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DEVELOPMENT OF SCIENTIFIC INQUIRY SKILLS OF SCIENCE TEACHING THROUGH ARGUMENT-FOCUSED VIRTUAL LABORATORY APPLICATIONS

Aysegul Kınık Topalsan

Abstract. *This research designed within the scope of a TUBITAK 4005 project aimed to give science teachers training on argumentation-based learning, to provide them with scientific inquiry experience, to ensure that they gain skills to develop argumentation-based experimental learning methods. Throughout the research, 100 science teachers were given a four-day (28 hours in total) training program in virtual labs that would enable them to make scientific inquiries through argumentation-based experimental activities developed in accordance with the science curriculum. The "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry-Teacher" were applied to the participants as a pre-test and post-test. Following the implementation phase, the "Assessing Argumentation-based Science Learning Activities- Scale" was applied to the participating students and teachers. In addition, semi-structured interviews were conducted with randomly selected 15 teachers and 15 students. When all the obtained data were evaluated qualitatively and quantitatively, a statistically moderate effect was determined on the teachers' post-test scores from the "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry-Teacher." Also, the participating students and teachers mostly expressed positive views in the "Assessing Argumentation-based Science Learning Activities- Scale" applied after the implementation phase.*
Keywords: *argumentation-based experimental learning methods, mixed-method, scientific inquiry, semi-structured interviews, virtual laboratory.*

Aysegul Kınık Topalsan
Istanbul Aydin University, Turkey

Introduction

The rapid change in science and technology, changing needs of individuals and society, and innovations and developments in learning-teaching theories and approaches have direct effects on the roles expected from individuals. Hence, education systems now aim to raise risk-taking, determined, communicative individuals, who can produce information, use it functionally, solve problems, think critically, empathize, and contribute to society and culture (MoNE [Ministry of National Education], 2018). The updated curriculum seeks to offer a teaching method that promotes the use of metacognitive skills and provides meaningful and permanent learning that is connected with prior learning experience and is integrated with other disciplines and everyday life in terms of values, skills, and competencies (MoNE, 2018).

In this regard, closed-ended questions and instructions that tell students about every step they should take in laboratory environments and that allows no space for autonomy seem to be insufficient to achieve the aforementioned goals (Topalsan, 2018). Science textbooks, which are designed based on the curriculum, do not contain very clear descriptions about which skills the theoretical knowledge provided in the textbooks aims at developing. Moreover, there is not much room in the textbooks for open-ended experimental environments where students can form their own questions about scientific phenomena or find answers to the questions posed by the teacher. Also, there are very few experimental activities that allow students to perform experiments. In contrast, science classes held in labs help students to understand the nature of science and learn ways to produce knowledge, ensure that they understand learning contents more easily, and improve students' reasoning and critical thinking skills by providing them with experience to use knowledge (Akdeniz et al., 1999; Hofstein & Lunetta, 2004). The active participation of students in this process improves them in many areas and increase awareness in terms of the desired skills. Setting up experiments that allow students to test their hypotheses is one of the educational requirements of our age. Creating learning environments where students are responsible for their own learning and where they can test their scientific hypotheses through empirical or theoretical evidence, interact with each

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other, and do scientific inquiry naturally lead to more effective learning outcomes. The search for such learning environments has led to the development of virtual laboratory environments that can be used as an alternative to real laboratory environments. Designing and using virtual laboratories for educational purposes is one of the computer-assisted learning methods. According to Prieto-Blázquez et al. (2009) who introduced a new definition of virtual labs by examining those given in many studies, a virtual laboratory is an interactive virtual learning environment that encompasses all technological, pedagogical, and human-specific resources adapted to the needs of students and teachers in order to carry out experiments. To make a general definition of the virtual laboratory, it is a computer technology-based interactive learning environment, where learners play an active role, that can be used in place of traditional laboratory environments and provide learners with the opportunity to conduct experiments. Virtual laboratories are very practical for pre-experiment preparation and post-experiment analysis and calculations (Gershenson et al., 2000).

Learners who get prepared for experiments in a practical way save time by using virtual laboratory environments for calculations for similar experiments. In particular, argumentation-based experimental activities allow students to conduct a large number of experiments, thereby helping them put forward their evidence and rationale more easily. In addition, students who obtain the necessary data with the help of virtual laboratories can easily prepare experiment reports (Morozov et al., 2004). Virtual laboratories increase learners' motivation by offering them the opportunity to learn from their mistakes (Subramanian, 2002). Through simulations, virtual laboratory environments also offer the opportunity to observe experiments that are impossible to observe in real life (Dalgarno, 2002). For virtual laboratory environments to be able to increase students' higher-order thinking skills, scientific skills, and scientific inquiry skills, the activity forms to be used by students should contain open-ended questions and instructions rather than closed-ended questions and instructions. In this regard, argumentation-based learning environments and scientific arguments can be useful.

Role of Argumentation in Science Education

According to relevant studies, the use of scientific arguments brings about many benefits in science teaching (Driver et al., 2000; Erduran et al., 2006; Yerrick, 2000; Zohar & Nemet, 2002). The data and information used to support hypotheses in scientific arguments allow concepts to be learned more effectively and permanently. Scientific arguments also improve students' reasoning skills as well as their ability to express their thoughts more effectively (Erduran et al., 2006). Besides, scientists combine their knowledge with data to advocate the scientific claims they put forward (Toulmin, 2003). Argumentation-based learning environments where students can communicate with each other improve students' scientific and social skills, as well as facilitate their adaptation to society. In addition, such learning environments enable students to improve their communication skills (Erduran et al., 2006; Topalsan, 2015; Ulucinar Sagir, 2008). However, scientific arguments may not directly provide students with new information. Instead, they can improve students' thinking skills and ensure that they develop new thoughts and opinions. They also enable students to further enhance their existing knowledge (Aufschnaiter et al., 2008).

Since scientific arguments allow students to use the methods used by scientists (collecting data, providing rationale, considering alternative opinions, using the inductive method), they increase students' scientific inquiry skills (Driver et al., 2000). Numerous studies have been conducted to examine the effects of scientific arguments on students' inquiry skills (Driver et al., 2000; Yerrick, 2000). These studies have found evidence that scientific arguments help students understand cause-effect relationships better, set up experiments, develop solutions to real-life situations, and develop scientific inquiry skills. In addition, the group work enabled by scientific arguments promotes collaboration among students. Also, testing and disproving ideas in scientific arguments have an impact on conceptual change. In terms of conceptual change, the scientific argument method is also closely related to revealing students' ideas and eliminating mislearned conceptions (Topalsan, 2015; Ulucinar Sagir, 2008). In addition, students question alternative opinions and become aware of opposing scientific views during scientific arguments, which accelerates the conceptual change process (Niaz et al., 2002). Science education should include different scientific methods and activities, epistemological view, the history of science, contemporary scientific approaches as well as scientific concepts and principles. The role of scientific arguments in developing students' scientific skills should be considered. In conclusion, scientific arguments are important in helping students develop an insight into scientific methods (Driver et al., 2000).

Arguments also lead to cognitive outcomes in science education. From a cognitive perspective, scientific arguments involve the use of reasoning skills, and in classrooms that promote scientific arguments, students find

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a chance to express, prove, or even disprove their views about scientific phenomena. Expression of ideas enables the student to move from the internal psychological field (mind) and rhetorical discussions to the external psychological field (class) and dialogical discussions. If students believe in the advantages of arguments, they engage in quality arguments and improve both themselves and their friends; their interactions with peers enable them to develop common knowledge, values, and beliefs. Moreover, since understanding the relationship between a scientific claim and evidence means understanding the scientific claim and justification, their critical thinking skills improve, as well (Erduran et al., 2004).

Scientific arguments in science classes offer at least five important interconnected contributions (Aufschnaiter et al., 2008; Duschl & Osborne, 2002; Erduran, et al., 2006; Jimenez & Erduran, 2008; Karamustafaoglu & Yaman, 2006; Simon et al., 2006):

1. Supports cognitive and metacognitive processes,
2. Supports critical thinking,
3. Improves scientific literacy,
4. Supports scientific culture and epistemic criteria for the evaluation of knowledge,
5. Supports reasoning skills.

Table 1 summarizes the contributions mentioned above and the dimensions affected by these contributions (Jimenez & Erduran, 2008).

Table 1
Contributions of scientific arguments and the dimensions influenced by these contributions

Potential benefits of scientific arguments	Dimensions
Modeling and revealing cognitive processes.	Cognition, learners
Critical thinking.	Sociocultural dimension
Scientific literacy.	Language, social symbols
Getting familiar with scientific culture, developing epistemic criteria.	Science studies, epistemology
Improves reasoning skills	Development of philosophy and psychology

If it is desired to engage students in scientific arguments to help them develop positive attitudes towards science classes, it is necessary to create learning environments where they can exchange their views. Some of the scientific argument activities that can be used in classes are as follows (Erduran et al., 2004):

Table of Statements: Students are given a table with expressions developed with a particular subject. Students are asked to state if they agree or disagree with the statement and to state the reasons for their choices (Erduran et al., 2004).

Concept Map of Student Ideas: Students are given a concept map of expressions derived from student conceptions. All concepts and links in the concept map are examined one by one. They then decide whether these statements are scientifically correct or false. Students are asked to state the reasons for their choices (Osborne, 1997).

A Report of a Science Experiment Undertaken by Students: Students are given an experiment report. The report is deliberately prepared to contain information that is lacking. Students are to provide answers to how they think the experiment could be improved, and why (Goldsworthy et al., 2000).

Competing Theories – Cartoons: Students are presented with cartoons on two topics that contain two or more different theories. Students are asked to choose one that they believe in. Students are asked to think about why the ideas they believe are correct and discuss their correctness. This activity is an excellent stimulus to encourage students to think scientifically (Keogh & Naylor, 1999; Naylor & Keogh, 2000).

Competing Theories –Story: Students are given a story that advocates different views on a topic. There are different theories in this story. They are then asked to provide evidence for which theory they believe in and why they believe it is correct (Erduran et al., 2004).

Competing Theories –Ideas and Evidence: Students are told about two different explanations. Afterwards, some statements about or not related to these explanations are given. It is provided to discuss which of these statements they can use as evidence for the explanations or not (Solomon, 1991; Solomon et al., 1996).

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Constructing an Argument: Students are given an interpretation and a number of data statements about a physical phenomenon. They are then asked to discuss which data statements provide the strongest interpretation for the phenomenon and provide an argument why (Garratt et al., 1999).

Predicting, Observing, and Explaining: Students are given a phenomenon without demonstrating it. They are then asked to discuss this phenomenon in small groups, to think about it and to predict the outcome. The phenomenon is then demonstrated. Students are asked to compare their results with their first estimates and to reconsider and re-evaluate their initial arguments (White & Gunstone,1992).

Designing an Experiment: In order to test a hypothesis, students are expected to design one experiment by working in groups. In this approach, along with the variables to be measured, the order of operations should also be known. The students come together in groups to discuss about their ideas. The purpose of this application is to discuss alternative and relative values.

Lab Report: Students are given a record of another student's experiment and their findings. The report is written in a way to intentionally include unscientific information. Students are asked to state the lacking or unscientific information in the report and argue how its conclusions could be improved.

Evidence Cards: In this approach, students are introduced to two or more competing explanations about a physical phenomenon. Students are then given evidence cards that may support these explanations. Students are asked to consider the evidence cards and use them to argue for one idea or another. Students work in small groups and reach an agreement about the explanation provided to them (Osborne et al., 2004).

Discussing with Models: Students are asked to create a model about a physical phenomenon or concept. They are then asked to decide whether the models they created are scientifically correct or false. The students with different opinions about the same concept are expected to create different models and provide reasons and arguments advocating their models and disproving others' models (Osborne et al., 2004).

To be able to create argumentation-based learning environments that promote students' scientific inquiry skills, it is first necessary to provide teachers with relevant skills and have them experience the process from the first hand. Claiming that investing in teachers in Turkey is impossible due to the lack of necessary (financial) resources is a failure to see in which economic conditions countries such as South Korea and Finland have prioritized teachers since the 1970s. Teachers make a difference. Effective teaching processes depend on teachers' skills and motivation. As the World Development Report states, "many education systems do not take seriously teachers' skills and motivation" (World Bank, 2018). In order to improve the teaching and learning processes, it is necessary to improve teachers' skills and motivation and for this, three basic principles should be taken into account: Firstly, for effective teacher training, individual goals should be determined, repetitions should be made, and coaching services should be provided for teachers using specific pedagogical techniques and practices. Secondly, goals and achievements should be determined in accordance with the individual learning speeds of students and teachers should use support mechanisms, such as catch-up classes, to achieve the desired level of learning. Thirdly, tangible and intangible incentives should be used to increase teachers' motivation.

The Aims of the Research and Research Questions

The main purpose of this research was to provide science teachers with the necessary knowledge and skills through a training program to enable them to make scientific inquiries in virtual laboratory environments through argumentation-based experimental activities, to ensure that they can develop argumentation-based experimental activities and apply them together with their students in virtual laboratory environments, and to help them raise awareness in their students about the importance of scientific arguments. Throughout the research, the participating science teachers were provided with knowledge and skills about argumentation-based learning environments and about how to conduct scientific inquiries. Thus, teachers were given the opportunity to experience from the first-hand how scientific claims are tested and evaluated with empirical or theoretical evidence in scientific arguments. It was also aimed to provide them with the necessary skills and knowledge about how to have scientific arguments and apply scientific principles in their classes. It was also aimed to provide them with the necessary skills and knowledge about how to have scientific arguments and apply scientific principles in their classes.

Following the implementation phase, answers to the following research questions were sought:

1. To what extent have the participating teachers' views about virtual labs changed?
2. To what extent have the participating teachers' views about the principles of scientific research changed after argumentation-based virtual laboratory activities?

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3. What do the participating teachers and students think about argumentation-based virtual laboratory activities?
4. How do the participating teachers and student evaluate argumentation-based science learning activities?

Research Focus

The current research is important in that it aimed to give science teachers training on argumentation-based learning, to provide them with scientific inquiry experience, to ensure that they gain skills to develop argumentation-based experimental learning activities that they can apply in their classes and use in virtual laboratories with their students without any time and learning material restrictions, and to help them develop their students' scientific skills with a self-paced learning approach with the help of scientific arguments and social interaction so that they can become scientifically literate individuals and develop positive attitudes towards science classes.

Research Methodology

General Background

This research was mixed-method research that involved collecting, analyzing, and integrating both quantitative and qualitative data. The research did not include experimental and control groups; instead, a pre-test and a post-test were applied to the study group. As a pre-test and post-test, the "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry- Teacher" scale were applied to the participants. In this research design, no change is made on the measurement tools applied as a pre-test and a post-test and they are applied to the same sample group (Buyukozturk et al., 2008).

Following the implementation phase, the "Assessing Argumentation-based Science Learning Activities- Scale" was applied to the participating students and teachers. Also, semi-structured interviews were conducted with randomly selected 15 teachers and students who were included in the study. The main purpose of using the interview technique is usually not to test a hypothesis, but on the contrary, to understand the experiences of other people and how they make sense of these experiences. Therefore, the focus is on other people's explanations, descriptions, and thoughts (Seidman, 2006). With the interview technique, the researcher tries to enter the inner world of the interviewed person and to understand the studied phenomenon or concept from his/her perspective (Patton, 1987).

Participants

The research group consisted of 100 volunteered science teachers working in secondary schools affiliated to the Ministry of National Education in Istanbul, Erzurum, Adana, and Izmir. 25 science teachers from each city were included in the research. Only science teachers were preferred as the participants, as all the contents developed within the scope of the research includes science concepts. Teachers who wanted to participate in the research submitted their applications by clicking a link on the web page created for the project. The link redirected the applicants to a Google form. The form included questions aimed at finding out about demographic information of the participants, why they wanted to participate in the research, and whether they had ever used a virtual lab with their students. Then, the applicants' answers were examined, priority was given to disadvantaged districts and schools of the cities included in the project, lists of original and substitute participants were created for all cities, and study groups were identified. Participation in the research was voluntary. The teachers and the students were informed about the data to be collected, the goal of the collection, and the mode of processing, according to the TUBITAK project ethical standards. The participants were informed that they might renounce their participation in the study at any stage. The training was delivered in the form of a 4-day-long workshop, including 28 hours of classes.

Following the training program, the participating teachers used their experience and knowledge in their classes, as a result of which a total of 1240 students were indirectly included in the research. Views of all students participating in the process were also included in the research. Table 2 shows some basic information about the participating teachers, students, and cities.

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Table 2
Participating teachers, students, and cities

	City	Science Teachers		Number of participating students in each city
		Female	Male	
Participants	Erzurum/Turkey	13	12	280
	Adana/Turkey	10	15	320
	Istanbul/Turkey	19	6	400
	Izmir/Turkey	18	7	240

Ethical Considerations

In this study, all the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed.

Ethics Committee Permit Information

Ethical Evaluation Board Name: Istanbul Aydın University Social Sciences Ethics Commission Decision

Date of Ethical Assessment Decision: 10.01.2017

Ethics Assessment Document Number: 2018/02

Data Collection Tools and Procedures

100 science teachers participating in the research were provided with a training program delivered in the form of a 4-day-long workshop, including 28 hours of classes. On Day 1, applied practices were held on models and principles of scientific argument. Also, information was given on the basic principles of scientific argumentation and the strategies and materials developed by Erduran et al. (2004), who studied Toulmin's model of argument. In addition, sample activities on how to use scientific arguments in the classroom environment were shown. The flow of Day 1 was as follows:

- The "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry- Teacher" were applied to the participants as a pre-test.
- A presentation was made about the basic principles of the argumentation method.
- Different scientific arguments were shown and held.
- The following strategies and sample materials that would help teachers easily apply scientific arguments in the classroom were examined.
    - Table of Statements
    - Competing Theories –Story
    - Evidence Cards
    - Concept Map of Student Ideas
    - A Report of a Science Experiment Undertaken by Students
    - Competing Theories – Cartoons
    - Competing Theories – Ideas and Evidence
    - Constructing an Argument
    - Predicting, Observing, and Explaining
    - Discussing with Models

On Day 2, the participants were informed about virtual laboratory environments and the scientific argumentation method. Throughout the training program, interactive activities and scientific arguments were held with science teachers in argumentation-based virtual laboratory environments. The flow of Day 2 was as follows:

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- Teachers applied argumentation-based virtual laboratory activities developed in accordance with the achievements of the science curriculum.
- Teachers first applied argumentation-based activities developed for different learning areas and then tried to design different arguments for the same study.

On Day 3, teachers developed arguments suitable for virtual environments in three different pre-determined strategies and prepared materials for the implementation of these arguments in the classroom environment. The flow of Day 3 was as follows:

- Teachers were given further information about three of the argument strategies to ensure that they can use scientific arguments easily in the classroom environment.
- In accordance with the given strategies, activities were designed in virtual laboratory environments (Phet and E-Chalk).
- Necessary revisions were made so that the activities designed by the teachers could be easily applied in the classroom environment.
- Teachers then prepared materials for the selected study and applied it in a classroom environment.

On Day 4, the implementation of the developed arguments continued. The flow of Day 4 was as follows:

- Groups of participants presented the scientific arguments they had developed.
- The arguments were evaluated with the participation of all participants according to the achievements of the science curriculum, the skills desired to be gained by students, and the implementation of the chosen strategy.
- Then, the "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry- Teacher" scale were applied to the participants as a post-test.

The data collection tools used as a pre-test and a post-test were as follows:

Opinion Scale for the Virtual Lab: At the beginning and the end of the research, the "Opinion Scale for the Virtual Lab" developed by Ekici (2015) was applied as a pre-test and a post-test. The scale consisted of 36 items. The reliability of the scale was calculated as .762.

Principles of Scientific Inquiry- Teacher: At the beginning of the research, the "Principles of Scientific Inquiry- Teacher" scale was applied to the teachers. The same scale was also applied as a post-test once the teachers applied in their classrooms the scientific arguments, they developed during the training program. The scale was developed by Campell et all. and published in the Journal of Science Teacher Education in 2010. The Principles of Scientific Inquiry-Teacher scale was developed to examine in detail teachers' views on the activities that enable students to engage in scientific research in science classes. The scale was developed based on five basic principles identified by National Research Council (2005). The correlation coefficient of the scale was calculated as .88.

The research proceeded with the participating teachers applying in their own classes the argumentation-based virtual laboratory activities they developed during the training program. Thus, a total of 1240 students indirectly participated in the research. Following the implementation phase, the "Assessing Argumentation-based Science Learning Activities- Scale" was applied to the participating students and teachers. In addition, semi-structured interviews were conducted with randomly selected 15 teachers and 15 students.

Assessing Argumentation-based Science Learning Activities- Scale: At the end of the research, the "Assessing Argumentation-based Science Learning Activities- Scale," developed by Cigdem (2010), was applied as a post-test to the teachers and students. The instrument consists of 20 three-point items ("No," "Sometimes," "Yes"). These questions are aimed at learning the views of teachers and students about argumentation-based science learning. The questions also aim to find out about the learning outcome provided by learning environments based on argumentation-based science learning approach, the challenges encountered during the implementation phase, and whether they think it is appropriate to use the argumentation-based science learning approach in other lab classes. The correlation coefficient of the scale was calculated as .922.

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Data Analysis

Wilcoxon Signed Ranks Test was used to determine whether there was a statistically significant difference between the teachers' pre-test and post-test scores from the "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry- Teacher" scale. First of all, it was tested whether the differences between pre-test and post-test scores were normally distributed. According to the results of the normality test, the differences were not normally distributed "$p < .05$", and since the assumption was not met, the Wilcoxon Signed Ranks Test, which is the nonparametric test equivalent to the dependent *t*-test, was used.

The participating teachers' and students' responses to the "Assessing Argumentation-based Science Learning Activities- Scale" was examined and the frequency and percentage distributions of the responses were interpreted in detail.

Within the scope of the research semi-structured interviews consisting of four questions were held with 15 randomly selected teachers following the teachers' implementation of science arguments in their classes. Then, the teachers' responses to the questions were subjected to content analysis, and as a result, themes and categories were determined. Besides, semi-structured interviews about argumentation-based virtual laboratory activities were conducted with 15 randomly selected students. The content analysis method was used to analyze the data (Yildirim & Simsek, 2005). The obtained data were encoded separately by the researcher and a faculty member experienced in qualitative research. In this way, categories were formed by merging similar codes. A total of seven themes were identified after the content analysis of students' responses. The themes were then elaborated and interpreted. In addition, in order to improve the reliability and validity of the findings, sample excerpts from the interviews were included.

Research Results

Teachers' Views about Virtual Labs

Wilcoxon Signed Ranks Test was used to determine whether there was a statistically significant difference between the teachers' pre-test and post-test scores from the "Opinion Scale for the Virtual Lab." First of all, it was tested whether the differences between pre-test and post-test scores were normally distributed. According to the results of the normality test, the differences were not normally distributed "$p < .05$", and since the assumption was not met, the Wilcoxon Signed Ranks Test, which is the nonparametric test equivalent to the dependent t-test, was used. As a result of the analysis, a significant difference was found between the teachers' pre-test and post-test scores ($z = -3{,}939$; "$p < .05$", $r = .43$). Given the mean rank and sum of ranks for the difference scores, the observed difference was found to be in favor of positive ranks, or in other words, the post-test. Accordingly, it can be said that the research had a statistically significant effect on teachers' views about the virtual laboratory. When the effect size is analyzed, it can be said that the research had a moderate effect on teachers' views about the virtual laboratory.

Table 3
Results of the Wilcoxon signed ranks test of the teachers' mean pre-test and post-test scores from opinion scale for the virtual lab

Post-test - Pre-test	*n*	Mean Rank	Sum of Ranks	*z*	*p*
Negative Rank	29	37.86	1098.00	-3.939	< .0001
Positive Rank	62	49.81	3088.00		
Equal	0				

Teachers' Views about the Principles of Scientific Research

Wilcoxon Signed Ranks Test was used to determine whether there was a statistically significant difference between the teachers' pre-test and post-test scores from the "Opinion Scale for the Virtual Lab." First of all, it was tested whether the differences between pre-test and post-test scores were normally distributed. According to the

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results of the normality test, the differences were not normally distributed "$p < .05$", and since the assumption was not met, the Wilcoxon Signed Ranks Test, which is the nonparametric test equivalent to the dependent t-test, was used. As a result of the analysis, a significant difference was found between the teachers' pre-test and post-test scores (z=-4,240; "$p < .05$"). Given the mean rank and sum of ranks for the difference scores, the observed difference was found to be in favor of positive ranks, or in other words, the post-test. Accordingly, it can be said that the research had a statistically significant effect on teachers' views about the virtual laboratory. When the effect size is analyzed, it can be said that the research had a moderate effect on teachers' views about the virtual laboratory.

Table 4
Results of the Wilcoxon signed ranks test of the teachers' mean pre-test and post-test scores from the principles of scientific inquiry- teacher scale

Post-test - Pre-test	*n*	Mean Rank	Sum of Ranks	*z*	*p*
Negative Rank	20	38.72	774.00	-4.240	< .0001
Positive Rank	71	51.77	3676.00		
Equal	0				

Teachers and Students' Views about Argumentation-Based Virtual Laboratory Activities

Within the scope of the research, semi-structured interviews consisting of four questions were held with 15 randomly selected teachers following the teachers' implementation of science arguments in their classes. Then, the data from the interviews were subjected to content analysis, and as a result, themes and categories were determined.

Table 5
The most remarkable aspects of the process of argument-focused virtual laboratory applications

Themes	Codes	Number of Mentions
Quality learning environment	Better understanding	2
	Getting rid of theoretical lessons	1
	Quality content	1
	Feeling comfortable	2
	Abundant application	4
	Learning while practicing	4
	Eliminates issues that are difficult to learn in normal life	2
Responsibility for learning	Learning while searching for evidence	1
	Providing freedom	2
	Trying different ways to reach the conclusion	2
	To be like a teacher in the course	3
	Providing learning by living	3
Differences of application	Being visual	4
	Active use of the computer.	2
	Like a game	3
	Different from classical courses	3
	To be able to practice at the same time	1
	Teaching in a fun way	3
	Moving learning to a virtual environment	1
	Interesting	4

It is seen that the students summarized the process in short and effective sentences after their activities in the lesson. The views of the most remarkable aspect of the process are presented under the themes of "Differences of

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application", "Responsibility for learning" and "Quality learning environment". The argument-focused virtual laboratory applications process freed the students from the theoretical lessons and gave the responsibility to the student completely. Students stated that they learned more comfortably because the application was so interesting for students and they had the chance to do plenty of practice. Students had the opportunity to learn by living during the practice and they felt like teachers during the practices. They sought out evidence for their argument-focused work, moved away from theoretical lectures, and enjoyed the learning environment as playing games in virtual lab environments. Some excerpts from the interviews with our students are as follows:

"This applications showed me the topic in a fun way. Like we played." (S1, 10.01.2019)

"I was very comfortable in the virtual environments of the computer."(S5, 24.11.2018)

"It was very interesting to have a virtual environment. " (S3, 10.01.2019)

"It was very interesting to have a virtual environment. I learned all conceptions in this environment without being bored because I like it very much." (S3, 10.01.2019)

" Very impressive because it is visual." (S15, 10.01.2019)

"I had the opportunity to learn the topics in a shorter time while doing the virtual applications.." (S7, 24.12.2018)

"I had a lot of fun looking for evidence.." (S6, 10.12.2018)

"I felt comfortable.In the same time, I felt like a teacher guiding the course." (S13, 10.01.2019)

"We do not use such practices during our school lesson so I was very interested in." (S8, 17.11.2018)

Table 6
Contributions of argumentation-based virtual laboratory activities to students

Themes	Codes	Number of mentions
Contributions to scientific process skills	Observational learning	2
	Designing skills	2
	Being able to state reasons and justifications	1
	Being able to classify	1
	Being able to set up experiments easily	5
	Being able to reach conclusions in a short time	2
Contributions to learning	Makes learning fun	2
	Creates a competitive environment	1
	Provides more effective learning	3
	Reinforces learning	2
	Enables students to learn quickly	3
	Helps students develop a positive attitude towards science	2
	Improves students' thinking skills	2
	Applies science to everyday life	2
	Provides a fun learning environment	5
	Helps expand knowledge	2
	Makes it easier for students to remember what they have learned	2

When the contributions of the implementation phase to the students are examined, two themes come to the fore. Students' views are shown under the "Contributions to scientific process skills" and "Contributions to learning" themes. It is seen that the students mostly shared their views on the experiments they set up in the virtual lab. Thanks to the experiments that they set up in the virtual lab, they were able to reach the correct results in a shorter time through trial and error. Therefore, it can be said that such fun learning environments can help students achieve the learning outcomes specified in the curriculum in a shorter time. Also, with these fun activities, students not only developed scientific process skills but also reinforced what they had learned and developed a positive attitude towards science classes. Some excerpts from the interviews that support this finding are as follows:

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"We got good results in a short time. I have learned to develop different points of view and state the reasons and rationale for my findings." (S15, 10.01.2019)

"I found the opportunity to learn the subjects in a shorter time by doing the activities." (S7, 24.12.2018)

"I like science classes more now." (S6, 10.12.2018)

"(These activities) helped us learn to give reasons and rationale (for our scientific claims). We had the opportunity to make observations." (S13, 10.01.2019)

"I have reinforced what I have learned and made classifications with the results in the virtual lab. It was (a) very different (experience)." (S8, 17.11.2018)

"The competitive environment helps us learn the subjects better." (S14, 17.11.2018)

"(These activities) helped me like designing. I was able to set up the right experiments and had the opportunity to try many things at once." (S12, 21.12.2018)

Table 7
The challenges encountered during the implementation of argumentation-based virtual laboratory activities

Theme	Codes	Number of mentions
Challenges in implementation	Complicated menus	1
	Limited number of texts	1
	Difficulties with explaining	1
	The phase of defending the arguments	1
	Justification	1

It is seen that the students were able to perform the activities without having much difficulty. Although they were not much familiar with scientific arguments and virtual labs, most of the students had fun while learning. This is indeed the desired outcome. With such approaches to be included in curricula, faster progress and more academic achievement can be achieved in science classes. Only two of the interviewed students expressed that they had some difficulties defending and finding reasons and rationale for their arguments, which is the key feature of arguments. Another challenge stated by the students is that they found the menu of the virtual lab quite complicated. Some excerpts from the interviews with the students are as follows:

"I had a hard time advocating my arguments to my friends and convincing them to approve them. Sometimes I failed to find a reason while defending." (S15, 10.01.2019)

"I couldn't understand the menu and had difficulty using the limited texts on the menu." (S12, 21.12.2018)

Table 8
Students' feelings during argumentation-based virtual laboratory activities

Theme	Codes	Number of mentions
Feelings	Having fun	5
	Interesting	2
	Being fond of activities	4
	Making them feel like a professional	2
	Pleasure	2
	Freedom	1
	Easy	1
	Makes them feel like a scientist	2
	Makes them feel like a teacher	2
	Makes them feel like a playing kid	3
	Excitement	3
	Joy	2
	Wonderful	1

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When asked about how they felt about virtual laboratory activities, most of the students stated that they had fun. According to them, argumentation-based virtual laboratory activities were fun, interesting, and exciting activities that felt like a game to them.

"Being able to do what I couldn't previously do was very exciting." (S15, 10.01.2019)

"Excitement and joy." (S7, 24.12.2018)

"Fun and easy to learn." (S6, 10.12.2018)

"I thought our teacher left all control to us. It was more fun than traditional science classes." (S13, 10.01.2019)

"It was like playing a game. I could apply different ideas." (S8, 17.11.2018)

"I sometimes felt like a scientist and sometimes a kid playing games." (S14, 17.11.2018)

"It was a lot of fun to learn a theoretical subject in this way. I got excited." (S12, 21.12.2018)

Table 9
Some remarkable aspects of argumentation-based laboratory activities

Theme	Codes	Number of mentions
Education dimension	Students learn by exchanging information	2
	Students easily find evidence in the virtual environment	2
	Easy planning	3
	Self-paced learning	4
	Students can plan the process	2
Student dimension	Increased student participation	5
	Fun for students	4
	They find the activities exciting	3

As a result of the interviews with the teachers, the most remarkable features of argumentation-based laboratory activities were classified under two groups as "teaching dimension" and "student dimension." Under these themes, teachers expressed their opinions about the process by referring to their students and the teaching of the course. Teachers mostly underlined increased participation in classes and self-paced learning. They stated that they did not have much difficulty getting the students' attention to the activities and that they had fun teaching the lessons.

"We were able to find the evidence for our arguments in the virtual environment and we had to think about what could happen next when doing these activities." (T3, 10.01.2019)

"The students participated in activities with great joy and excitement and they were able to plan the duration of time they needed to learn the new information." (T8, 24.12.2018)

"The students were able to interact and exchange information with each other in classes." (T9, 10.12.2018)

"It is a process that increases student participation in the course. The students easily planned the process and engaged in scientific arguments." (T11, 10.01.2019)

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Table 10
Contributions of argumentation-based virtual laboratory activities to education

Theme	Codes	Number of mentions
Contributions to education	Makes the use of laboratories more meaningful	1
	Fun learning	5
	Promotes cooperation among students	2
	Improves students' academic achievement	3
	Learning by doing	4
	Makes studying theoretical subjects fun	2
	Education is more meaningful	1
	Helps students question the process of the scientific method	3
	Effective communication	2
	Promotes trial and error	3
	Applies science to everyday life	5

During the interviews, all the participating teachers gave positive feedback about virtual lab activities. The teachers' observations during the activities show that the activities generally had positive effects on the students. These activities, according to the participating teachers, promote meaningful learning rather than rote learning, giving the students an opportunity to learn by doing, relate what they have learned to everyday life, and establish cooperation and stronger communication with their friends. Some excerpts from the interviews with the teachers that support this finding are as follows:

> *"It creates a fun learning environment by minimizing the need to use a laboratory. Thanks to the collaboration between students at this stage, even students with communication problems did not have difficulty participating in the lesson." (T15, 10.01.2019)*
>
> *"We got positive feedback from the students. These activities helped students learn by doing." (T7, 24.12.2018)*
>
> *"(It is) a method that makes it easier for children to discover scientific steps." (T1, 10.12.2018)*
>
> *"That the students tried to relate their answers to everyday life and to find examples from everyday life provided more meaningful learning." (T13, 10.01.2019)*
>
> *"Thanks to these activities, I have experienced that education provides significant and meaningful contributions." (T12, 10.01.2019)*

Table 11
Contributions of argumentation-based virtual laboratory activities to students

Theme	Codes	Number of mentions
Contributions to students	Increases students' interest	3
	Ensures effective learning	5
	Cognitive flexibility	2
	Creativity	5
	"I can do it" feeling	3
	Easy to understand	5
	Easy to apply	2
	Curiosity	2

During the interviews, the teachers summarized the contributions of the activities to students with simple but effective sentences. The teachers emphasized that the activities provided more meaningful learning, which increased the students' creativity, cognitive flexibility, curiosity, and self-confidence. Some excerpts from the interviews with the teachers are as follows:

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"The most important contribution is that (these activities) increased students' interest in classes." (T1, 10.12.2018)

"Students were able to use the virtual lab to perform the experiments that they cannot usually perform on their own." (T7, 24.12.2018)

"(These activities) improved the students' cognitive flexibility, creativity, and made them say 'I can do it.'" (T9, 10.12.2018)

"The activities increased the students' curiosity and helped achieve meaningful learning. They learned because they were interested." (T12, 10.01.2019)

Table 12
Contributions of argumentation-based virtual laboratory activities to teachers

Theme	Codes	Number of mentions
Contributions to teachers	Time-saving	3
	Gives them the chance to do experiments on their own	1
	Eliminates the lack of materials	3
	Offers necessary physical settings	2
	Assists visualization	1
	Concretization of abstract concepts	2
	Positive educational climate	4
	Easy to apply	2

The most remarkable contribution of the activities to the teachers, as can be inferred from the interviews, was the positive learning environment that emerged as a result of these activities. The teachers also underlined the time-saving feature of the activities and that they were able to use the virtual lab to perform the experiments which they were not able to perform previously due to the lack of necessary materials. Some excerpts from the teachers' responses to the relevant question are as follows:

"Considering the necessary physical conditions, materials, and time for real-life experiments, argumentation-based virtual laboratory activities provided us with important advantages." (T3, 10.01.2019)

"The activities helped us concretize abstract concepts for the students. They enabled a more effective learning environment." (T12, 10.01.2019)

"(The virtual lab) helps the teacher save time by minimizing the procedures to be done before and after the laboratory work. Also, the students can have the chance to perform experiments on their own." (T6, 10.12.2018)

"We used to have difficulty motivating the students. But this activity helped us (do this). All the students tried to actively participate in classes." (T5, 10.01.2019)

Views of Teachers and Students about Argumentation-Based Science Learning Activities

Considering the participants' responses to the "Assessing Argumentation-based Science Learning Activities-Scale," it is clear that the research had positive impacts on them. Also, they mostly expressed their satisfaction with the activities performed throughout the research. This can be understood from the scarcity of "No" responses in the scale. This shows that the research achieved its goals and objectives. The percentages of responses to the key questions in the scale and the interpretation of these percentages are given in detail below.

93.33% of the teachers and 96.80% of the students who participated in the research stated that the laboratory activities based on the argumentation-based science learning approach helped them understand the subjects better. 94.44% of the teachers and 74% of the students thought that the activities increased student interest in classes. Also, 91.11% of the teachers and 69.0% of the students responded 'yes' to the question, "Have the laboratory activities based on the argumentation-based science learning approach helped you develop scientific process skills?" On the other hand, 8.88% of the teachers and 26.0% of the students responded 'sometimes' to the same question.

90% of the teachers and 54.0% of the students were of the opinion that argumentation-based science learning made it easy for the students to establish connections among research questions, stages of research, data, evidence, and claims. However, to the same question, 10% of the teachers and 36.0% of the students responded 'sometimes.'

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3.33% of the teachers responded 'no," 27.77% sometimes, and 70% yes to the question, "Have the laboratory activities based on the argumentation-based science learning approach made you feel like a scientist?". Also, 15% of the students responded 'no,' 15% 'sometimes,' and 70% 'yes' to the same question. This is a desirable result. Since the argumentation-based virtual laboratory activities place all the responsibility on the learner, it is one of the biggest achievements that a majority of the students felt like a scientist.

Besides, 90% of the teachers and 87% of the students stated that they would like to use the laboratory activities based on the argumentation-based science learning approach in other lab classes. This finding shows that teachers and students want to have more scientific arguments in their laboratory classes.

7.77% of the teachers and 31% of the students responded 'yes' to the question, "Have you had any difficulty applying the laboratory activities based on the argumentation-based science learning approach?" while 38.8% of the teachers and 33% of the students responded 'sometimes' to the same question. This result needs further consideration. In order for the concept of argumentation, which is inherent in science, to be easily applied by teachers, necessary materials should be made more available.

In addition, 80% of the teachers and 77% of the students were of the opinion that the laboratory activities based on the argumentation-based science learning approach enriched the classroom environment, while 17.77% of the teachers and 17% of the students thought that these activities 'sometimes' enriched the classroom environment. This result indicates that some of the teachers and students had difficulty adapting to the process.

The vast majority of the teachers 87.77% and students 80% think that the laboratory activities helped them develop the ability to ask the right research questions for the solution of a scientific problem.

The argumentation-based science learning approach requires teachers and students to discuss the research questions with peers at the beginning of lab classes. 94.44% of the teachers and 77% of the students thought this was helpful. On the other hand, 19% of the students thought that this was 'sometimes' helpful.

96.66% of the teachers and 84% of the students responded 'yes' to the question, "Do you think that designing different experiments according to research questions was helpful?"

Furthermore, a great majority of the teachers (90.00%) and the students (84.00%) thought that the argumentation-based science learning approach increased their motivation. Besides, 94.44% of the teachers and 87% of the students responded 'yes' to the question, "Has your active participation in all stages of laboratory activities increased your interest in the subject?"

While 80% of the teachers and 70% of the students responded 'yes' to the question, "Do you think that all the students in the classroom were actively involved in the laboratory activities based on the argumentation-based science learning approach?" 17.77% of the teachers and 21% of the students responded 'sometimes' to the same question. This result also needs further consideration.

Also, 77.7% of the teachers and 73% of the students were of the opinion that the argumentation-based science learning approach provides a collaborative learning environment, and 21.11% of the teachers and 21.0% of the students thought that this approach 'sometimes' provides a collaborative learning environment. Creating collaborative learning environments is very important in education. Collaborative learning environments arising from the right activities can enable students to improve each other.

On the other hand, the percentage of the teachers who were of the opinion that the argumentation-based science learning approach allowed them to exchange and organize information was greater than that of the students: Of the teachers, 94.44% thought that they could fully exchange information and 87.77% thought they could fully organize information. In the students, these percentages were determined as 72.00% and 70%, respectively.

94.44% of the teachers and 75% of the students responded 'yes' to the question, "Considering the argumentation-based science learning approach in general, have these activities improved your critical thinking skills?" On the other hand, 23% of the students responded 'sometimes' to the same question.

One of the most effective materials for argumentation-based virtual lab activities is the pencil. The student is expected to write what he/she has learned, the evidence he/she has found, his/her reasons, and the reasons for his/her changing thoughts. In short, in these activities, students are expected to write what they think. Of the participating teachers and students, 77.77% and 41%, respectively, were of the opinion that the argumentation-based science learning approach improved their writing skills. On the other hand, 8.88% of the teachers and 37% of the students were of the opinion that the approach did not improve their writing skills.

Finally, 91.11% of the teachers and 76% of the students responded 'yes' while 18% of the students responded 'sometimes' to the question, "Have the laboratory activities based on the argumentation-based science learning approach improved your ability to collect data and evaluate the obtained data?"

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Discussion

93.33% of the teachers and 96.80% of the students who participated in the research stated that the laboratory activities based on the argumentation-based science learning approach helped them understand the subjects better. This is quite a crucial result in terms of effective education. The rote-learning method is unfortunately sometimes used by teachers to teach scientific concepts and definitions. However, abstract concepts and subjects taught in this way are usually forgotten by students in a short time. Also, incorrect or ineffective methods and approaches used in science education cause students to develop negative attitudes towards science classes. What needs to be done is to let children have more experience with concepts and to include them in scientific processes. Scientific knowledge alone is not enough for a student to gain scientific literacy. The student needs to understand, interpret, and apply scientific knowledge (Benjamin et al., 2017; Lederman et al., 2013; Milar & Osborne, 1998; NRC, 2012; Roberts & Bybee, 2014; Tytler et al., 2008). According to the constructivist theory, well-organized argumentation-based virtual laboratory environments can provide students with the opportunity to perform experiments on their own, as well as help them develop the skills required for scientific literacy. Argument-based science inquiry can engage students in epistemic activities that closely model that of professional scientists (Erduran et al., 2004).

The US National Science Education Standards (NSES) draws attention to the need for students to improve scientific process skills such as using scientific information, critically evaluating data, making claims, and supporting and discussing evidence and arguments (NRC, 2005). These guidelines aim to ensure that students can establish meaningful connections between evidence and questions, can question the accuracy of the information, and construct scientific knowledge by using sociological processes used by scientists (Hand et al., 2007). In this context, the argumentation-based science learning approach provides student-centered collaborative learning environments based on research and inquiry, promoting self-paced and self-directed learning and students' engagement in scientific arguments, thereby improving the above-mentioned key scientific literacy skills (Hohenshell & Hand, 2006).

However, there are very few activities that allow teachers to use this method. Teachers need to master the argumentation-based science learning method so that they can easily adapt to the process and use it in their classes. Teachers who wish to use such activities in their classes should also be able to develop different activities and learning materials that serve their students' needs. It is also very important for teachers to present the materials they developed to the students in a fun way. Therefore, argumentation-based virtual laboratory activities serve as a more acceptable and applicable learning material for both teachers and students. Indeed, the change in the participating teachers' views about virtual laboratory activities and about the principles of scientific research shows that they feel more prepared for the activities that they can use at school. NRC (2005) has stated 20 articles under five titles for conducting scientific research. Considering the importance of research-based learning (Harwood et al., 2006) and the emphasis on research-based learning in the science curriculum in Turkey, it is thought that argumentation-based virtual laboratory activities can provide the necessary fun and collaborative learning environments that will allow students to do scientific inquiry and research.

Interviews with randomly selected teachers and students after the implementation phase of the research presented results demonstrating the effect of argumentation-based virtual laboratory activities. The point that the interviewed teachers most underlined was the positive educational climate. Students' easy adaptation to the activities and teachers' role as a facilitator and counsellor in these activities were some very important indicators of a positive learning climate. In fact, numerous studies have pointed to the role of virtual laboratory activities, compared to teacher-centred teaching, in increasing students' academic performance and achieving permanent learning (Basciftci et al., 2011; Chang, 2000; Comek, 2003; Demircioglu & Geban, 1996; Huppert et al., 2002; Mitra & Hullett, 1997; Olgun, 2006; Ozmen & Kolomuc 2004; Yenice et al., 2003; Yigit & Akdeniz, 2003). Thanks to argumentation-based virtual laboratory activities, learning can be made more permanent through scientific inquiries and arguments. Furthermore, as can be inferred from the interviews with the students, argumentation-based virtual laboratory activities made learning more fun and engaging for the students. This is today quite a precious result. For the development of scientific literacy in children, NSTA (2007) recommends using games that encourage students to discover, asking open-ended questions that promote scientific inquiry, research, and developing models, creating a learning environment where students are encouraged to do research, collect data, interpret the collected data, and share their conclusions, and involving students in science and engineering activities. The participating students were able to perform experiments in virtual environments, question the accuracy of their existing knowledge through arguments, and develop an awareness of the learning outcomes specified in the science curriculum. For this reason, such activities that reflect the constructivist learning theory should be made available throughout the country for more teachers and students.

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Conclusions and Implications

Argumentation-based virtual laboratory activities help teachers create a positive and fun learning climate which, in turn, develops different skills in students. Also, argumentation-based virtual laboratory activities to be developed according to the learning outcomes specified in the science curriculum offer an opportunity not only for self-paced learning, but also for the development of scientific process skills. As a matter of fact, the participating teachers stated that argumentation-based virtual laboratory activities increased students' interest and made learning more fun and that with these activities, their students could relate what they have learned to everyday life. On the other hand, as can be inferred from the interviews with the participating students, the laboratory activities based on the argumentation-based science learning approach "increased their interest, were fun to participate, and helped them learn the subjects better." Considering that increasing student motivation is the fundamental requirement for empowering students with 21st-century skills that express the high-level skills that students need for life in the information age, the number of such activities to be carried out in schools should increase, and training programs that will educate teachers about how to develop such materials should be made more widespread.

Considering the participating teachers' responses to the "Opinion Scale for the Virtual Lab" and the "Principles of Scientific Inquiry- Teacher" scale applied both as a pre-test and as a post-test, it can be seen that the research had a moderate effect on the teachers' views. This finding indicates that the teachers embraced the new and fun learning environment made possible through argumentation-based laboratory activities. During the training program, the teachers both developed argumentation-based materials to be used in virtual labs and frequently underlined the necessity of using such activities in their classes.

Argumentation-based virtual laboratory activities were developed with the aim of providing students with a learning environment where they can learn new scientific information, discuss scientific facts, and draw evidence-based conclusions. The emphasis on raising individuals involved in the process for the solution of scientific matters that concern society, which was included in the PISA 1999 and 2006 framework documents, was replaced by the emphasis on scientific inquiry, scientific evidence and scientific knowledge in PISA 2015. The materials and contents developed within the scope of the current research are very important in that they aimed to achieve the goal specified in PISA 2015. Teachers and students found opportunities for more systematic thinking on scientific knowledge developed through these materials. Argumentation-based virtual laboratory activities have emerged a more effective class model. Students who have the opportunities to understand science subjects better attended the lesson more eagerly and motivated. In addition, teachers' and students' abilities to ask research questions for the solution of a scientific problem have also improved through this research. In this way, the course contents progressed by gaining a more scientific and critical direction.

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Aysegul Kinik Topalsan　PhD, Assistant Professor, Department of Elementary Education, Faculty of Education, Istanbul Aydin University, Istanbul, Turkey.
E-mail: aysegulkinik@aydin.edu.tr
ORCID: https://orcid.org/0000_0003_0947_5355