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Investigating the Effects of Argument-Driven Inquiry Method in Science Course on Secondary School Students' Levels of Conceptual Understanding*

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ABSTRACT
This study aimed to determine the effects of the argument-driven inquiry learning method on students' conceptual learning in science education. The study is conducted with embedded mixed-methods research design from mixed research methods. The study was conducted with 64 7th-grade students consisting of 31 students in the experimental group and 33 students in the control group from a public school in the Aegean Region in Turkey. The unit "electrical energy" was taught using the argument-driven inquiry learning method in the experiment group, and the 2013 science curriculum and activities in the control group. The quantitative data collection tool used in this research was the "Conceptual Learning Test" while the qualitative data collection tools used were daily student reflections, research observation notes. To determine students' conceptual learning, of non-parametric tests, the Wilcoxon Z test was used for within-group comparisons and the Mann-Whitney U test was used to compare groups. For qualitative data analysis, descriptive analysis and content analysis were used based on the situation. According to the analysis of data, a significant difference in favor of the experiment group was observed in students' conceptual learning. The reason for the positive change in experiment group students' conceptual understanding was that the method presents an opportunity for students to explore information (the conceptual relationships by exploring the effects of the variables within the cases), discuss information within the group and out-group peers, and structurize. In conclusion, the current study might contribute to using the argument-driven inquiry learning method in a science course to literature and shed light on new studies.

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Introduction

During and after World War II, the developments in science and technology that have survived the era have made today's world a global village. People can now access information from one corner of the world in a short time and interpret this information from their own perspective by searching through different sources. This has brought to the agenda the need to redefine the competencies individuals need to have in the 21st century. In parallel with this, different classifications of 21st-century skills have been made by different communities and organizations such as Partnership for 21st Learning (P21), enGauge, Assessment and Teaching of 21st Century Skills (ATC21S), The Organization for Economic Co-Operations and Development (OECD), Ministry of National Education (MNE), World Economic Forum (Çepni & Ormancı, 2018). It can be stated that in these classifications, skills and literacy related to information and communication technologies, creativity, innovativeness, entrepreneurship, teamwork, adaptation to new situations, communication, metacognitive skills, and epistemological beliefs are emphasized.

However, as emphasized in the 21st-century learning outcomes and support systems of the P21 community, in particular, all these skills are built on "fundamental issues and 21st-century themes (physics, chemistry, biology, mathematics, etc.)". In other words, today competent people know the basic knowledge of fields such as physics, chemistry, and biology. This made it necessary to reinterpret the concept of science literacy. In this context, when the MNE (2013; 2018) science course curriculum is examined, science-literate individuals are able to inquire, make effective decisions, communicate effectively, learn lifelong with the awareness of continuous development, as well as basic knowledge of science (Biology, Physics, Chemistry, Earth, Sky and Environmental Sciences, Health and Natural Disasters). This may let us think that concept teaching has an important place in science lessons.

The concept means that individuals group events, objects, thoughts, emotions, or in short, each element that includes concrete and abstract features, in a way that they can be remembered more easily according to their similarities and differences, and to give each group a special name (İnel, 2012). According to Kaptan (1999), the concept is the common name given to each group when grouped according to the similarities of entities, events, people, and thoughts. According to Ülgen (2001), concepts are information structures that represent the changeable similar properties of different objects and phenomena that become meaningful in the human mind and can be expressed in a word generally. Concepts are actually making sense of what is happening around us. Therefore, concepts are mental structures that enable people to make meaning of various events, facts, and objects they encounter (Bowen & Bunce, 1997). For example, when the concept of "animal" is mentioned, a lot of information about animals comes to life in people's minds. For this reason, as concepts enable information to be grouped and organized systematically, the basis of communication between people forms and this facilitates communication (Bacanak, Küçük & Çepni, 2004; Çalık et al., 2007; Suhartono et al., 2019).

Moreover, people learn concepts and their names, starting from childhood, and find the relationships between concepts, classes, and concepts. Thus, they give meaning to their knowledge, reorganize them, and even new concepts produce new knowledge (Kaptan, 1999). However, since the concepts are generally abstract, it is exceedingly difficult for students to visualize these concepts in their minds. For this reason, concept teaching is an important process that should be given importance since the first years of primary education, and it is also very important for students to understand the concepts in secondary education and later periods, that the basic concepts of scientific disciplines that are abstract are taught completely and accurately in primary education (Bacanak et al., 2004). In other words, unless these ideas that students bring into the classroom environment are noticed and changed, they accumulate sequentially in the later stages of their education and become resistant to change (Alkış-Küçükaydın, 2020). Since science education should be seen as a kind of thinking method and this method should shed light on their efforts to understand the world, effective science education can be achieved by addressing at the level of concepts that are the cornerstones of human knowledge (Koray & Tatar, 2003). Therefore, the aim of science teaching is to enable students to learn science concepts meaningfully and to use these concepts in their lives in line with their needs (Çalık et al., 2007; Djudin, 2021; Köse, Ayas & Taş, 2003).

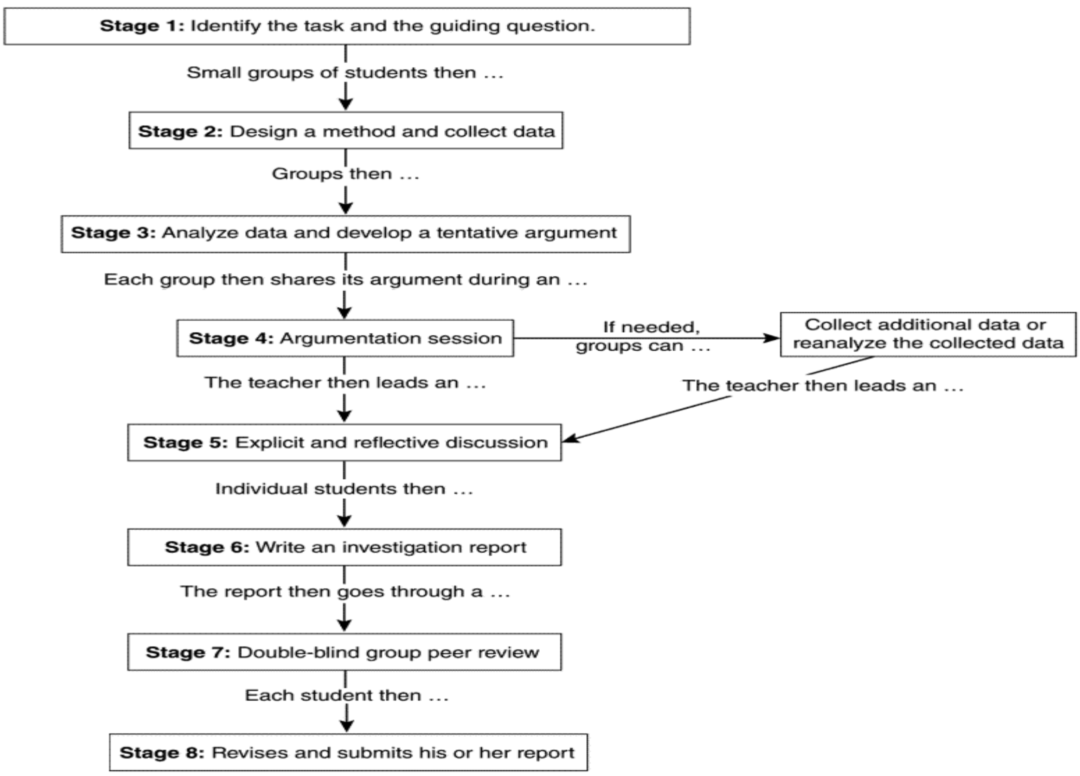
For this purpose, many researchers determine students' concept learning in science subjects, and examine the effects of various teaching methods and techniques on students' success in science and overcoming their misconceptions. Researchers emphasize the necessity of using different teaching approaches, strategies, methods, and techniques in science education. Different methods and techniques developed to make science education more effective refer to learning environments where students and teachers interact in science classrooms, in which students can discover information, investigate-question, create arguments and counter-arguments. In this context, in science education, students need to participate actively in both writing and speaking processes in order to be able to think about the scientific events, experiments, and explanations presented to them and make sense of them (Driver et al., 1994). The first of these writing and speaking activities to be done in accordance with the student profile and needs of our age is the argument-driven inquiry method (Chen et al., 2019; Driver, Newton & Osborne, 2000; Newton, Driver & Osborne, 1999; Walker, 2011). For this reason, it is thought that the use of the argument-driven inquiry method in science lessons may be effective in learning science concepts.

Argument-Driven Inquiry Method

The argument-driven inquiry method is a learning method in which argumentation and inquiry method are well integrated. It can be said that this learning method removes the deficiencies related to the inquiry process in the argumentation and argumentation-based learning method in the inquiry method. In other words, the argument-driven inquiry method is a laboratory-based method that includes research and inquiry that contributes to the importance of argumentation in science education (Walker et al., 2012). As can be seen in Figure 1, this learning method includes eight stages.

Figure 1

Stages of Argument-Driven Inquiry Instructional Model



Note. (Grooms et al., 2016, pp.2).

Moreover, as emphasized in Figure 1, this learning method attaches great importance not only to the experimental characteristics of laboratories (asking questions, developing methods) but also to the presentation of scientific claims (argumentation, writing) in developing students' science literacy (Çetin & Eymur, 2018; Kaçar & Balım, 2018; 2021). In other words, it offers a broad perspective by combining argumentation with laboratory-based teaching (Fakhriyah & Rusilowati, 2021; Walker & Sampson, 2013a; 2013b). In this context, the argument-driven inquiry method is based on a learning experience based on students' real laboratory experience, and in this process, it is an effort to develop students' ability to participate in scientific argumentation in a certain inquiry process (Hosbein, Lower & Walker, 2021; Sampson & Walker, 2012). Depending on this effort, the argument-driven inquiry method involves students' production and presentation of an argument during interactive argumentation sessions, students' inquiry skills (e.g., how to collect and analyze data), reasoning skills (e.g., understanding how to support arguments with evidence) and important habits of mind (e.g., understanding the value and limits of data) (Walker et al., 2010; 2012). In other words, this method of learning requires students to design and implement their own methods of collecting and analyzing data, sharing and communicating their opinions with others, and justifying their ideas, writing investigative reports and peer review to share and document their work (Hosbein et al., 2021; Eymur, 2019; Sampson, Grooms & Walker, 2009a; 2009b; 2011; Sampson & Gleim, 2009; Walker et al., 2012). It can be stated that such a teaching method teaches the students to do science in which scientific explanations about the phenomena in nature are presented consistent with the scientific research process, beyond learning about scientific facts, laws, theories, and models.

Moreover, the argument-driven inquiry method is designed to create a classroom community that will help students understand complex course content, learn how to create scientific evidence, and reflect the nature of scientific knowledge (Walker, Sampson & Zimmerman, 2011). In this way, the argument-driven inquiry method encourages students to develop and use conceptual models, develop explanations, share ideas, and critique, all of which enable students to develop the knowledge and skills they need to become science literate individuals (Sampson et al., 2017). Moreover, the students exposed to the argument-driven inquiry method made significant gains with respect to their scientific writing abilities and understanding of the development (Antonio & Prudente, 2021). In parallel with this, it can be thought that students can construct the basic concepts of science in fields such as physics, chemistry, biology, and environmental sciences effectively in their minds.

Research on Students' Understanding of Electricity

Regarding the electricity subject, research has been carried out investigating primary and secondary education students' conceptions on several issues, such as the connection of a battery to a lamp, the concepts of electric current, voltage and resistance, the direction and the retention of electric current in an electric circuit as well as the luminescence of lamps connected in series and parallel (e.g. Çepni & Keleş, 2006; Duit & von Rhöneck, 1997; Glauert, 2009; Kärrqvist, 1985; Osborne, 1981; 1983; Psillos, Koumaras, & Valassiades 1987; Shipstone, 1984; 1988; Shipstone et al., 1988; von Rhöneck & Grob, 1991). As a result, it was found that the students used alternative concepts/misconceptions rather than using scientific concepts related to electricity.

In addition, there are studies examining the effects of different teaching methods and techniques on students' learning about electricity (e.g. Atılğanlar, 2014; Chiu & Lin, 2005; Colley & Windschitl, 2016; Demir, 2008; Engelhardt & Beichmer, 2004; Jaakkola, Nurmi & Veermans, 2011; Küçük, 2011; Küçük & Çalık, 2005; Leone, 2014; Öztürk, 2013; Tsai, 2003; Ulu, 2011). The results obtained from these studies showed that various teaching methods and techniques contributed to changing students' misconceptions about electricity and acquiring scientific concepts.

Research on the effect of argument-driven inquiry method on students' learning

When the argument-driven inquiry method is examined, it has been found that this method has positive effects on the scientific writing skills of university and high school students, their learning about science concepts, their self-efficacy, scientific writing and presentation skills, and the development of verbal-written argument skills. (Aktaş & Doğan, 2018; Antonio & Prudente, 2021; Çetin & Eymur, 2018; Demirci-Celep, 2015; Eymur & Çetin, 2017; Enderle et al., 2013; Erenler, 2017;

Kalemkus, Bayraktar & Çiftçi, 2021; Sampson et al., 2011; Sampson & Walker, 2012; Walker et al., 2012). In addition, very few studies have been encountered on the application of the argument-driven inquiry method which is a very new method, in primary education. In the first of these, the effect of the argument-driven inquiry method on fourth-grade students' learning of science and their desire to participate in argumentation was examined (Chen et al., 2016). In another, the effect of the argument-driven inquiry method on the academic achievement of seventh-grade students, their desire to participate in the discussion, and their argumentation levels was tried to be determined (Aktaş & Doğan, 2018). In another study explored the possibilities to improve students' argumentation ability concerning factors that affect dissolving, through the implementation of two versions of a teaching scheme, with and without particle theory (Angeloudi, Papageorgiou & Markos, 2018).

In this context, when the relevant literature is examined, direct studies on the teaching of electricity with the argument-driven inquiry method have not been found. However, it has been determined that there are a few studies that examine the inquiry-based learning method and the subject of electricity together (e.g. Aboagye et al., 2018; Moynihan et al., 2020; Subari et al., 2018; Taramopoulos & Psillos, 2018). Considering the points emphasized in these studies, it was thought that the argument-driven method, which includes the effective use of inquiry learning would improve students' conceptual understanding of electricity. In this context, considering the relevant literature, it is thought that the argument-driven inquiry method is unique in terms of investigating the effects on secondary school students' conceptual understanding of electricity. For this reason, the problem statement of the research is:

"What is the effect of using argument-driven inquiry method in the science lesson on the conceptual understanding of students?"

Methods

Research Design

In this study, it was decided to use the embedded mixed-method design, which is one of the mixed methods designs in which quantitative and qualitative data collection and analysis methods are used together and in harmony. This design consists of collecting and analyzing research data in traditional quantitative and qualitative data collection designs by adding a qualitative phase to a quantitative phase such as an experimental study (Creswell, 2003; Creswell & Clark, 2017; Çepni, 2018; Greene, Caracelli & Graham, 1989). In other words, a mixed research method is a research approach that includes combining, correlating, and supporting quantitative and qualitative data collection and analysis processes (Creswell & Clark, 2017; Fraenkel, Wallen & Hyun, 2012). In this context, This study aimed to closely examine whether the argument-driven inquiry learning method develops students' conceptual understanding, as well as how this change occurs or in which situations it does not. For this reason, the quantitative data collection for the development of students' conceptual understanding, and the qualitative data collection processes were used in order to better describe the change and development in conceptual understanding. Parallel to this, the conceptual understanding test constitutes the quantitative dimension, while the reflective journal protocol ve researcher observation notes constitute the qualitative dimension.

Participants

The participants of this study are 7th-grade students in a secondary school affiliated to Uşak Province National Education Directorate. Within the scope of the study, research permission no. 29425508-605.01-E7688270 was obtained. A purposive sampling method was preferred while determining the students in the research group. Because, in determining the participants within the scope of the study, the method followed is first determining science course teachers and giving them training, and then selecting one of the 7th-grade classes in the school where one of these teachers worked. Teacher selection and training have an important role within the scope of the study. Because the teacher of the relevant course carried out the process of applying the argument-driven inquiry method in the science course. In addition, it was considered important for teachers to have a sufficient level of pedagogical content knowledge on laboratory materials (for example, setting up a simple electrical circuit, using an ammeter-voltmeter, etc.) and teaching technologies that assist science teaching (for example, interactive whiteboard, simulation, video, etc.).

Following the determination of the teacher who will perform the experimental application, the teacher was given practical training on the theoretical and teaching materials for one month on the argument-driven inquiry method. After the training, two of the seventh-grade classes, where the teacher taught were selected, and one was determined as the experimental group and the other as the control group. The criteria for determining the classes in which the experimental and control group students are located are, first of all, the students being in the 7th-grade for the quality of the argument, the 6th-grade academic score levels being the closest to each other in the 2015-2016 academic year, minimal or no interaction, having a moderate level of skills such as enjoying to write and speak. Then, one of the two classes with these specified criteria, one being the experimental class and the other being the control class, were randomly selected. In this context, the study group of the study consists of 64 students who are studying which is one of the central secondary schools in the Aegean Region, in the 7th-grade in the 2016-2017 academic year. In this context, the students studying according to the use of the argument-driven inquiry method in the science course constituted the experimental group, while the students studying only according to the 2013 science curriculum and course content constituted the control group. The information of the students in the study group is given in Table 1.

Table 1

Information of the Experimental and Control Group Students, which Constitute the Study Group

Group	Gender				Total	
	Female		Male			
	N	%	N	%	N	%
Experimental Group	14	20.32	17	26.56	31	46.88
Control Group	16	25.00	17	28.12	33	53.12
Total	29	45.32	35	54.68	64	100

As seen in Table 1, 31 students, including 14 girls and 17 boys in the experimental group, and 33 students, 16 girls and 17 boys in the control group, participated in the study. In this context, the study group of the research consisted of 64 students.

Data Collection Instruments

In this study, multiple data collection tools were used to determine the effect of the argument-driven inquiry learning method on students' conceptual understanding. For this purpose, the conceptual understanding test, student reflective journals, researcher observations, and notes were used.

Conceptual Understanding Test

In the study, in order to determine the effects of the argument-driven inquiry method on the conceptual understanding levels of the experimental and control group students, and to monitor the change and development, a two-stage diagnostic test (conceptual understanding test) was developed for the 7th-grade "Electrical Energy" unit.

In the process of developing the conceptual understanding test, the main headings of the participants' understanding and/or learning alternative concepts related to simple electrical circuits and electrical energy in primary and secondary schools were determined. Then, under these headings, related domestic and international studies and the information obtained in these studies regarding alternative learning of students were analyzed. As a result, it was determined that alternative learning such as "Unipolar Model or Sink Model", "Weakening Current Model, Current Consumption Model or Attenuation Model", "Shared Current Model" is defined in the related literature. The questions developed by Cohen et al. (1983), Engelhardt & Beichner (2004), Küçüközer (2003; 2004), Lee & Law (2001) and Peşman & Eryılmaz (2010) on the topic of electricity were examined. After this stage, on the condition of sticking to the originals of the questions developed by the aforementioned authors, a few changes were made on the questions, and multiple-choice test items (with four options, one of which is the correct answer) were prepared with a rationale part consisting of open-ended questions. As a result, the items of the multiple-choice test, the rationale part of which is open-ended, where the first part is from multiple-choice questions, and in the second part, where the students explain their reasons for choosing the answer option they chose in the first part, "The reason for your answer above..." was developed. Subsequently, the indicator table was prepared for each test item. After this stage, expert opinion was sought to determine the content validity of the test prepared. To this end, the test was presented to the opinions and suggestions of 2 academicians who were experts in science education and 3 academicians who were experts in physics education. Experts were asked to evaluate whether each problem in the prepared test measures conceptual understanding, to what extent it corresponds with the concept/alternative concept and curriculum achievements to be measured, and its scientific accuracy (proper use of terminology). In this process, the indicator table and alternative learning list prepared with the test were shared with the experts. As a result, according to the feedback from the experts, the necessary adjustments were made in the test and the conceptual understanding test consisting of 34 questions was finalized. After the feedback from the experts, the percentage of agreement among experts was calculated. Accordingly, the percentage of agreement among experts was calculated as 87% regarding the test's conceptual understanding measurement status, 93% regarding the overlap with concept/alternative concepts and acquisitions, and 89% regarding scientific relevance.

After the expert opinion, in order to determine the comprehensibility of the questions in the test, it was applied to an eighth-grade student group of 12 students who are equivalent to the student group to which the experimental application was being made. The students were asked what they understood from each question in the test and what they were expected to do. After the feedback from the students, it was decided that the questions were clear and there was no need for changes. It can be said that a conceptual understanding test with high validity was developed after expert feedback and student opinions.

After the validity studies, the reliability calculations of the test were made. The test developed for this was applied to a total of 189 students studying at 8th-grade in four secondary schools in two different provinces in the Aegean region. In the process of data analysis, a part of the same data set selected from the collected data in order to ensure the reliability of the data analysis was scored separately and independently by two different researchers. Then, based on the data obtained, the agreement between the researchers was calculated with the in-cluster correlation analysis. As a result of the analysis, the consensus value was calculated as .89. Moreover, the Cronbach Alpha reliability coefficient of the test was calculated as .84 as a result of analyzing all the collected data.

Reflective Journal Protocol

In the research, another data collection tool was student reflective journals. Parallel to this, while writing the reflective journal protocol open-ended questions for concept understanding, the concept map prepared during the development of the two-stage diagnostic test, the students' alternative concept learning list, and the seventh-grade "Electrical Energy" unit achievements were used. Care was taken to organize each problem in the protocol by including some alternative concept learning common to students. The reflective journal protocol developed as a result was presented to the opinions and suggestions of three academicians and two science teachers who are experts in the field of science education. Experts were asked to examine the developed reflective journal questions in terms of suitability to student level, understandability, correct and effective use of scientific terminology, and the compatibility of the questions with the variable they serve (conceptual understanding, metacognition, etc.). The feedback from the experts was examined and some questions were simplified in line with their suggestions. In order to determine the agreement between experts' evaluations, the percentage of agreement developed by Miles and Huberman (1994) was calculated. The agreement between experts was found to be 76.78%. Moreover, in order to determine the reliability of the developed journals, the journal protocol was examined by nine eighth-grade students who were similar to the characteristics of the target students, where the experimental applications of the research were being carried out. The students were asked to read the questions, say the points that were not understood, and try to answer the questions. The contradictions in some questions tried to be eliminated by looking at the feedback and answers they gave. After this study, the journals were finalized, and 15 open-ended questions were included in the conceptual understanding of journal protocol. In this context, presenting prepared journal protocols to the opinion of experts and a certain student group and arranging them according to their feedback can be interpreted as increasing the validity and reliability of the reflective journals.

Researcher Observation (Field) Notes

Other data collection tools used in this study are researcher observation and field notes. In this context, two situations have been used. The first is the structured classroom observation form; the second is the part where the short notes about the observations are taken. While developing the classroom observation form, alternative learning about electricity was taken into consideration in the conceptual understanding test and an observation form was prepared in parallel with this situation.

The observation form prepared was presented to the opinions of two academicians who were experts in the fields of science education who conduct scientific studies in the field of determining variables. The feedback from the experts was in the direction of writing the items for the variables desired to be observed in a more specific and simpler way. In line with the recommendations of the experts, the observation form was finalized and made ready for application. The observation form is arranged as a five-point Likert type: always, often, sometimes, rarely, and never. In the final form of the observation form, 17 items related to conceptual understanding are included. At the same time, the observation forum has included gaps in which researchers can take notes on things such as the situation, time, reason, and rationale of the variables and items in the observation form, and the dialogue between student-teacher and student-student.

Experimental Application Process

In this study, in which the effects of the use of the argument-driven inquiry method in the science course on the conceptual understanding of the students were examined, a pretest-posttest control group quasi-experimental design was used. In parallel, the experimental application process was completed in 9 weeks, four hours a week. In this process, the electricity unit (the course hour foreseen in the science program) was processed for five weeks. In the first and last week of the remaining four weeks, pre-test and post-tests were administered to the students. During the two weeks just before the experimental application, practice exercises were conducted with the students on the argument-drive method on biodiversity, which occurs just before the electrical unit. Thus, the disruptive variable in the students' lack of knowledge about the method was controlled. However, the whole process (teaching the science lesson), except pre-test and post-test applications, was followed by the science teacher in both the experimental and control groups.

In this study, after the conceptual comprehension test was applied as a pre-test, exercises (warm-up exercises) on the argument-driven inquiry method were carried out with the students in the experimental group. These familiarization phase studies were carried out on another science subject, biodiversity, independent of the electrical unit where the experimental application was conducted. Subsequently, the science lessons in the experimental group were continued with the argument-driven inquiry method, and in the control group, the lessons were continued with only the 2013 Science Curriculum content and the activities in the Science textbook. During this period, secondary school experimental group students participated in five argument-driven inquiry activities. In this context, the experimental group students performed the activities shown in Table 2 by following the eight steps of the argument-driven inquiry method.

Table 2

Activities Handled in the Implementation Process

Activity No	Activity Name	Activity Content
1	Let's Examine Series and Parallel Circuits	In this activity, students discover how to connect in series and parallel and draw a circuit diagram consisting of light bulbs connected in series and parallel. Observes the brightness differences on the circuit when the bulbs are connected in series and parallel and interprets the result.
2	Measuring Current and Voltage	In this activity, students know that electrical energy sources supply electrical current to electrical circuits and that an electrical current is a form of energy transfer. By connecting the ammeter to the circuit in series, it names the value it reads as current intensity and expresses its unit. It measures the voltage (potential difference) between the circuit ends by connecting the voltmeter in parallel to the circuit and expresses its unit.
3	Let's Examine Series Connected Circuits	In this activity, students associate the reason for the difference in brightness when light bulbs are connected in series and parallel with electrical resistance.
4	What is the Reason for Different Bulb Brightness?	In this activity, students explore the relationship between the voltage between the ends of a circuit element and the current flowing through it and associate the reason for the difference in brightness when the light bulbs are connected in series and parallel with the electrical resistance.
5	Energy Conversions	In this activity, students learn about the transformation of electrical energy into heat and light energy, the conversion of electrical energy into motion energy and motion energy into electrical energy, power plants, and the conscious and efficient use of electrical energy.

Within the scope of the research, student booklets for the activities seen in Table 2 were prepared. In these booklets, a phenomenon that draws students' attention to the subject and motivates them to learn, and at the same time introduces the research subject that they will deal with in the course and determines their own tasks, research questions, the list of tools and equipment they can use in establishing a circuit, the security measures they should follow in their studies, and open-ended questions in which they can write information such as justification, claim and evidence they have developed.

In addition, observations were made by the researchers in both the experimental and control groups during these five weeks during which the argument-driven inquiry method was applied and observation notes were taken. At the same time, the students in the experimental and control groups were asked to answer the questions in the reflective journal protocol given to them.

Data Analysis

In order to determine the effect of the argumentation-based learning method on the conceptual understanding of the students, the conceptual understanding test was applied to the students in both the experimental and control groups as a pre-test before the experimental application process and as a post-test after the experimental application. The scoring key developed by the researcher was used for scoring the questions in the conceptual understanding test. When the literature was examined, it was understood that different scoring keys were used by the researchers in the analysis of two-stage diagnostic tests. For this reason, the first stage of the two-stage diagnostic test was multiple-choice, and the second stage focused on scoring keys used in the analysis of open-ended questions. The literature on rubrics used in scoring two-stage diagnostic tests was examined. As a result, considering that the students gave correct reasons despite marking the wrong option in the multiple-choice part of the questions, or did not present justifications despite marking the correct option, or made wrong reasons, the most appropriate scoring of the two-stage diagnostic tests was evaluated together with the answers given to the multiple-choice questions and the reasons for these questions together. It has been decided. Therefore, it was thought that the justification part of the test should be scored more than the multiple-choice part. In this context, the scoring key used in the evaluation of the two-stage conceptual understanding test questions in this study is given in Table 3.

Table 3

The Scoring Key Used in the Evaluation of the Electrical Unit Two-Stage Conceptual Understanding Test Questions.

Explanation	Score
Right Option-Full Explanation	5.5
Wrong Option / No Answer-Full Explanation	5
Right Option - Partial Explanation	4.5
Wrong Option / No Answer-Partially Explanation	4
Right Option - Partial Explanation but Containing Alternative Grasp	3.5
Wrong Option / No Answer - Partial Explanation but Containing Alternative Grasp	3
Right Option - Alternative Grasp	2.5
Wrong Option / No Answer - Alternative Grasp	2
Right Option – No Grasp	1.5
Wrong Option / No Answer - No Grasp	1
Right Option - No Answer	0.5
Wrong Option / No Answer - No Grasp	0

All data collected before and after the experimental application with the conceptual understanding test tool were evaluated using the 0 - 5.5-point range in Table 3. Then, the kurtosis and skewness values of the data collected with the conceptual comprehension test collection tools before and after the experimental application of this research, and the Kolmogorov-Smirnov and Shapiro-Wilk values were calculated. As a result, it was determined that the conceptual comprehension test pretest and posttest scores did not show a normal distribution. As a result, since the number of students in the experimental and control groups was over 30 (meeting one of the parametric test conditions) but the collected data did not meet the normal distribution condition, nonparametric tests were used in the analysis of the quantitative data. For this reason, the Wilcoxon Z test, which is one of the non-parametric tests, was used in the comparison of the scores obtained by the students from the measurement tools within the group, and the Mann Whitney U test was used for the comparison between the groups.

In addition, student journals and researcher observations, and notes were used to answer this research question. Both content and descriptive analysis were used in the analysis of student journals.

Descriptive analysis was used to determine which concepts of the electrical unit they emphasize in the journals of the students (serial connection, parallel connection, etc.), and the data were analyzed with content analysis in order to determine the learning outcomes of the students in electricity. In the descriptive analysis process, the conceptual framework used in the development of the conceptual understanding test was used. In the content analysis, the explanations written in the journals of each student were coded by two independent researchers and it was tried to create meaningful categories by classifying these codes. Descriptive analysis was performed in the structured observation part of the research observations and notes, another data collection tool, and content analysis was performed in the unstructured open-ended part.

Findings

Findings and Comments Obtained from the Conceptual Understanding Test

The conceptual understanding test was applied to the students in the experimental and control groups as a pre-test and a post-test, and the scores obtained by the students from this test were compared with the Mann Whitney U test, which is one of the non-parametric statistical techniques.

Table 4 includes the mean rank of the experimental and control group students' scores from the conceptual understanding test related to the "Electrical Energy" unit and Mann Whitney U test analysis results before the experimental research.

Table 4

Mann Whitney U Test Results on Comparison of Groups' Pre-Test Conceptual Understanding Levels

Groups	N	Rank Average	Rank Total	U	p
Experimental group	31	36.19	1122.00	397.000	.124*
Control Group	33	29.03	958.00		

Note. *Since p> .05, the difference is not significant.

When the findings in Table 4 are examined, it is seen that there is no statistically significant difference in the results of the Mann Whitney U test applied to compare the scores of the students in the experimental and control groups in the conceptual understanding test regarding the "Electrical Energy" unit before the experimental application (U=397.000; p=.124>.05). The rank average of the pre-test scores of the students in the experimental group was found to be 36.19, and the rank average of the pre-test scores of the students in the control group was found to be 29.03. The fact that the rank averages of the groups obtained from the conceptual understanding test related to the "Electrical Energy" unit are close to each other indicates that the conceptual understanding levels of the students in the experimental and control groups about the concepts in the "Electrical Energy" unit before the experimental application are approximately equal.

In Table 5, after the experimental application, the rank averages of the experimental and control group students' scores from the conceptual understanding test related to the unit of "Electrical Energy" and Mann Whitney U test analysis results are given.

Table 5

Mann Whitney U Test Results Regarding Comparison of Post-Test Conceptual Understanding Levels of the Groups

Groups	N	Rank Average	Rank Total	U	p
Experimental group	31	43.19	1339.00	180.000	.000*
Control Group	33	22.45	741.00		

Note. *Since p< .05, the difference is significant.

When the findings in Table 5 are examined, it is seen that there is a statistically significant difference in the results of the Mann Whitney U test applied to compare the scores of the students in the experimental and control groups after the experimental application in the conceptual understanding test related to the "Electrical Energy" unit (U=180.000; p=.000<.05). The rank average of post-test scores of students in the experimental group was found to be 43.19, and the rank average of post-test scores of students in the control group was 22.45. When the rank averages of the groups are examined, it is seen that the conceptual understanding levels of the students in the experimental and control groups participating in the study, regarding the unit of "Electrical Energy", differed significantly in favor of the experimental group. According to this result, it can be said that the use of the argument-driven inquiry method in the science lesson improved the seventh-grade students' understanding of the concepts related to the "Electrical Energy" unit more than the use of the 2013 Science curriculum in the learning environment.

In Table 6, the sum of negative and positive ranks of the students' scores from the conceptual understanding test regarding the "Electrical Energy" unit applied to the experimental and control group students before and after the experimental application and the analysis results of the Wilcoxon Signed Ranks test are given.

Table 61

Wilcoxon Signed Ranks Test Results Regarding the Comparison of Pre-Test - Post-Test Conceptual Understanding Levels of Students in Experimental and Control Groups

Groups	Posttest-Pretest	N	Rank Average	Rank Total	Z	p
Experimental group	Negative Ranks	1	1.00	1.00	4.841	.000*
	Positive Ranks	30	16.50	495.00		
	Ties	1				
Control group	Negative Ranks	1	4.50	4.50	4.932	.000*
	Positive Ranks	32	17.39	556.50		
	Ties	1				

Note. *Since p> .05, the difference is significant.

When the findings in Table 6 are examined, it is seen that there is a significant difference between the conceptual understanding test pre-test and post-test scores of the students in the experimental and control groups regarding the unit of "Electrical Energy" (Experimental group Z=4.841; Control group Z=4.932; p=.000<.05). The total score of the students in the experimental group from the conceptual understanding test for the unit of "Electrical Energy" was found to be 1 for negative ranks and 495.00 for positive ranks. The total score of the students in the control group from the conceptual understanding test was 4.50 for negative ranks and 556.50 for positive ranks. Considering the rank totals of the difference scores, it is seen that the observed difference is in favor of the positive ranks, in other words, the post-test scores of the experimental group. According to this result, it can be said that the use of the argument-driven inquiry method in the science course and the instruction carried out only with the activities in the 2013 Science curriculum enabled students to understand the concepts related to the subject.

Findings and Comments from Student Journals

In order to determine the effect of the argument-driven inquiry method on the conceptual understanding of secondary school seventh-grade students, the experimental and control group students were asked to keep a reflective journal. The reflective journal data collected from the students were analyzed by descriptive analysis method in order to determine the frequency of repetition of the subjects related to the electrical unit and compared and compared in terms of experimental and control groups. In this context, since the number of reflective journals collected from the experimental and control groups is different from each other, a standardization was made in the analysis results and the comparison was made on percentage values. In Table 7, descriptive analysis findings of the data obtained from the comparison and comparison of the student reflective journals of the experimental and control groups are given in order to determine the effect of the use of argument-driven inquiry method in the science lesson on the frequency of repetition of the subjects related to the electrical unit.

Table 72

Frequency and Percentage Values of the Findings Regarding the Repetition Frequency of Electrical Subjects from the Reflective Student Journals of the Experiment and Control Groups

Category	Code	Experimental group		Control group	
		f	%	f	%
Simple electrical circuit	Circuit elements Simple electrical circuit setup The effect of the number of bulbs on the brightness of the light bulb in a simple electrical circuit The effect of the number of batteries on the brightness of the light bulb in a simple electrical circuit Drawing a simple electrical circuit	113	25.68	51	34.69
Transmission of electricity	Electrical resistance	15	3.41	4	2.72
Bulb connection	Series connection Parallel connection Electrical current Measuring electrical current Voltage (potential difference) Measuring voltage (voltmeter) Short circuit Ohm's law	198	45.00	63	42.86
Bulb brightness	Bulb brightness in a series circuit Bulb brightness in a parallel circuit Effect of electrical resistance on light bulb brightness in series and parallel circuits	72	16.36	19	12.93
Electrical energy	Conversion of electrical energy into various types of energy Power stations Conscious and economical use of electrical energy	42	9.55	10	6.80
Total		440	100	147	100

As it can be seen in Table 7, when the findings obtained from the experimental and control group student reflective journals about the experimental application process in order to determine the effect of the subjects related to the electrical unit on the frequency of repetition, it was found that the experimental group students mentioned the simple electrical circuit with a frequency of 25.68% and the control group students with a frequency of 34.69% determined. It was understood that the experimental group students mentioned the subject of electrical conduction with a frequency of 3.41% and the control group students with a frequency of 2.72%. It has been observed that the subject of the connections of the bulbs repeats with a frequency of 45.00% of the experimental group students and 42.86% of the control group students. Moreover, it was seen that the experimental group students emphasized the bulb brightness with a frequency of 16.36% and the control group students with a frequency of 12.93%. At the same time, it was understood that the subject of electrical energy was repeated by the experimental group students with a frequency of 9.55% and by the control group students with a frequency of 6.80%. In the light of these findings, it can be said that the argument-driven inquiry method has positive effects on students' conceptual meanings.

Moreover, the student reflective journals were analyzed with the content analysis method to determine the conceptual understanding of the students about electricity, in other words, what students' achievements were. Table 8 includes the content analysis findings of the data obtained from the student reflective journals in the experimental group in order to determine the effect of the use of the argument-driven inquiry method on students' conceptual understanding (student acquisitions) in the science course.

Table 83

Frequency and Percentage Values Regarding Findings of Student Acquisition from Experimental Group Reflective Student Journals

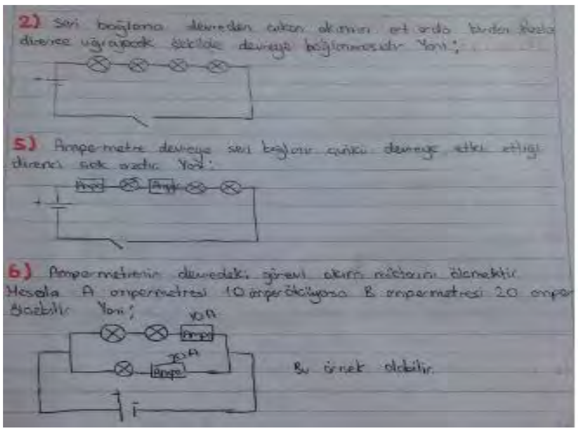
Category	Code	f	%	f	%
Bulb connection	Ability to explain how the voltmeter will be connected to the circuit and what its function is by setting up the circuit	25	5.80	234	54.29
	Ability to indicate what is a serial and parallel circuit and what is the difference	24	5.57		
	Expressing that current is a kind of energy transfer	22	5.10		
	Ability to express the voltage read on the voltmeter in unit	20	4.64		
	Ability to draw circuit diagrams consisting of light bulbs connected in series and parallel	20	4.64		
	Being able to determine the direction of the current from an electrical circuit	19	4.41		
	Being able to explain the short circuit	17	3.94		
	Ability to express that the value read by the voltmeter is voltage (potential difference)	16	3.71		
	Ability to explain how the ammeter will be connected to the circuit and what its function is by setting up the circuit	14	3.25		
	Ability to express that the value read by the ammeter is current	13	3.02		
	Being able to express the relationship between voltage and current	13	3.02		
	To be able to express the intensity of the current read in the ammeter in unit	11	2.55		
	Being able to emphasize that the energy difference between two ends of a circuit element is voltage.	11	2.55		
	Ability to explain the relationship (Ohm's law) between voltage, current and resistance	9	2.09		
Simple electrical circuit	To be able to draw a simple electrical circuit	20	4.64	91	20.18
	Ability to design, install and run a simple electrical circuit	19	4.41		
	Ability to show circuit elements with symbols	15	3.48		
	To be able to express the effect of the number of batteries on bulb brightness in a simple electrical circuit	14	3.25		
	To be able to define the function of the circuit elements that make up the simple electrical circuit	12	2.78		
	To be able to express the effect of the number of light bulbs on the brightness of the light bulb in a simple electrical	11	2.55		

	circuit.				
Bulb brightness	Ability to explain the brightness of the bulb in a series circuit on the circuit diagram	20	4.64	76	17.63
	Ability to explain the current in a series circuit	18	4.18		
	Ability to explain bulb brightness on circuit diagram in a parallel circuit	15	3.48		
	Being able to explain the difference in light bulb brightness in series and parallel circuits	13	3.02		
	Ability to explain the current in a parallel circuit	10	2.32		
Electrical energy	To be able to explain the conversion of electrical energy to various types of energy	7	1.62	17	3.94
	To be able to express the importance of the conscious and economical use of electrical energy	5	1.16		
	Expressing power plants	5	1.16		
Transmission of electricity	To be able to express what electrical resistance is	13	3.02	13	3.02
Total		431	100	431	100

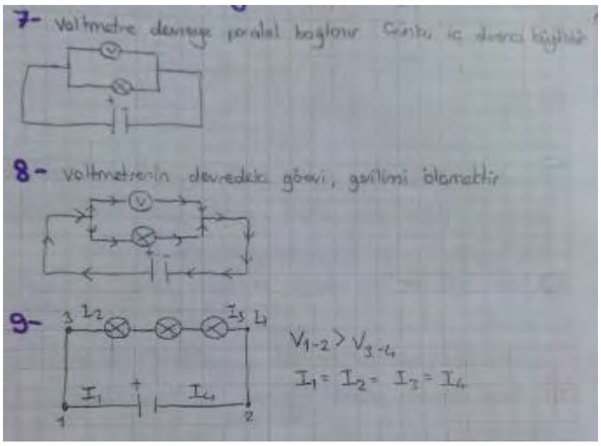
As seen in Table 8, when the findings obtained from the experimental group student reflective journals were examined in order to determine the conceptual understanding of the students about electricity, it was determined that the students were able to grasp the way of connecting the light bulbs with a frequency of 54.29%. It is understood that students can explain how the voltmeter will be connected to the circuit and what its function is by setting up a circuit with a 5.80% frequency, 5.57% can often state what the circuit is connected in series and parallel and what the difference is, 5.10% frequently express that current is a kind of energy transfer, 4.64% they can draw circuit diagrams consisting of light bulbs that are frequently connected in series and parallel and they can express the voltage that they read on the voltmeter with a frequency of 4.64%.

Figure 2

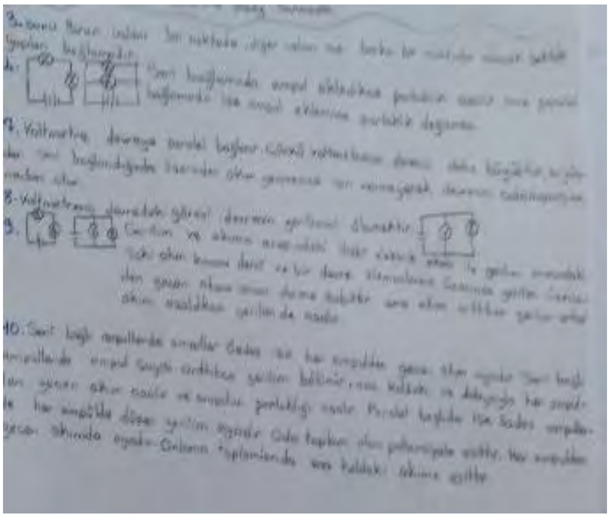
Experiment Group Students Journal Note Samples



(EG-S13)



(EG-S02)

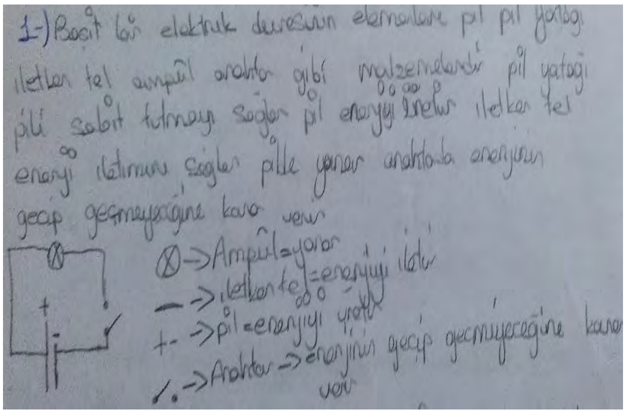


(EG-S01)

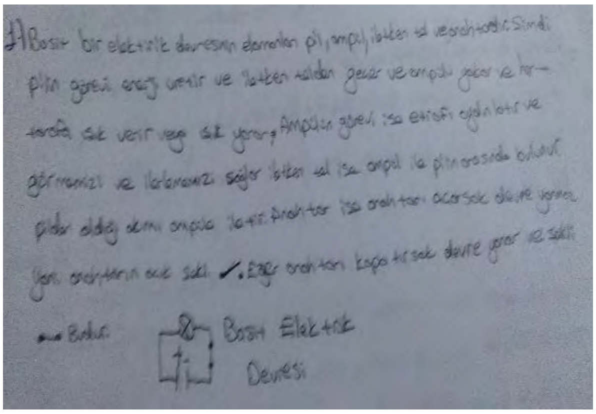
As seen in Table 8, Figure 2, and 3, it was determined that the experimental group students could draw a simple electrical circuit with a frequency of 4.64%, design, set up, and operate a simple electrical circuit with a frequency of 4.41%, and represent the circuit elements with symbols with a frequency of 3.48%.

Figure 3

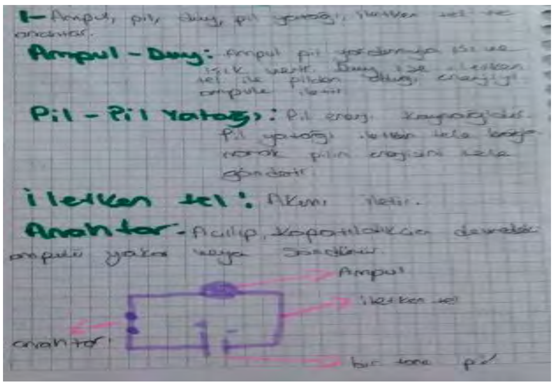
Experiment group students journal note samples



(EG-S12)



(EG-S31)



(EG-S27)

When the findings of the data obtained from the student reflective journals in terms of qualitative data were evaluated, it was determined that there was a positive development in the conceptual understanding of the experimental group students. During the experimental application process, it was observed that the students could learn many subjects such as connecting bulbs in series and parallel, current, voltage, Ohm's law, and the difference in light bulb brightness in series and parallel circuits. In this context, it can be said that the argument-driven inquiry method has positive effects on secondary school students' learning about electricity, in other words, their conceptual understanding.

Findings and Comments from Researcher's Observations and Field Notes

In order to determine the effect of the argument-driven inquiry method on the conceptual understanding levels of secondary school seventh-grade students, during the experimental application process, 20 lesson hours of researcher field (observation) notes were kept in the science course of the experimental group. In the observations of the researcher, the data obtained from the classroom observation form were analyzed by descriptive analysis method, and the data obtained from unstructured observations (short notes on open-ended questions) were analyzed by content analysis method.

Table 9 includes the descriptive analysis findings of the data obtained from the classroom observation form regarding the effects of the use of the argument-driven inquiry method in the science course on the conceptual understanding of students.

When the findings in Table 9 are examined, it was understood that 2.65% of the students were able to understand the subject frequently discussed in the introduction activity (concept cartoons, etc.), 2.06% were able to determine the task expected from them and develop the research question, 2.06% sometimes could recall their previous knowledge on the subject, and 2.85% of them could sometimes perceive what information they needed to search for to solve the research question. Moreover, it was determined that 2.65% of the students were always able to explore different research ways (circuit assemblies) and try these ways to solve the research question on the subject, 2.65% could sometimes solve the research problem on the subject, 2.35% rarely had different ideas about the subject in the argumentation 1.76% of them could sometimes evaluate and interpret different ideas, alternative solutions or evidence related to the subject in the argumentation process. Similar situations explaining this situation were obtained from the researcher's field notes-unstructured observation (open-ended questions).

When it comes to the subject of parallel and series-connected circuits in the experimental application process, it was seen that the students confused serial and parallel-connected circuits with each other at the beginning of the lesson. It was observed that some of the students established a series-connected circuit assembly instead of a parallel-connected circuit in the circuit setups they built to answer the research question posed to them. Moreover, students who succeeded in establishing a parallel circuit setup stated that although the lamps in the circuit are identical, the brightness of each lamp in the parallel arms is different from each other. For example, it has been determined that they have alternative misconceptions such as *"Of these arms connected in parallel, the lower one (meaning proximity to the battery) lights up brighter. Because most of the energy of the battery comes to this lamp."*, or *"The lamp below lights up. Because it is closer to the battery and no energy goes to the lamp above. That is why the lamp does not light. [Experimental Group (EG)-11]"*. However, towards the end of the lesson, it was observed that a great majority of the students stated that since each lamp in the electrical circuit is identical, their brightness is also equal. During the reflective class discussion process of the students, *"In our period, the lamps on both arms burned equally brightly. We think the brightness of lamps A and B are equal. Because when we measured it with a light sensor, we measured the brightness of both lamps as 0.9. Therefore, in our opinion, as long as the lamps are identical, in lamps connected in parallel, the lamp brightness is equal… (EG-2)"*.

Table 94

Frequency and Percentage Values of the Findings Obtained from the Experimental Group Observation Form

Codes	Always		Often		Sometimes		Rarely		Never		Total	
	f	%	f	%	f	%	f	%	f	%	f	%
To be able to understand the subject addressed in the introductory activity (concept cartoons, etc.)	6	1.76	9	2.65	3	0.88	2	0.59	-	-	20	5.88
To be able to determine the task that is highlighted in the introduction activity and expected from them on the subject and to develop the research question	4	1.18	7	2.06	4	1.18	3	0.88	2	0.59	20	5.88
To be able to remember previous information about the subject	4	1.18	4	1.18	7	2.06	5	1.47	-	-	20	5.88
To be able to perceive what information to research on the subject in order to solve the research question	1	0.3	5	1.47	8	2.35	5	1.47	1	0.3	20	5.88
To explore different research methods (circuit assemblies) and try these ways to solve the research question on the subject.	9	2.65	3	0.88	3	0.88	3	0.88	2	0.59	20	5.88
To be able to solve a research problem on the subject	-	-	-	-	9	2.65	7	2.06	4	1.18	20	5.88
Ability to put forward different ideas on the subject in the argumentation process	2	0.59	4	1.18	5	1.47	8	2.35	1	0.3	20	5.88
To be able to evaluate and interpret different ideas, alternative solutions or evidence on the subject in the argumentation process	5	1.47	2	0.59	6	1.76	4	1.18	3	0.88	20	5.88
Asking effective questions to learn different opinions of peers on the subject	1	0.3	2	0.59	6	1.76	6	1.76	5	1.47	20	5.88
Understanding the basic concepts related to the subject of the lesson	3	0.88	4	1.18	7	2.06	6	1.76	-	-	20	5.88
To be able to make connections between the concepts covered in the course and real-world events	-	-	-	-	6	1.76	10	2.64	4	1.18	20	5.88
Expressing basic concepts (current, voltage, etc.) with symbols	8	2.35	5	1.47	5	1.47	2	0.59	-	-	20	5.88
Ability to use various visual tools (circuit drawing, etc.) to show and express events or arguments related to the subject	2	0.59	9	2.65	7	2.06	2	0.59	-	-	20	5.88
To be able to use appropriate equipment (battery, ammeter, etc.) correctly and effectively in experiments on the subject (electrical circuit, etc.)	-	-	-	-	8	2.35	6	1.76	6	1.76	20	5.88
To be able to exhibit verbal and non-verbal behaviors that indicate the subject content in the course (what information has been learned)	-	-	6	1.76	5	1.47	9	2.65	-	-	20	5.88
To be able to answer the evaluation activities related to the subject in general correctly	1	0.3	1	0.3	8	2.35	7	2.06	3	0.88	20	5.88
Participating actively in the lesson	8	2.35	2	0.59	7	2.06	3	0.88	-	-	20	5.88
Total	54	15.88	63	18.53	104	30.59	88	25.88	31	9.12	340	100

Moreover, in the later stages of the experimental application, when it came to the activity related to the subject of electric current, it was understood that the students confused the current subject with subjects such as energy, the fixed energy source of the battery, and the electron. In this context, students, regarding the formation of current: it has been understood that they have alternative concepts such as non-scientific explanations *which can be exemplified as "When the switch is closed in the electrical circuit, the current flows from the negative end of the battery to the positive end. It circulates in the circuit like this. (EG-3)", or "The switch must be closed for current to occur. Current comes out of the positive terminal of the battery and moves towards the negative terminal and travels in the circuit like this (EG-9)"*. Moreover, it was determined that some of the students had a scientifically valid conceptual understanding of the formation of current, such as *"Vibration of electrons results in current. (EG-11)", "Current occurs from the positive end of the battery to the negative end. It is formed by the vibration of electrons. (EG-23)", "The battery has energy. There are negative charges in the battery. Electrons are negatively charged. Electrons vibrate from the negative end of the battery to the positive end and transfer the energy in the battery. This happens with the help of cables. The current is created by the vibration of the electron. (EG-19)"* Moreover, while explaining the direction of electric current and its direction, it was understood that the students had alternative conceptual learning, which is not scientifically valid: *"The energy of the battery is called current. Current moves from the negative pole of the battery to the positive pole.", "It is energy. Energy is carried from the positive end of the battery to the negative end by cables. (EG-21)", "Current is something created by electrons. Electrons are carried by wires from the negative end of the battery to the positive end. Therefore, the direction of the current is from the negative end of the battery to the positive. (EG-18)", "The direction of the current is from the negative pole of the battery to the positive pole. (EG-11)"*. Moreover, some students have been shown to compare the motion of electrons to water particles moving along a hose. According to this idea, students have an unscientific belief that the electron particle emanating from the negative pole of the battery moves along the conductive cable to the positive pole of the battery. Moreover, it was observed that some students could not establish a relationship between electron and current. However, towards the end of the course in which the subject of current was tackled, students generally said "*The direction of the current is from the positive pole of the battery to the negative pole. (EG-13)", "The direction of the current and the movement of its electrons are opposite to each other. Current moves from the positive terminal to the negative terminal of the battery. Electrons move from the negative end of the battery to the positive end. (EG-11)*", "*Current is created by the vibration of electrons. The energy of the battery is transferred from electron to electron. The direction of the current is from the positive pole of the battery to the negative pole. (EG-3)*". When these statements are considered, it can be thought that students' conceptual understanding, as well as scientifically valid thinking about direct current, has developed. At the beginning of the week's lecture, Ohm's law, that is, current, resistance, voltage, and the relationship between these concepts in series and parallel circuits was evaluated at the beginning of the week, although the students learned the current subject, it was observed that they learned alternative concepts in this subject. In this context, when the students were asked to express the relationship between lamp brightness and current in a series-connected circuit, some of the students established a series-connected circuit setup consisting of two identical bulbs. Some of the students who set up this setup said *"…The bulb that is close to the positive pole of the battery is the B bulb. That is why the most current comes to bulb B and therefore bulb B shines brighter. Since some of the current is spent in bulb B, less current goes to bulb A and bulb A burns less brightly… (EG-1)*". Some student groups were found to use three ammeters in a series-connected circuit consisting of two identical bulbs. When asked why they use these ammeters and why they have preferred to connect it this way, *"…We measured the current immediately after leaving the positive pole of the battery. Then we put it between two light bulbs, where we wanted to measure the current. Then, after the second bulb, we connected another ammeter near the negative end of the battery. Because if we measure the current in the circuit, we can say something about the lamp brightness. (EG-5)*" they responded. When the arguments of the student groups who set up this and a similar circuit setup are examined, it has been observed that they developed arguments such as "*In a series-connected circuit, the lamp brightness is equal because the current measured throughout the circuit is equal*. (*EG-17)"*. In this context, it can be said that the development of students' conceptual understanding is based on their own experiences and in the light of the data they collect. Moreover, it can be said that a counter-argument coming from one of the students in the course of the course provides a better structuring of the course content. In this context, one of the student groups made the opposite argument *"…if we add a third identical light bulb to this circuit, what would be the brightness? We think you are wrong. In a series circuit, the brightness cannot be equal. (EG-4)"*. In this case, some of the other groups, especially those who argue that the bulb brightness is different in series circuits, show that the magnitude of the current decreases as we go from the positive end of the battery to the negative end, because some of the current is consumed in the lamps and therefore the brightest lamp is the bulb that is close to the plus pole of the battery. They emphasized that it was the secondary and last bulb, respectively. For example, it was determined that some of the students had alternative conceptual learning: "*As the number of light bulbs in the circuit increases, the brightness of the bulb decreases… and adding a new light bulb to the circuit means the extension of the cable… it consumes some of the current in the cable. This means that the battery releases more current into the circuit ... so the brightness of all the bulbs in the circuit decreases. However, because the battery is single, the lamp brightness does not change… (EG-13)*". However, when the students with this alternative conceptual learning consider the circuit setup and data reconstructed by their peers in the other group, "*If the lamps are identical in series circuits, the lamp brightness is also equal and the current is the same everywhere. However, it has been observed that they agree with the argument that the lamp brightness in this new circuit (referring to the one consisting of four bulbs) is lower compared to the first circuit (referring to the circuit consisting of two lamps)".* At the same time, it was seen that some students made statements such as *"If the current decreases, the lamp brightness decreases… (EG-22)*", "*The current flowing through the lamps is equal, so the lamp brightness is equal. Because when the lamp was added, the total resistance of the circuit increased. There is only one battery in the circuit. As the voltage of the battery is constant, the current decreases. (EG-30)*". It can be thought that the biggest factor here is that they correctly record and interpret each value read in the ammeter in an electrical circuit assembly consisting of four identical bulbs and four ammeters before and after the bulb, and based on this, they try to convince their peers.

Current and voltage in parallel and series circuits are discussed. Students will learn about the light bulb A (first circuit) in a simple electric circuit consisting of a light bulb; When an identical bulb is added in series to the first circuit, they are asked to compare the brightness of bulb A in the series-connected circuit (second circuit) and the bulb A in the parallel-connected circuit formed by connecting an identical bulb to the first circuit in parallel. Considering the students' discussions with their groups at the beginning of the lesson, it was observed that some of the students had alternative conceptual learnings such as *"…The brightness of the A bulb does not change. Because their currents are equal… (EG-1)", "…the brightness of A bulbs in the second and third circuits is equal and less bright than the ones in the first circuit. Because there is only one bulb in the first circuit. When both bulbs are added, resistance increases. In the second and third circuits, the current is less…(EG-9)*". However, it was observed that the initial conceptual understanding of the students changed after they set up their own circuits and collected their data. At this point, when examining how the students gathered the data in the electrical circuit they set up, it was determined that some groups of students used one voltmeter in the first circuit, three voltmeters in the first circuit with three and four ammeters in the second circuit, three voltmeters in the second circuit, and three voltmeters in the third circuit to measure the current in each circuit. After these groups interpreted the data they collected, it was seen that they developed the argument "*The brightness of the bulbs A in the first and third circuit is equal to each other and is greater than the brightness of the bulb A in the second circuit. (EG-11)*". When the reasons they put forward to convince the other groups about these arguments are examined, considering the values they read from the ammeters in the first, second, and third circuit and the values they read from the voltmeter in all three circuits shows that the students have reached a very good level in conceptual understanding. At this point, they made explanations such as "*We measured 2A current in the ammeter in the first circuit. In the second circuit (referring to the series circuit) we measured the current flowing through lamp A as 1A. In the third circuit (referring to the circuit connected in parallel) the current was 2A in each of the parallel branches. Since the currents are equal, the brightness of A lamps in the first and third circuits is equal. (EG-4)*", "*We used* *the voltmeter. In the first circuit, the potential difference at both ends of the A bulb was equal to the volts of the battery. In the second circuit, the voltmeter connected to the ends of the A bulb was showing half the volt of the battery that we looked at. Our battery was 6 volts, we read 3V. Our voltmeter in the third circuit was showing the volt of the battery. We connected this one to the ends of lamp A. When we look at them, the brightness of A bulbs in the first and third circuits is equal to each other. Lamp A in the second circuit is less bright…(EG-17)*".

Concerning electrical energy, most of the students stated that the energy of the battery, that is, the energy of the battery, is consumed when the light bulb gives off. For example, they used expressions such as "*The bulb uses the energy of the battery to turn it on. (EG-5)*", "*The bulb uses the energy of the battery to give light. (EG-14)*". Moreover, some students argued that battery energy was consumed by the lamp. According to this idea, students used expressions such as "*The lamp uses the energy of the battery to give light. That is why the battery ends in time, the lamp goes out (EG-8)*", "*We used a battery with 3V energy in our experiment. But if we used a battery with more energy like 9V, the lamp would burn brighter. Why is that? Because the greater the energy in the battery, the higher the brightness of the lamp. The energy of the battery is consumed by the lamp... (EG-11)*", "*…in our circuit, the light bulb was burning brighter at first, but when we forgot the battery turned on, the brightness of the bulb decreased over time as the energy in the battery was exhausted by the lamp…(EG-14)*", "*The cables in the circuit carry the energy of the battery to the lamp...(EG-23)*". However, it was understood that towards the end of the activity on energy, students started to emphasize the concept of energy conversion more. Parallel to this, students stated "*The potential energy stored in the battery causes the lamp to heat up while the lamp is emitting light and thus the electrical energy to turn into heat energy (EG-27)*", "*The energy in the battery is not consumed by the circuit elements. For example, the light bulb gets warmer over time while burning. Because the energy in the battery turns into heat energy in this way. (EG-2)*".

Conclusion, Discussion, and Suggestions

In the study, "What are the effects of using argument-driven inquiry method in the science course on students' conceptual understanding?" The answer to the question was sought. Before the experimental application, it was understood that there was no statistically significant difference between the two groups according to the results of the Mann Whitney U test applied for the conceptual understanding test of the "Electrical Energy" unit of the students in the experimental and control groups ($p=.12>.05$). As a result of this finding, it shows that the conceptual understanding levels of the students in the experimental and control groups regarding the concepts in the "Electrical Energy" unit before the experimental application are approximately equal to each other. However, after the experimental application, when the scores of the experimental and control group students in the conceptual understanding test of the "Electrical Energy" unit and the "Electrical Energy" unit were compared, it was determined that there was a statistically significant difference between the two groups in favor of the experimental group according to the Mann Whitney U test ($p=.00<.05$). According to this result, it can be said that the use of the argument-driven inquiry method in the science lesson improved the seventh-grade students' understanding of the concepts related to the "Electrical Energy" unit more than the use of the 2013 Science program in the learning environment. Moreover, it was found that there is a significant difference between the conceptual understanding test pre-test and post-test scores of the students in the experimental group regarding the unit of "Electrical Energy" ($p=.00<.05$). According to this result, it can be said that the use of the argument-driven inquiry method in the science course enables students to understand the concepts related to the subject. At the same time, it was understood that there was a significant difference between the conceptual understanding test pre-test and post-test scores of the students in the control group regarding the unit of "Electrical Energy" ($p=.00<.05$). According to this result, it can be said that only the teaching carried out with the activities in the 2013 Science curriculum enabled students to understand the concepts related to the subject.

In the qualitative aspect of this study, it was aimed to determine the effect of using the argument-driven inquiry method on students' frequency of repetition of subjects related to the electrical unit. As a result of the descriptive analysis performed for this purpose, it was determined that the experimental group students mentioned the simple electrical circuit with a frequency of 25.68% and the control group students with a frequency of 34.69%. It was understood that the experimental group students mentioned the subject of electrical conduction with a frequency of 3.41% and the control group students with a frequency of 2.72%. It was observed that the subject of connecting the bulbs was repeated with a frequency of 45.00% of the experimental group students and 42.86% of the control group students. Moreover, it was observed that the experimental group students emphasized the bulb brightness with a frequency of 16.36% and the control group students with a frequency of 12.93%. At the same time, it was understood that the subject of electrical energy was repeated by the experimental group students with a frequency of 9.55% and by the control group students with a frequency of 6.80%. Moreover, it was determined that the experimental group students could grasp the way the light bulbs were connected with a frequency of 54.29%, the simple electrical circuit with a frequency of 20.18%, and the brightness of the light bulb with a frequency of 17.63%. Moreover, in the findings obtained from the researcher's field notes, it was found that the students in the experimental group could frequently understand the subject discussed in the introduction activity (concept cartoons, etc.) with a frequency of 2.65%. In addition, with a frequency of 2.06%, it was frequently emphasized in the introduction activity that they were able to determine the task expected from them and develop the research question, with a frequency of 2.06% they could sometimes recall their previous knowledge on the subject, and with a frequency of 2.85%, they could sometimes perceive what information to research on the subject to solve the research question. In the light of all these qualitative and quantitative findings, it can be said that there is a positive development in the conceptual understanding of the experimental group students. In other words, it can be accepted that the argument-driven inquiry method has positive effects on secondary school students' learning about electricity, in other words, their conceptual understanding. In this context, when the related literature is examined, there are studies emphasizing that the argument-driven inquiry method has positive effects on students' academic achievement and conceptual understanding (Aktaş, 2017; Aktaş & Doğan, 2018; Antonio & Prudente, 2021; Bidwell, 2016; Çetin et al., 2018; Demirci-Celep, 2015; Demircioğlu, 2011; Demircioğlu & Uçar, 2015; Kalemkus et al., 2021; Kim & Hannafin, 2016; Myers, 2015; Sampson et al., 2013; Walker et al., 2012; Walker et al., 2016). Based on these results, it can be said that this research is supported by the findings in the literature. However, it can be stated that this study differs from the literature at some points. Because it has been understood that the argument-driven inquiry method, which is a new learning method, is mostly studied at the high school and university level, but there has not been any study examining its effect on the conceptual understanding of secondary school students. Moreover, it was understood that there were two studies conducted at the secondary school level on the argument-driven inquiry method, and they aimed to determine the effect of this learning method on students' academic achievement (Aktaş, 2017; Aktaş & Doğan, 2018). For example, Aktaş (2017) and Aktaş and Doğan (2018) stated in their study that the argument-driven inquiry method was more effective than the traditional method in increasing seventh-grade students' academic achievement on force and motion. When other studies in the literature are examined, Demirci-Celep (2015) investigated the effect of the argument-driven inquiry method on tenth-grade students' conceptual understanding of gas. At the end of this study, they found that there was a significant difference in favor of the experimental group, and the experimental group of high school students had fewer misconceptions about gas concepts. In a similar study, Çetin et al. (2018) aimed to determine the academic success of students in the chemistry course of the argument-driven inquiry method in their study with high school students, and as a result of this study, they stated that there was a statistically significant difference in favor of the experimental group. Antonio and Prudente (2021) investigated the effects of the metacognitive argument-driven inquiry approach on improving students' conceptual understanding, and as a result of this study, they found that there was a significant difference students' conceptual understanding. In another study, Sampson et al. (2011) and Myers (2015) taught high school biology lessons according to the argument-driven inquiry method and stated that students could learn biology subjects better after this experimental practice.

In addition, Walker et al. (2012) concluded in their study that students who attended the general chemistry laboratory course conducted with the argument-driven inquiry method at the university, even if they completed fewer laboratory activities, were at a better level than students in traditional laboratory departments in the evaluation of conceptual understanding. However, while no significant difference was observed between the conceptual understanding of university experimental and control group students, it was emphasized that there were significant differences between students' teaching approaches regarding their ability to use evidence and reasoning skills. In a similar study, Walker (2011) stated that the argument-driven inquiry method positively affected university students' understanding of chemistry subjects. Demircioğlu (2011) found that general physics laboratories education, which was treated with the argument-driven inquiry method, was more effective in increasing the academic success of pre-service science teachers in optics compared to the traditional method. In this context, it can be said that the findings of this study are in parallel with the literature. In this case, it can be concluded that the argument-driven inquiry method has positive effects on students' conceptual understanding. When the results of the studies in the relevant literature and the results obtained from this study are examined, it is not surprising that the argument-driven inquiry method has a positive effect on increasing students' conceptual understanding or academic success. Because argument-driven inquiry method is a learning method that supports the conceptual dimension of science at a good level by its nature. Throughout the argument-driven inquiry method, students benefit from both existing and new science concepts that they will learn while solving a science event and a related problem. In other words, students use all the concepts they know about electricity together. In this study, the students first determined a research question to explain the "Ohm" law based on the science event given to them, and they conducted trial and error or deliberate experiments to solve this question. While explaining the claims they reached as a result of these experiments to both themselves and different groups, they constantly emphasized their data and the science concepts behind these claims. Students often used their knowledge of more than one science concept (e.g. current, resistance, circuit structure, etc.) to explain a concept (e.g. ohm's law). This enabled them to construct the information themselves and even discover it themselves. For this reason, it can be thought that it is natural for students to develop their conceptual understanding of science.

Moreover, it can be said that the inquiry-based learning method also contributed to the development of students' conceptual understanding. Because in the argument-driven inquiry method, students identify a research question just like in the inquiry-based learning method, and design-apply-finalize the research method in order to find an answer to this research question, and write a research report on the whole process including this result. In this context, when the related literature is examined, the academic success of the inquiry based learning method (Arafah et al., 2020; Arslan, 2007; Bilir, 2015; Brown, 2010; Çelik & Çavaş, 2012; Farrell et al., 1999; Furtak et al., 2012; Glasson, 1989; Hanson & Wolfskill, 2000; Hein, 2012; Jensen & Lawson, 2011; Lewis & Lewis, 2005; Maknun, 2020; Ortakuz, 2006; Straumanis & Simons, 2008; Tatar; 2006; Timur & Kıncal, 2010; Tretter & Jones, 2003; Uludağ, 2003; Vacek, 2011; Vanags et al., 2013) and there have been studies showing that it has positive effects on improving their conceptual understanding (Arslan, 2007; Bertsch et al., 2014; Campbell, 2014; Chang & Mao, 1998; Kula, 2009; Küçük, 2011; Orcutt, 1997; Mao & Chang, 1998; Mao et al., 1998; Parim, 2009; Pedretti, 2010; Şen, 2015; Tsai, 2003; Ulu, 2011 Varma-Nelson & Coppola, 2005; Zacharia & Anderson, 2003). Aboagye et al. (2018), Moynihan et al. (2020), Subari et al. (2018), and Taramopoulos and Psillos (2018) found in their research that the inquiry-based learning method is an effective method in improving students' conceptual understanding and academic success on the subject of electricity. Ulu (2011) concluded that conducting laboratory practices in the form of activities based on the science writing tool, which is an inquiry-based approach, improves the academic achievements and conceptual understanding of the subject of electricity in our lives. Yalçın (2014) revealed that the inquiry-based learning method is an effective method to overcome pre-service teachers' misconceptions about electrical conductivity. Lord and Orkwiszewski (2006) found in their study that inquiry-based learning practices in biology laboratories increased success more than classical experiments of recipe type. Hofstein and Walberg (1995) stated that inquiry-type laboratories are highly effective in students' learning science because it consists of stages such as problem-solving and finding a hypothesis formula. Gülmez-Güngörmez (2018) revealed in her study that the nature of science activities included in the process-oriented guided inquiry learning method improves students' academic achievement and conceptual understanding. Mutlu (2011) stated that experimental activities based on guided inquiry and traditional approaches performed in real and virtual laboratory environments are effective in improving the academic success and conceptual understanding of science teacher candidates regarding General Chemistry subjects. Stohr-Hunt (1996) found in their research that the science achievement of students who do research activities every day and once a week is higher than the success of students who do these activities once a month or less. As a result of their longitudinal study on technology-supported inquiry-based learning method, Marx et al. (2004) found that the method in question was effective in developing students' conceptual meanings. Lawson et al. (1990) reached the conclusion that this method supports and improves the concept learning of the students after the research-based learning ring model they carried out to provide an understanding of biology concepts and theories. In this context, it can be said that the findings obtained from this study coincide with the literature. This can be thought that the inquiry-based learning method has positive effects on learners' academic achievement and conceptual understanding and is a good method to reduce their misconceptions.

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