generalizations, and targeted skills. The weekly implementation process is presented in Table 1.

Table 1

Implementation Process of Study

Week	The Subject of the Course
1. Week	Pre-test application Introduction of the course
2. Week	Science literacy, Asking questions skills, The importance of conversation in science teaching *Activity 1:* Peanut monkey experiment. *This activity aims to reveal the research and questioning skills of teacher candidates.*
3. Week	Claims, Evidence concepts, Elements of argumentation *Activity 2:* Death of Mr. Star, Ghosted house. *With this activity, it is aimed that teacher candidates gain awareness about the concepts of a question, claim, and evidence that constitutes the general structure of the argumentation process and distinguish these concepts from each other.* *Activity 3:* Greenhouse effect. *With this activity, it is aimed that teacher candidates gain awareness about the research question, dependent, independent, control variables, and the elements of the argument (claim, evidence, justification, supportive, qualitative, rebuttal), which form the general structure of the argument-based inquiry process and distinguish these concepts from each other.*
4. Week	Introducing the report format Concept map preparation The importance of reflective daily questions
5. Week	*Activity 4:* Investigation of floating and sinking conditions of an object. *This activity was aimed at the teacher candidates to design and carry out different activities based on argument-based inquiry related to the factors affecting an object's floating and sinking conditions.*
6. Week	*Activity 5:* Investigation of gravitational forces and air resistance effect on objects. *This activity was aimed at the teacher candidates to design and carry out different activities based on the argument-based inquiry related to gravity force and air resistance.*
7. Week	*Activity 6:* Investigation of motion and friction force in the inclined plane. *This activity aimed at the teacher candidates to design and carry out different activities based on the argument-based inquiry related to the factors affecting the movement on the inclined plane and the factors affecting the friction force.*
8. Week	*Activity 7:* Investigation of invisible forces (magnetic and electrostatic). *This activity was aimed at the teacher candidates to design and implement different activities based on argument-based inquiry related to invisible forces.*
9. Week	*Activity 8:* Investigation of conductivity and insulation conditions of materials and liquid solutions. *This activity aimed at the teacher candidates to design and carry out different activities based on the argument-based inquiry related to electrical conductivity.*

10. Week	*Activity 9:* Investigation of factors affecting the brightness of the lamp. *This activity aimed at teacher candidates to design and carry out different activities based on argument-based inquiry related to the factors affecting the brightness of the lamp.*
11. Week	*Activity 10:* Investigation of heat-temperature relationship and heat transfer between materials. *This activity aimed at teacher candidates to design and carry out different activities based on argument-based inquiry related to the heat and temperature relationship and heat transfer between substances.*
12. Week	*Activity 11:* Investigation of factors affecting evaporation and boiling. *This activity aimed at teacher candidates to design and carry out different activities based on argument-based inquiry related to the factors affecting the evaporation, boiling, and surface tension.*
13. Week	*Activity 12:* Investigation of factors affecting melting and dissolution. *This activity aimed at teacher candidates to design and carry out different activities based on argument-based inquiry related to the factors affecting melting and dissolution.*
14. Week	Post-test application

In the first week, quantitative data tools were applied as a pre-test. Teacher candidates will carry out activities by doing a group study. Therefore, the teacher candidates were divided into seven groups. An activity table was identified for each group. In addition, requested to identify own group name from each group. In the second week, activities started to be implemented. The first three activities are an introduction activity. The process of argumentation and inquiry was introduced to teacher candidates through introduction activities. Starting from Activity 4, main activities, including argument-based inquiry practices, were carried out. The primary teaching-learning approach of activities is the integration of argumentation and the open inquiry process. The researcher developed this process due to synthesizing various models in the literature. The main activities process comprises three stages. In the first stage, big group discussion reveals knowledge through reasoning; The second stage, small group discussion, takes place to design argument-based inquiry activities; The third stage, each group shares the results. Big group discussion takes place to decide the accuracy of the results. The stages of the argument-based inquiry teaching model are presented in Figure 2.

Figure 2

Stages of Argument-Based Inquiry Teaching Model

The first stage is aimed to be able to understand the environment of teacher candidates. To create a sense of curiosity, ask open-ended questions rather than questions with one correct answer to teacher candidates. Thus, it was provided that teacher candidates realized what they were true about the subject, false about the subject, or what they wanted to learn about it. In the second stage, the teacher candidates are aimed to design and conduct experiments. Teacher candidates are expected to reason based on experimental data and make inferences from experimental data. In stage 2, teacher candidates designed and carried out their experiments and wrote experiment reports. Teacher candidates were guided by asking questions. In Stage 2, teacher candidates used the activity report format of nine sections prepared by the researcher. The activity report format was created by synthesizing the *"Science Writing Heuristic"* developed by Keys et al. (1999) and *"The Inquiry-Based Learning Cycle*" developed by Pedaste et al. (2015). Activity reports prepared by teacher candidates during the activities were collected every week. The researcher gave feedback by reading the reports of the teacher candidates every week. The reports were redistributed to teacher candidates the following week. Thus, the weekly development of teacher candidates was followed. In the third stage, it is aimed that teacher candidates share and explain the experimental results using scientific terminology. Each group presented their experimental results and compared the similarities and differences of the experimental results with the other groups. In stage 3, it was ensured that the teacher candidates could explain their thoughts with their reasons, express their unclear explanations, produce different explanations, and question the explanations' accuracy. In these processes, no evaluation was made about the answers of the teacher candidates correctly or incorrectly. All activities between the fifth and thirteenth weeks were carried out similarly. Activity 12 teacher's guide is presented in appendix II as an example. At the end of the practice, quantitative data collections were reapplied as a post-test.

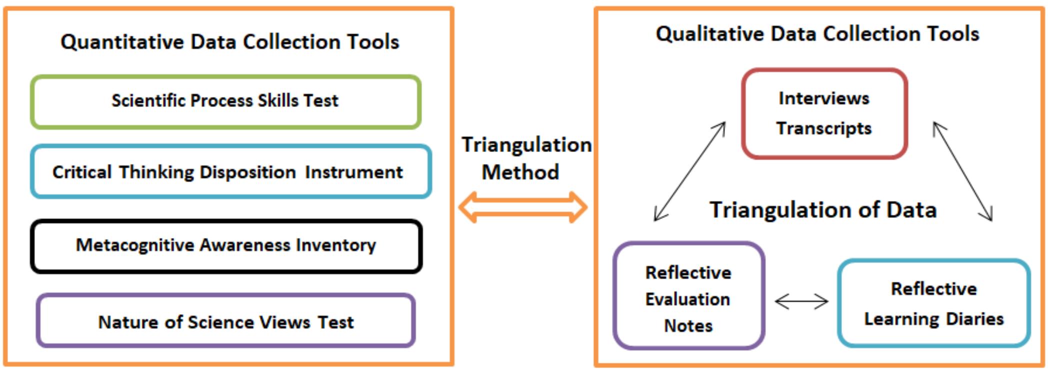
Data Analysis

Quantitative data were analyzed by using SPSS 22 Statistical Program. It is recommended to use the paired samples t-test to discover whether the mean grades of the relationship measurement sets differ significantly (Büyüköztürk, 2015). However, some assumptions must be met to implement for paired samples t-test. For this reason, firstly, kurtosis and skewness coefficients were examined to discover whether the data showed normal distribution. Then, it was examined by the normality test. It was determined that the data were distributed normally. Paired samples t-test was used from parametric tests.

The descriptive analysis method was used to analyze the qualitative data (Yıldırım & Şimşek, 2008). The qualitative data obtained were analyzed and interpreted according to the quantitative themes (scientific process skills, higher-order thinking skills, and the views of the nature of science). Direct quotations were presented to reflect the views of teacher candidates.

Figure 3

Confirmation of Data



Even if qualitative and quantitative findings were collected and analyzed separately, the findings and results section was compared by combining them by the research design, and to what extent they supported each other were discussed. The data collection tools, data collection phase, and data analysis methods used in the sub-problems of the research are presented in Table 2.

Table 2

Data Collection Tools, Data Collection Phase, and Data Analysis Methods

Sub-Problems	Data Collection Tools	Data Collection Phase	Data Analysis Method
First Sub Problem Related to *scientific process skills*	Scientific Process Skills Test	Pretest-Posttest	Paired Samples T-Test
	Semi-Structured Interview Form Reflective Learning Diaries Reflective Evaluation Notes	After Practices Practices Process	Descriptive Analysis
Second Sub Problem Related to *higher-order thinking skills, critical thinking, metacognitive awareness*	Critical Thinking Disposition Instrument Metacognitive Awareness Inventory	Pretest-Posttest	Paired Samples T-Test
	Semi-Structured Interview Form, Reflective Learning Diaries Reflective Evaluation Notes	After Practices Practices Process	Descriptive Analysis
The Third Sub Problem Related to *views of the nature of science*	Nature of Science Views Test	Pretest-Posttest	Paired Samples T-Test
	Semi-Structured Interview Form, Reflective Learning Diaries Reflective Evaluation Notes	After Practices Practices Process	Descriptive Analysis

Validity, Reliability, and Ethics

The fact that the research does not pose an ethical problem has been confirmed by the ethics committee report issued 1413 and dated 08.06.2016 received from the Human Research Ethics Committee of Hacettepe University.

Before starting the implementation, the teacher candidates were informed about the research. The teacher candidates participated in the pre-posttest based on entirely voluntary. Similarly, voluntary teacher candidates were interviewed. The names of teacher candidates were reported using codes by ethical rules.

Quantitative data collection tools are measurement tools conducted previously for validity and reliability studies. However, reliability studies were re-conducted within the scope of the research. There are 13 weeks between pre-test and post-test applications. Considering the length of the implementation, it can be interpreted that the test grades of individuals are not increased with maturation threat. The researcher took courses and practiced argumentation and inquiry-based learning before the application.

Direct quotations are included in the findings section to ensure external validity in the qualitative aspect of the research. To ensure internal validity, qualitative data collected were analyzed by another expert except the researcher. Huberman and Miles's (2002) [Consensus/(Consensus+Disagreement)x100] formula was used to calculate inter-experts compliance. This value was calculated as 87%.

In the study, both quantitative and qualitative methods are recommended to enrich the study data and provide reliability-validity (Lincoln & Guba, 1985). Fraser and Tobin (1992) indicate that "*the use of quantitative and qualitative data in the study increases the data richness and the level of reliability of the results obtained in these studies is much higher"* (p. 33). In this study, which was conducted as a mixed method, the study's internal validity was strengthened with the triangulation of quantitative and qualitative methods. Using the triangulation method, the findings obtained from the quantitative and qualitative data collection instruments were integrated, compared, and connected. Thus, the findings were made rich and more detailed. Direct quotations are presented in the findings section to provide external validity to qualitative findings.

Results

First Sub-Problem Results

The first dependent variable examined in the study is scientific process skills. The averages of the pre-post scientific process skills scores were compared using paired samples t-test. The findings are presented in Table 3, along with descriptive statistics.

Table 3

T-Test Results of Scientific Process Skills Test Pre-Post Test

Test and Sub-Dimensions		*N*	*x*	*S*	*sd*	*t*	*p*
Scientific Process Skills Test	Pre-test	33	66	11.90	32	-10.282	.000*
	Post-test	33	87	7.69			
Identifying Variables	Pre-test	33	54	19.98	32	-9.784	.000*
	Post-test	33	88	15.99			
Identifying Hypotheses	Pre-test	33	72	13.91	32	-6.060	.000*
	Post-test	33	87	10.80			
Operationally Defining	Pre-test	33	61	21.10	32	-3.689	.001*
	Post-test	33	77	14.32			
Investigations Designing	Pre-test	33	81	22.19	32	-1.647	.109
	Post-test	33	89	18.00			
Graphing and Interpreting Data	Pre-test	33	79	18.62	32	-4.055	.000*
	Post-test	33	93	9.26			

*$p<.05$

The mean score before the practice of scientific process skills was 66 out of 100, and it increased to 87 points after the implementation. Table 4 shows a statistically significant difference between pre-test and post-test mean scores, $t(32)=-10.282$ $p<.05$. This result shows that the argument-based inquiry teaching practices for 14 weeks had a statistically significant influence on the improvement of the scientific process skills levels of the teacher candidates. When the sub-dimensions of scientific process skills were examined at the end of the practices, it was seen that identifying variables, identifying hypotheses, operationally defining, graphing, and interpreting data of teacher candidates' post-test scores were significantly higher than pre-test scores ($p<.05$). When the pre-test and post-test mean scores of the dimension of investigations designing were examined, it was determined to increase, but there was no statistical significance ($p>.05$).

The data collected with qualitative data collection tools were analyzed using the descriptive analysis method. The triangulation method aims to connect the results obtained by qualitative and quantitative methods. In this way, the results are compared and validated. The codes and frequencies obtained from the interviews within the scientific process skills theme are presented in Table 4.

Table 4

Codes and Frequencies Obtained from Interviews on Developing Scientific Process Skills

Theme	Code	*f*
Scientific Process Skills	Designing and conducting experiments	12
	Identifying research questions	4
	Identifying hypothesis	2
	Identifying variables	7
	Determination of test materials	5
	Create an experiment set up	4
	Observation	3
	Using measurement and measurement units	1
	Data collection and recording	3
	Drawing tables and graphics	12
	Data interpretation and inference conclusion	7
	Report experiment results	4

During the interview, the teacher candidates suggested that the second stage of the course practices improved their scientific process skills. The teacher candidates stated that they had developed the skills of designing experiments, determining and controlling the variables, drawing tables and graphing, and writing reports. For example, a teacher candidate made his assessment as follows: *"At first, I was not very dominant in making research questions and determining variables. Something was going on in my mind, but it was hard to write and present in a way everyone could understand. I developed these skills. I am better at drawing graphics. For example, I was not exactly dominant in the claim, evidence, and hypothesis. I learned these. I know* *what they are."* Another teacher candidate expressed the development of scientific process skills in this process: *"My skills in making observations have evolved. I think that interpreting and designing experiments have shown great improvement. We did our experiments ourselves. I've never been in the process of experimenting so much before. Now I can design an experiment on any subject."* After the practice, it is seen that the teacher candidates are more confident about designing and conducting an experiment.

Data triangulation was performed to support the qualitative data obtained from the interviews. For triangulation, quotations were made from evaluation notes and learning diaries.

The reflective evaluation notes of teacher candidates revealed explanations about the development of scientific process skills. For example, a teacher candidate's reflection is as follows. *"For example, we learned dependent, independent, and control variables. It was the most confusing topic."* It shows that this process has developed scientific process skills. Another of the teacher candidates made the following explanations regarding the development of scientific process skills in the reflective learning diary. In the first weeks, *"I started to produce more questions on a subject. I am on my way to producing different solutions for questions. This shows that my scientific process skills have improved*." In the middle of the implementation, "*It has been a great pleasure for me to experiment. When I became a teacher, I decided to apply what I learned."* At the end of the process, *"I can say that my scientific process skills are greatly improved and will make great contributions to me in the future."*

In the learning diaries of the teacher candidates, some findings were found that scientific process skills improved. For instance, a teacher candidate stated an improved ability to design experiments in the learning diary. *"Through this course, I have learned to design experiments to embody the concepts easily."* Another teacher candidate stated that he/she learned the dependent and independent variables. This indicates that he/she has learned to identify the variables.

The qualitative and quantitative findings support each other. Consequently, it can be determined that the scientific process skills of teacher candidates are improving as a result of the argument-based inquiry activities.

Second Sub-Problem Results

The second dependent variable examined in the study is the higher-order thinking skills. The first variable examined within higher-order thinking skills is critical thinking tendencies. The averages of pre-post-test the critical thinking dispositions levels were compared using paired samples t-test. The findings are presented in Table 5, along with descriptive statistics.

Tablo 5

T-Test Results of UF/EMI Critical Thinking Disposition Pre-Post Test

		N	*x*	*S*	*sd*	*t*	*p*
UF/EMI Critical Thinking Disposition	Pre-test	33	4.10	.32	32	-3.274	.003*
	Post-test	33	4.30	.44			
Engagement Dimension	Pre-test	35	4.03	.40	34	-3.012	.005*

	Post-test	35	4.25	.48			
Cognitive Maturity Dimension	Pre-test	38	4.25	.34	37	-2.249	.031*
	Post-test	38	4.39	.39			
Innovativeness Dimension	Pre-test	35	4.11	.32	34	-2.993	.005*
	Post-test	35	4.29	.46			

*$p < .05$

Critical thinking disposition grades of science teacher candidates show a statistically meaningful difference between pre-post implementation, $t(32)=-3.274$, $p<.05$. The mean levels of teacher candidates' critical thinking disposition before the practices were 4.10 out of 5, and it increased to 4.30 points after the practices. When the sub-dimensions of critical thinking dispositions are examined, teacher candidates' engagement, cognitive maturity, and innovativeness post-test levels were significantly higher than pre-test levels ($p<.05$). This result shows that the argument-based inquiry teaching practices for 14 weeks had a statistically significant influence on improving the critical thinking disposition levels and sub-dimensions of teacher candidates' cognitive maturity, engagement, and innovativeness.

On the other hand, the data collected with qualitative data collection instruments were analyzed using the descriptive analysis method. The triangulation method aims to connect the results obtained by qualitative and quantitative methods. In this way, the results are compared and validated. The codes and frequencies obtained from the interviews within critical thinking disposition category scope are presented in Table 6.

Table 6

Codes and Fre. Obtained from Interviews on Developing Critical Thinking Dispositions

Category	Code	*f*
Critical Thinking Dispositions	Gain a different perspective	12
	Scientific thinking	6
	Scientific inquiry	7
	Critical thinking	9
	Establishing a cause-effect relationship	2
	Presenting claim and evidence	2
	Defending an idea	2
	Rest with respect	2

The interviewed teacher candidates claimed that critical thinking skills were developed in this process. For example, a teacher candidate expressed the development of critical thinking disposition in this process: "Now I think I have learned to look at facts and *events from a different perspective. I have started to take events from a different perspective."* Another teacher candidate stated that she/he started to look at the events more critically and thought more deeply. *"My thoughts have evolved. I had a* *little more mature. My point of view has changed. I started questioning. I wonder why this? Why so? How else could it be?"* Another teacher candidate stated that he gained critical thinking skills at the end of this process. *"I started to critical looking. I think this is a huge gain for me."* The other teacher candidate stated that he listened carefully to the ideas of others even if he disagreed with them. *"One of our friends within and among the groups, I listen to it even if it is an opposite thought. I am not saying that is not right now. I listen to him/her first, I consider."* This situation shows that the teacher candidates' critical thinking skills have improved because thinking critically requires consciously evaluating their own thoughts and the thoughts of others.

Data triangulation was performed to support the qualitative data obtained from the interviews. For this purpose, quotations were made from evaluation notes and learning diaries.

In the reflective evaluation notes, teacher candidates explain developing critical thinking skills. For example, a teacher candidate reflected that this process developed critical thinking skills. "*We gained different perspectives through class discussions.*" Another teacher candidate evaluated his/her development in this process as follows. *"I feel I'm quite improving critical thinking."*

In the learning diaries of the teacher candidates, some findings were found that critical thinking skills improved. For example, a teacher candidate has expressed critical thinking in the process of practice. *"At the end of this activity, I think we use our skills such as persistent learning, curiosity, teamwork, creative thinking, critical thinking, and effective communication."*

The qualitative and quantitative findings support each other. Consequently, it can be said that teacher candidates' critical thinking dispositions are improving due to the argument-based inquiry activities.

Another variable examined within the context of higher-order thinking skills is metacognitive awareness. The averages of the metacognitive awareness levels pre-posttest were compared using a paired samples t-test. The findings are shown in Table 7, along with descriptive statistics.

Tablo 7

T-Test Results of Metacognitive Awareness Pre-Post Test

		N	*x*	*S*	*sd*	*t*	*p*
Metacognitive Awareness Inventory	Pre-test	31	3.75	.37	30	-2.327	.027*
	Post-test	31	3.95	.49			
Structure of Cognition	Pre-test	33	3.88	.44	32	-2.605	.014*
	Post-test	33	4.06	.46			
Regulation of Knowledge	Pre-test	35	3.71	.36	34	-2.202	.035*
	Post-test	35	3.88	.51			

*$p < .05$

The mean levels of teacher candidates' metacognitive awareness levels before the practices were 3.75 out of 5, and it increased to 3.95 points after the practices.

Metacognitive awareness levels of teacher candidates were significantly improved after argument-based inquiry teaching practices, $t(30)=-2.327$ $p=.027$. When the sub-dimensions of metacognitive awareness are examined, science teacher candidates' structure of cognition and regulation of knowledge post-test levels were higher than pre-test levels ($p<.05$). This result shows that the argument-based inquiry activities for 14 weeks had a statistically significant influence on improving the teacher candidates' metacognitive awareness levels and sub-dimensions (structure of cognition and regulation of knowledge). It can be interpreted that teacher candidates have a high grade of metacognition awareness after the implementation.

On the other hand, the data collected with qualitative data collection tools were analyzed using the descriptive analysis method. The triangulation method aims to connect the results obtained by qualitative and quantitative methods. In this way, the results are compared and validated. Codes and frequencies obtained from qualitative data within the metacognition awareness category are presented in Table 8.

Table 8

Codes and Frequencies Obtained from Interviews on Developing Metacognition Awareness

Category	Code	*f*
Metacognition Awareness	Learning to inquiry	2
	Learning to scientific research	7
	Learning scientific discussion	5
	Learning way to obtain knowledge	1
	Learning to teach	2
	Learning to learn	6
	Recognizing and correcting misconceptions	7
	Understanding and interpreting the world	2

During the interviews, teacher candidates explained the promotion of cognitive knowledge and regulation of knowledge. Teacher candidates stated that they realized what they knew, they had the misconceptions, and learned how they could use the knowledge and skills they learn when they are teachers. For example, teacher candidates explained the awareness that she/he has experienced in the first stage of the lesson as follows. *"We lost our ability to ask questions over time. I realized how little I was asking questions as a teacher. Thanks to you, I realized how little less critical I was thinking. Why is that? I noticed that I did not question."* It is seen that another teacher candidate makes the structure of cognition and regulation of knowledge while explaining his/her views about the second stage of the lesson. *"How can I ask children what is coming from? In fact, I saw exactly how I could teach the student. I learned how to ask students questions."* While other a teacher candidate expressed his/her thoughts about the third stage of the lesson, it is seen that he/she makes debugging for the regulation of knowledge *"Friends like this. Friends disagree with us. We discussed why this is the case."* According to the qualitative findings obtained from the interviews, it was determined that the practices carried out in all three stages impacted the metacognition awareness of teacher candidates. In addition to the teacher candidates, the following question was asked during the interviews. "*How do you evaluate your progress in this process by considering your situation before and after the implementation?"* With this question, it is ensured that teacher candidates evaluate themselves. This situation contributes to the development of metacognitive awareness. For example, a teacher candidate's statement in the following figure indicates that he/she will need what to do when he/she becomes a teacher. This shows that she/he could make the planning and planning of cognition. *"I am taking notes in class. This is to be done, this is to be done in this way. I think that this course improves me in terms of teacher."* Another teacher indicates that he/she evaluates cognition with his/her expression as follows. *"I am looking at my first report, for example, I see that there are really missing things. I cannot draw graphics. I could not determine my variables correctly. My research question is not appropriate. I think I have developed these slowly in my progressive activities reports."* Another teacher candidate can be said to be more confident about what he/she knows or does not know. *"Now, I can express my ideas clearly."* It is seen that another teacher candidate explains the usefulness of open-ended experiments and makes situational analysis in the knowledge dimension of cognition. "*In closed-ended experiments, people work until they find the truth. It does not matter what you found your own. We have found the truth, or it is over. That experiment is finished. You did the research. What was its result? You did this. You have to share the results. You should go on top of it, but we did not have it. This is the result, everyone found it, so I have to find it. But now I am trying to find my own. We have presented what our result is.*"

Data triangulation was performed to support the qualitative data obtained from the interviews. For triangulation, quotations were made from evaluation notes and learning diaries.

The reflective evaluation notes of teacher candidates revealed explanations about the development of metacognitive awareness. For instance, *"I learned excellent information and experiments that I could use in my professional life. The aim was to learn and apply the argumentation process rather than experiments. I think I learned this process well and that practice in this course."* It is seen that the teacher candidate evaluates how well he understood something.

In the learning diaries of the teacher candidates, some findings were found that metacognitive awareness improved. Such as *"Now, when I encounter a problem, I think as a solution-oriented. I am trying different solutions to solve the problem."* It is seen that the teacher candidate explains how he used his knowledge and skills in his daily life. This situation can be interpreted as the teacher candidate managing and monitoring the information in the regulation of knowledge. It can be interpreted that the learning diaries serve the development of metacognitive awareness because the teacher candidates are summarizing what they have learned on that day and directing them to assess the dimension of cognition.

The qualitative and quantitative findings support each other. Consequently, it can be interpreted that science teacher candidates' metacognitive awareness is improving due to the argument-based inquiry activities.

Third Sub-Problem Results

The third dependent variable examined in the study is the views of the nature of science. The averages of pre-posttest the BILTEST scores were compared using by paired samples t-test. The findings were presented in Table 9, along with descriptive statistics.

Table 9

T-Test Results of BILTEST Pre-Post Test

		N	*x*	*S*	*sd*	*t*	*p*
BİLTEST	Pre-test	37	81	12.39	36	2.089	.044*
	Post-test	37	85	8.79			

**p<.05*

BILTEST score of the teacher candidates was 81 out of 100 points and increased to 85 points after the practices. Table 7 shows a statistically significant difference between pre-test and post-test mean scores, $t(36)=-2.089$ $p<.05$. This result shows that the argument-based inquiry teaching activities had a statistically profound influence on improving the nature of science scores of the teacher candidates.

On the other hand, the data collected with qualitative data collection tools were analyzed using the descriptive analysis method. The triangulation method aims to connect the results obtained by qualitative and quantitative methods. In this way, the results are compared and validated. The codes and frequencies obtained from the interviews within the scope of the views of the nature of science theme are presented in Table 10.

Table 10

Codes and Frequencies Obtained from Interviews on Developing the Views of the Nature of Science

Theme	Code	*f*
Views of Nature of Science	Doing scientific research	12
	Learning by experiencing the scientific process	6
	Scientific thinking and questioning	7
	Understanding the changing nature of scientific knowledge	4
	Development of imagination and creativity	3

During the interviews, the teacher candidates stated that the practices developed an understanding of the nature of science. For example, a teacher candidate asserted that practices are an effective method for understanding the nature of science. *"I think these practices are a good way to raise individuals who are open to change, do not believe in the certainty of information, and believe that there may be different things.*" Another teacher candidate *"I thought science was unchanging. I am starting to question now. I* *wonder if that is true. Do you have proof? We are now that size. This information is correct in advance, it is ok to say yes, but now we are starting to question. We can even try to continue through that person's idea. For example, we can work on that idea. "In this statement, the* teacher candidate stated that s/he has an inadequate understanding of the nature of science before the practice and after the implementation and has a more advanced understanding of the nature of science. We learned from the other teacher candidates, "How a scientist goes through a process. *We learned how the scientific process works. This was an important improvement for me.*" In this statement, the teacher candidate expressed the effect of this process on the development of views of science's nature. Another teacher candidate *"I have learned that I should be open to change. It is necessary to investigate rather than accept that information is accurate. We need to look at another source. I learned this. Then I can interpret the information."* In this statement, the teacher candidate explained the improvement of the views on the nature of science.

Data triangulation was performed to support the qualitative data obtained from the interviews. For triangulation, quotations were made from evaluation notes and learning diaries.

In the reflective evaluation notes of the teacher candidates reflective revealed explanations about the development of the views of the nature of science. Such as a teacher candidate *"Before and after the course, I understood that every information was not correct when writing the report."* In this reflection, the teacher candidate states that this process impacts the development of the view about the nature of science. *"Our imagination and creativity have evolved. It contributed to our imagination and creativity.*" Many teacher candidates have included similar reflections. It can be interpreted that argument-based inquiry practices also foster the imagination and creativity of science teacher candidates.

In the learning diaries of the teacher candidates, some findings were found about the nature of science. In addition, some findings have been found in the learning diaries of teacher candidates. For example, one of the teacher candidates said I understand that we can obtain by investigating, questioning, and deducting science. Another teacher candidate, *"The results of another group doing the same experiment with us were different from ours. This situation shows us that the margin of error can always exist; we should be cautious in our observations."* The other teacher candidate "*We have measured at least three times and averaged them to be consistent and accurate. We made inferences."* In this reflection, the teacher candidate stated that they made inferences from the experiment and observation data during the implementation process.

The qualitative and quantitative findings support each other. Consequently, it can be said that teacher candidates' views of the nature of science are improving due to the argument-based inquiry activities.

Discussion and Conclusion

The first dependent variable examined in the research is the level of scientific process skills. Due to the nature of the science course and the expectations of the era, we argue that developing scientific process skills of teacher candidates should be aware of the importance of scientific process skills. The studies conducted with science teacher candidates demonstrate that teacher candidates gaining experience using scientific process skills help candidates provide inquiry-based science education more effectively when they are teachers and help students develop scientific process skills (Eick & Reed, 2002; Windschitl, 2003). It is thought that the practices in the second stage of the argument-based inquiry teaching model will promote the scientific process skills of the teacher candidates. Because, at this stage, it is aimed that teacher candidates design and conduct experiments, reasoning based on the data obtained, making abstract inferences from the data, and reporting the experiment results. The report format used during the practices at this stage requires the use of teacher candidates' basic and integrated process skills. According to the qualitative and quantitative analysis conclusions obtained from this research, it has been revealed that the argument-based inquiry teaching practices have played a role in developing the scientific process skills of teacher candidates. According to this finding, it can be said that the argument-based inquiry teaching practices are effective in developing the scientific process skills of teacher candidates. Although, according to the quantitative findings, there is no significant difference between pre-test and post-test scores of investigation designing, the teacher candidates claim that their investigation designing skills have improved during the interviews and document analysis. With this, the report format (see appendix 3) used in the second stage of the course was designed to improve the investigation designing skills of teacher candidates. Also, qualitative data collection tools show that teacher candidates said that the practices conducted in the second stage of the course improve their scientific process skills. As a result, both quantitative and qualitative findings support each other. It has been determined that argument-based inquiry activities conducted for 14 weeks contributed to developing the scientific process skills of teacher candidates. Like this result, Demircioğlu and Uçar (2015) found that the teacher candidates' arguments and inquiry-based laboratory practices develop the science process skills. Similarly, when the related literature was examined that laboratory applications based on argumentation (Aslan, 2016), inquiry-based approach (Akben, 2015; Arı et al., 2017; Ateş, 2004; Duru et al., 2011; Kaya & Yılmaz, 2016; Şen & Vekli, 2016; Şimşek & Kabapınar, 2010) argument-driven inquiry learning approach (Dina et al., 2022), inquiry-based science writing tool (Ulu, 2011) was effective in promoting scientific process skills.

The second dependent variable examined in the research is the level of higher-order thinking skills. Higher-order thinking skills were examined in the context of teacher candidates' critical thinking dispositions and metacognitive awareness levels. With the fourth industrial revolution, the importance of educating individuals with 21st-century skills that can keep up with the changing era is increasing. Considering the demands of the era, a teaching environment was provided where teacher candidates could gain the skills to develop higher-order thinking skills for future students. The practices of all course stages could contribute to the development of critical thinking skills and metacognitive awareness skills of teacher candidates. Because of the questioning during the big group discussions (in the first and third stages) are capable of developing the teachers' critical thinking and metacognitive awareness skills. Small group discussions in the second stage also serve this purpose. According to Coll et al. (2005), group work and peer discussions are essential in improving cognitive and metacognitive thinking skills. In addition, the 'claims, evidence, rebuttals, and backing' sections in the report format used during the second stage of the course contribute to the critical thinking skills of teacher candidates. 'The initial ideas, what to research, the materials I need, backings, rebuttals, and reflections' sections in the report format have the characteristics that contribute to the development of metacognitive awareness skills of teacher candidates.

Furthermore, it is thought that teacher candidates' reflective learning diary writing contributes to developing metacognitive skills. In his study, Martin-Kniep (2000) emphasized that candidate teachers improve metacognitive thinking skills while answering reflective questions. Reflective questions activate metacognitive processes such as planning, monitoring, and evaluating the individual's learning process (Lin et al., 1999). Çavuş (2015) stated that using a science diary in science and technology courses positively affects the level of metacognitive awareness of elementary school students. Within the scope of this research, it has been determined by the quantitative and qualitative analysis results that teacher candidates developed critical thinking dispositions and metacognitive levels after the argument-based inquiry teaching practices. Similar to this result, Usta Gezer (2014) found in his doctoral study that general biology laboratory activities based on reflective inquiry had an important effect on developing the critical thinking tendencies of science teacher candidates. In this research, it can be said that the argument-based inquiry practices are effective in developing the metacognitive awareness skills of teacher candidates.

Similarly, Ulu and Bayram (2014) found that inquiry-based science writing tool usage successfully developed students' metacognitive knowledge and skills. In the scope of this research, the argument-based inquiry report format and the science writing tool have similar sections. In addition, Keys et al. (1999) found that using science writing tools in laboratory practices provided metacognitive thinking in students. Research results show that science writing-based heuristic learning approach (Şahin, 2016), inquiry-based laboratory practices (Evren, 2012), argumentation-based learning (Öztürk, 2017), critical thinking-based science education (Yıldırım, 2009), and constructivist learning practices (Aydın & Yılmaz, 2010; Kaya, 2010) are effective in developing critical thinking and metacognitive awareness skills. Qualitative findings obtained from the interview and document analysis support the quantitative findings. Qualitative findings: It has been shown that teacher candidates develop critical thinking skills such as looking at events from a different perspective, critically looking at events and questioning. In addition, it reveals that the teacher candidates realize how they can use the knowledge and skills they have learned in the future when they are teachers. As a result, the qualitative and quantitative findings obtained support each other.

The third dependent variable studied in the research is the views of the nature of science. To educate individuals in science literacy, science teacher candidates need to develop their views on the nature of scientific knowledge (AAAS, 1990; Lederman, 1992; McComas et al. 2000). The development of teacher candidates' views on the nature of science helps them to teach science more effectively (Driver et al., 1996). It is thought that the practices made in the second and third stages of the argument-based inquiry teaching model will improve the views of the nature of the science teacher candidates. Because in the second stage, science teacher candidates designed and conducted experiments. This process enables them to how the scientific process studies, how scientists work, and how scientific knowledge is learned by experience. Although this process allows teacher candidates to explore the nature of science, research shows that such practices develop a limited understanding of science (Abd-El-Khalick, 2002; Khishfe & Abd-El-Khalick, 2002; Lederman, 1992). On the other hand, Welch et al. (1981) state that those who do not have enough experience in scientific research will develop an insufficient understanding of the nature of science. In this direction, it can be said that the designing and conducting experiment process, which is the second stage of the course, have an important place when teacher candidates are not enough to develop their understanding of the nature of science but when supported with an explicit-reflective approach. In this context, argumentation-supported big group discussions were conducted in the third stage of the course. During this period, scientific information is based on evidence, different conclusions can be made by using the same data, observation and inference are different from each other, and evidence can be obtained by direct observations or indirect observations, as there is no only method used in science, these themes of the nature of science are directly emphasized. In this manner, it is aimed at teacher candidates to internalize the themes of the nature of science. Furthermore, during the big group discussions, teacher candidates may realize that it is possible to interpret the same data in different ways, that it is not always possible to obtain definitive evidence in science and can create a more realistic understanding of the nature of science (Crawford et al., 2000; Driver et al., 2000). Big group discussions can benefit teachers' perceptions of science as a process where ideas are constantly put forward, questioned, and open to development and change (Strike & Posner, 1992). In this study, to develop the views of the nature of the science of teacher candidates, the process of designing and conducting an experiment based on argument-based inquiry was supported by an explicit-reflective approach. It can be said that teacher candidates effectively develop views of the nature of science. In parallel with this result, Özgelen (2010) conducted explicit-reflective and inquiry-based laboratory practices to improve science teachers' views on the nature of science. He found that discussions and presentations, the use of research skills, and inquiry-based laboratory activities improved teacher candidates' understanding of the nature of science. At the same time, he expressed that the explicit-reflective approach is complementary to each other by inquiry-based laboratory teaching and demonstrated an effective method for improving the nature of science. Also, in many studies, the explicit-reflective approach effectively develops the views of the nature of science (Abd-El-Khalick & Lederman, 2000; Kaya et al., 2016; Khishfe & Abd-El-Khalick, 2002). Tümay and Köseoğlu (2011) indicated that argumentation-based teaching could improve the views of the nature of science. In addition, as in this study, the nature of science effectively combines the use of more than one method in teaching (Allchin et al., 2014; Ecevit et al., 2018). Qualitative findings obtained from the interview and document analysis support the quantitative findings. Qualitative findings suggest that the teacher candidates' views on the nature of science evolve. As a result, the qualitative and quantitative findings obtained support from each other. In the 14-week practices, supporting the argument-based inquiry experiment process with an explicit-reflective approach contributed to the development of teacher candidates' views on the nature of science.

Suggestions

In science teacher education, argument-based inquiry practices can contribute to the training of better equipped and competent teachers. Argument-based inquiry practices can provide science teachers with the knowledge, skills, and attitudes necessary for science and provide convenience in science teaching when they start working as teachers. Research has pointed out that argument-based inquiry practices aiming to learn science by doing, living, and thinking can make students educated by the era's requirements. To educate science-literate individuals with 21st-century skills that can keep up with the changing era, it is recommended to conduct argument-based inquiry practices in preschool, primary and secondary school student education. It is possible to provide teachers with this learning method by planning practical in-service training rather than theoretical training related to current science teachers' argument-based inquiry learning method.

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Statement of Responsibility

All authors have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this manuscript has not been and will not be submitted to or published in any other publication before its appearance in the Journal of Theoretical Science.

Conflicts of Interest

This research has no financial, commercial, legal or professional relationship with other organizations or those working with them. There is no conflict of interest that would affect the research.

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APPENDIX I

SEMI-STRUCTURED INTERVIEW FORM

1. What kind of contributions do you think the first stage (big group discussion) of the course has for you?

   Probes: *Encouraging inquiry, developing creativity, thinking, developing opinions.*

2. What kind of contributions do you think the course's second stage (designing an argumentation-based inquiry experiment) has for you?

   Probes: *Did writing your own research question and identifying the variables for this question contribute to your learning? Which skills did you develop by presenting your experiment and observation results in the form of tables and graphs?*

3. What do you think about the activity report you used during your research in the 2nd stage of the lesson?

   Probes: Which part did you find more compelling? Can you explain why? In which part are you bored? Can you explain why? What would you recommend to make this section more effective?

4. What were the benefits of preparing an activity report in the 2nd stage of the lesson?
5. What was the benefit of sharing your research results and having a big group discussion in phase 3 of the lesson?
6. Considering your situation at the beginning and after the implementation, how would you describe your development in this process?

   Probes: Permanent trace learning, developing high-level thinking skills, developing scientific process skills, developing scientific communication skills, science teaching self-efficacy belief, positive attitude towards science, motivation for science.

APPENDIX II

Activity 12: Investigation of factors affecting melting and dissolution

The purpose of the activity

This activity aims to teach candidates to design and carry out different activities based on argument-based inquiry related to melting and dissolution factors.

Concepts

Dissolution, Resolution, Solution, Solute, Solvent, Factors affecting the dissolution rate, Melting, Factors affecting the melting time

Principles and Generalizations

- Changing the temperature of the liquid affects both the solubility and the rate of dissolution.
- Increasing the temperature increases the solubility of solids and liquids.
- Increasing the temperature increases the dissolution rate.
- The solubility of gases is inversely proportional to temperature.
- Dissolving solids in water is endothermic. As the temperature increases, the solubility increases.
- Pressure changes the solubility of gases.
- The particle size of the solute affects the dissolution rate; it does not change the solubility.

Skills to be Gained

Scientific Research Skills

Basic Process Skills

- ✓ Observation
- ✓ Communication
- ✓ Estimate
- ✓ Making Comments

Integrated Process Skills

- ✓ Defining and Controlling Variables
- ✓ Identifying Hypotheses
- ✓ Investigations Designing
- ✓ Graphing and Interpreting Data
- ✓ Experimenting

Argumentation Skills

- ✓ Claim
- ✓ Evidence
- ✓ Justification/ Backing
- ✓ Rebuttal

Higher Thinking Skills

- ✓ Critical thinking skills
- ✓ Reflective thinking skills
- ✓ Inquiry thinking skills

Views of Nature of Science

- ✓ Scientific knowledge is based on empirical data.
- ✓ Observation and inference are different from each other.
- ✓ Imagination and creativity

Stages of Argumentation based Inquiry Teaching Model

Stage 1: Exploring information by questioning, big group discussion

Stage 1 is aimed at teacher candidates can understand the world. In order to create a sense of curiosity was asked open-ended questions rather than questions with one correct answer to teacher candidates. Thus, it was provided that teacher candidates realized what they were true about, false, or what they wanted to learn about the subject.

1. Some water is poured into the beaker, adding and mixed sugar. Where did the sugar go? What happened to the sugar?
2. I have 100 ml of water and 10 grams of sugar in my hand. What do you think about the total mass and volume when I throw sugar into the water? So why didn't its volume increase while its mass increased?
3. When making coffee, we use hot water and mix it. What do we expect to happen when we use cold water? What difference does temperature make? How can you explain this situation regarding the particulate nature of matter?
4. What do you think is why you do not write cold drinks on acidic drinks?
5. What are the factors affecting resolution?
6. What is dissolution? What is the solution? What are solvent and solute? What do supersaturated, saturated and unsaturated solutions mean?
7. How do you prepare a 10 percent salt solution?
8. How does an increase in concentration affect the rate of dissolution?
9. What are the factors affecting the dissolution rate?
10. What happens when we throw a piece of ice into the water?
11. What is melting? How does the structure of ice change as it melts? Is this change a chemical or physical change?
12. When the ice melts, does it increase in mass, that is, in the number of particles?
13. How does the volume of ice change when it melts? What is the reason for the decrease?
14. What is why salty pebbles are thrown on the roads after a snowfall in winter? What would happen if sugar was used instead of salt?
15. Does the shape of the ice pieces affect the melting time? So, if it does, how does it affect it?
16. Which ice cubes, cylinders or circles do you prefer to keep your coke cold for longer?
17. What are the factors affecting the melting time of ice pieces?

Using the questions given above, the opinions of the teacher candidates about the subject are revealed. In this process, a learning environment must create where teacher candidates can easily explain their thoughts, put forward different views, and explain their thoughts with their justifications. In this process, it is essential to associate the subject with daily life and to question the reasons for the occurrence of events and phenomena. Key concepts from teacher candidates can be written on the board. Key concepts from teacher candidates can be written on the board to guide them on what to research.

Stage 2: Designing argumentation-based inquiry experiment, small group discussion

In the second stage, the teacher candidates are aimed to design and conduct experiments. The teacher candidates' are expected to reason based on experimental data and make inferences from experimental data. In stage 2, the teacher candidates design and carry out their own experiments and write experiment reports. The teacher candidates are guided by asking questions. In Stage 2, the teacher candidates use the activity report format of nine sections prepared by the researcher. The report format consists of the section presented below.

1) My initial thoughts *(know, wonder, learn)*
2) What will I investigate *(my question, dependent variable, independent variable, control variables, hypothesis)*
3) Materials I need *(for safety)*
4) Designing an experiment
5) Observations and findings
6) Claims
7) Evidence
8) Backing and rebuttal *(when I compare with my friends, sources of error)*
9) Reflection *(my ideas have changed because my ideas haven't changed because what questions would you ask to research again)*

The activity report format was created by synthesizing the student template of the Science Writing Heuristic developed by Keys, Hand, Prain, and Collins (1999) and the inquiry-based learning cycle developed by Pedaste et al (2015). See appendix 3. Activity reports prepared by teacher candidates during stage 2 collect every week. The researcher gives feedback by reading the reports of the teacher candidates every week. The reports redistribute to teacher candidates the following week. Thus, weekly the experience improvement of teacher candidates follows.

At this stage, teacher candidates will design experiments to investigate the factors affecting melting and dissolution. Each group is provided to inquire about different factors and design an experiment. Teacher candidates can design experiments such as presented below.

The first group can investigate the effect of temperature on dissolution.
The second group can investigate the effect of temperature on the dissolution rate.
The third group can investigate the effect of solvent type on dissolution.
The fourth group can investigate the effect of changing the type of solute on dissolution.
The fifth group can investigate the effect of mixing on the dissolution rate.
The sixth group can investigate the effect of the contact surface of solute on the dissolution rate.
The seventh group can investigate the effect of the shape of ice pieces on the melting time.
The eighth group can investigate the effect of the poured materials on the ice pieces on the melting time.

The teacher guides the groups in determining the research questions, and in this process, She/he asks guiding questions to the teacher candidates and assists the teacher candidates in the inquiry-based activity. Each group creates the research question themselves and discusses it with their groupmates, planning how to design an experiment to test the research questions. The following tools and equipment are offered to teacher candidates. At this stage, the teacher interacts with each group and guides them where the groups need them. Teacher candidates are active group members from the beginning to the end of the activity.

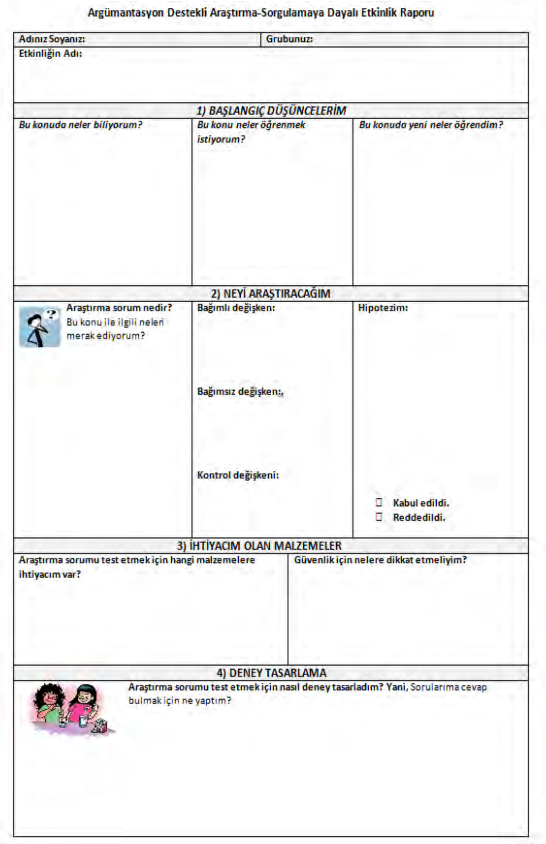
Required Tools and Materials: Hot and cold water, food coloring, ink, beaker, equal amounts of ice particles in different shapes, salt, baking powder, baking soda, powdered sugar, sugar cubes, granulated sugar, Alka-Seltzer tablets, naphthalene, vinegar, alcohol, weigher, mixer...

Stage 3: Presenting experiments, big group discussion

The third stage aims for teacher candidates to share and explain the experimental results using scientific terminology. Each group presented their experimental results and compared the similarities and differences of the experimental results with the other groups. In the third stage, it must be ensured that teacher candidates can explain their thoughts with their reasons, express their unclear explanations, produce different explanations, and question the accuracy of the explanations. There must be no evaluation of the teacher candidates' answers correctly or incorrectly in these processes.

Each group presents their experiment to the class. During the presentations, teacher candidates share their research questions, the variables they changed and controlled, what they claimed as a result of the experiment, and what their evidence is included. The groups' results with similar research questions are compared and discussed over their similarities and differences. Teacher candidates are guided to present the experiment's results using scientific terminology.

APPENDIX III
The Activity Report Format


Argümantasyon Destekli Araştırma-Sorgulamaya Dayalı Etkinlik Raporu

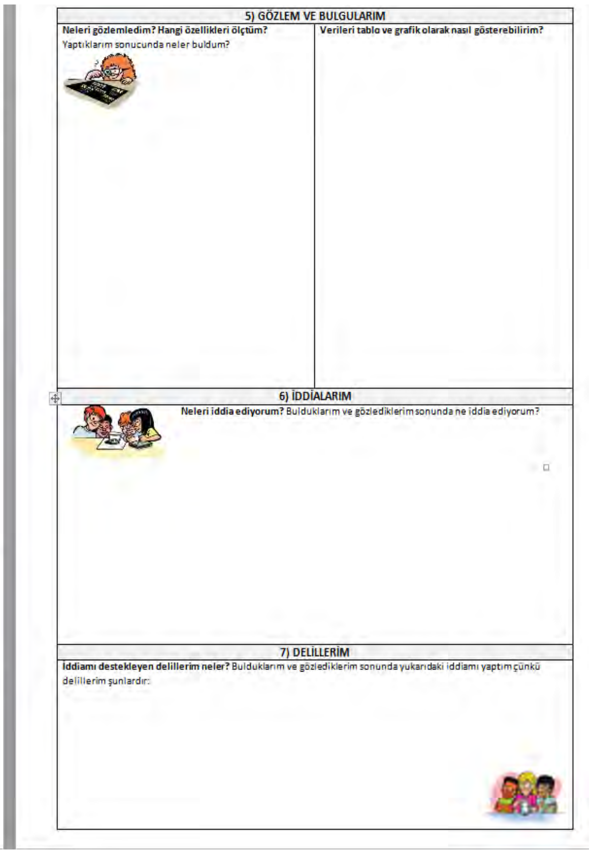
Adınız Soyanız: | Grubunuz:
Etkinliğin Adı:

1) BAŞLANGIÇ DÜŞÜNCELERİM
Bu konuda neler biliyorum? | Bu konu neler öğrenmek istiyorum? | Bu konuda yeni neler öğrendim?

2) NEYİ ARAŞTIRACAĞIM
Araştırma sorum nedir? Bu konu ile ilgili neleri merak ediyorum?
Bağımlı değişken:
Bağımsız değişken:
Kontrol değişkeni:
Hipotezim:
☐ Kabul edildi.
☐ Reddedildi.

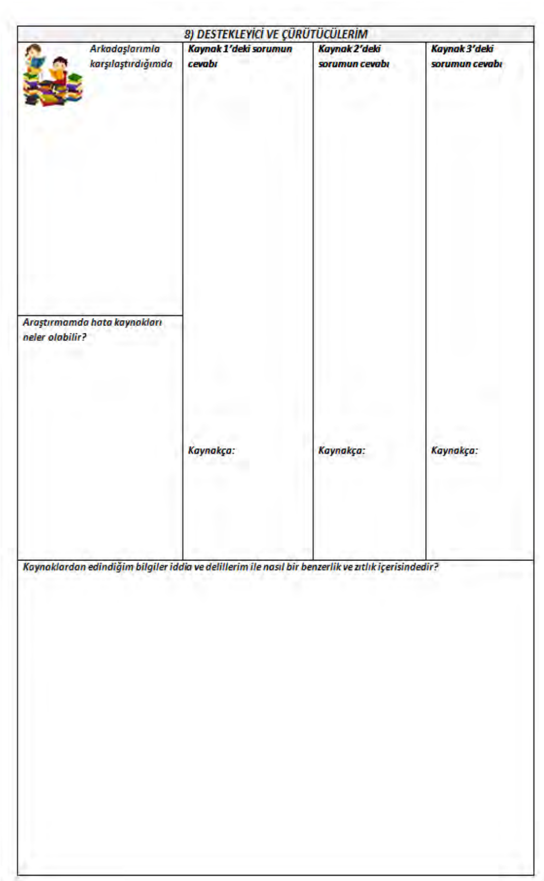
3) İHTİYACIM OLAN MALZEMELER
Araştırma sorumu test etmek için hangi malzemelere ihtiyacım var? | Güvenlik için nelere dikkat etmeliyim?

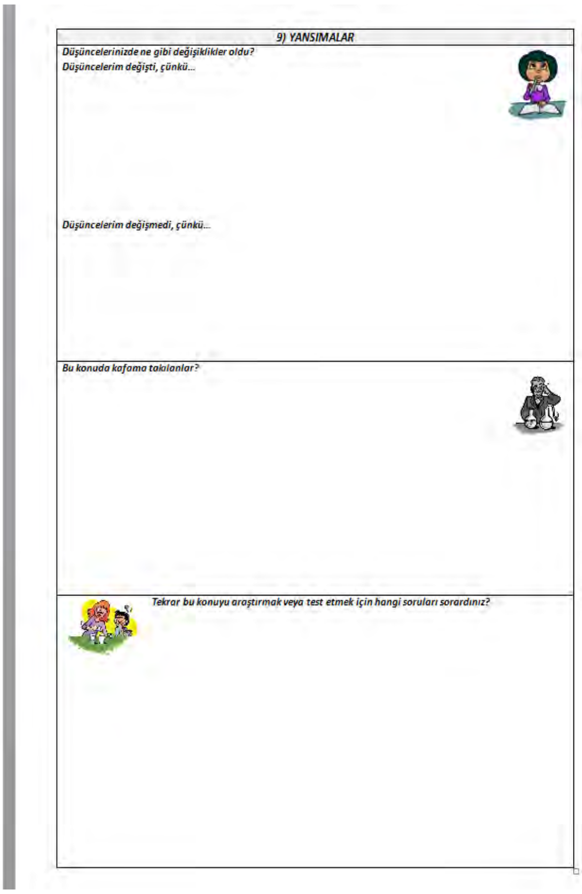
4) DENEY TASARLAMA
Araştırma sorumu test etmek için nasıl deney tasarladım? Yani, Sorularıma cevap bulmak için ne yaptım?


5) GÖZLEM VE BULGULARIM
Neleri gözlemledim? Hangi özellikleri ölçtüm? Yaptıklarım sonucunda neler buldum? | Verileri tablo ve grafik olarak nasıl gösterebilirim?

6) İDDİALARIM
Neleri iddia ediyorum? Bulduklarım ve gözlediklerim sonunda ne iddia ediyorum?

7) DELİLLERİM
İddiamı destekleyen delillerim neler? Bulduklarım ve gözlediklerim sonunda yukarıdaki iddiamı yaptım çünkü delillerim şunlardır:


8) DESTEKLEYİCİ VE ÇÜRÜTÜCÜLERİM
Arkadaşlarımla karşılaştırdığımda | Kaynak 1'deki sorumun cevabı | Kaynak 2'deki sorumun cevabı | Kaynak 3'deki sorumun cevabı
Araştırmamda hata kaynakları neler olabilir?
Kaynakça: | Kaynakça: | Kaynakça:
Kaynaklardan edindiğim bilgiler iddia ve delillerim ile nasıl bir benzerlik ve zıtlık içerisindedir?


9) YANSIMALAR
Düşüncelerinizde ne gibi değişiklikler oldu?
Düşüncelerim değişti, çünkü…
Düşüncelerim değişmedi, çünkü…
Bu konuda kafama takılanlar?
Tekrar bu konuyu araştırmak veya test etmek için hangi soruları sorardınız?