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The effect of online argumentation in open-ended physics experiments on academic achievement and the change in argumentation abilities

Tuba Demircioğlu[a] *

[a] *Çukurova University, Campus, Adana, Turkey*

Abstract

Due to the rapid change and development in science and technology, it has come to the fore to educate individuals with 21st-century skills. Scientific argumentation plays important role in developing 21st-century skills. Several studies were conducted on argumentation in science education and laboratory, however, the limited study examined argumentation in the physics laboratory. This study aimed to investigate whether online argumentation in open-ended physics experiments affects the academic achievement and argumentation abilities of preservice science teachers. Quantitative and qualitative research methods were used in this study. In the quantitative parts of the study the quasi experimental design was used. Qualitative data were collected through online argumentation to determine the change in argumentation abilities of students. The participants were consisted of 55 preservice science teachers. The experimental group students participated in online discussion in open-ended experiments and the control group students performed confirmatory experiments. It was found that online argumentation in open-ended experiments was more effective in improving the academic achievement of the students compared to confirmatory experiments. The results also indicated that argumentation abilities of the experimental group students improved throughout the intervention.

Keywords: Online argumentation, open-ended experiments, physics laboratory, science education

1. Introduction

The rapid change and development in science and technology have also changed the competencies expected from individuals' knowledge and expertise that are valuable for society. Therefore, it has come to the fore to educate individuals with 21st-century skills who can easily adapt to the present and the future. The 21st-century skills include critical thinking, collaboration, communication, problem-solving and social skills and scientific argumentation plays important role in developing 21st-century skills (Clark et

* Corresponding author Tuba Demircioğlu ORCID ID.: https://orcid.org/0000-0000-0000-0000
E-mail address: tubademircioglu@gmail.com

al., 2010). For example; when students engage in scientific argumentation, they learn to use appropriate evidence to justify their arguments and reason, evaluate the validity and the reliability of an argument made by their peers and in this way they develop complex communication skills, collaboration, critical thinking skills (Clark et al., 2010).

Argumentation has a crucial role in science education as a means of offering, supporting and evaluating ideas to make sense of problems and the knowledge develops with cognitive processes, the social norms of science and the conceptual structures in argumentation (Walker & Sampson, 2013). That is the way that scientists develop scientific knowledge. Scientists search solutions to the problems in unclear phenomena by collecting evidence, producing arguments and evaluating them to create and develop scientific knowledge (Katchevich et al., 2013). Scientific argumentation is a social process in the research and it is a bridge among the scientists in the development of scientific knowledge. The arguments constructed by scientists, the evidence of that arguments, the justifications of the evidences are criticized and assessed by other scientists (Grooms et al., 2015). By engaging in argumentation, students learn science content (Author, 20xxb; Walker et al., 2019; Zohar & Nemet, 2002) and have the chance to experience the scientific process as scientists develop new scientific knowledge (Alchin & Zemplen, 2020; Kind et al., 2011).

Argumentation abilities of students can develop by giving them opportunities, support and creating appropriate activities that students can experience argumentation (Berland & McNeill 2010; Duschl & Osborne, 2002; Hand et al., 2020; Osborne, Erduran & Simon, 2004). Teachers' being not skilled in argumentation is an obstacle for students to obtain argumentation abilities (Jonassen & Kim; 2010). Therefore, it is important to support the pre-service science teachers engage in argumentation as they can create appropriate activities in their science classrooms when they are a teacher.

This study allows pre-service science teachers engaging in online argumentation to organize their laboratory experiments to support their scientific knowledge and engagement in scientific argumentation.

1.1. Argumentation and science laboratory

The laboratory has a central role in science teaching and meaningful science learning occurs in laboratory activities (Katchevich et al., 2013). Meaningful science learning can occur when students determine the problem related to a phenomenon, identify the concepts that they know and they do not know, search for solutions to solve the problem and reconstruct their scientific knowledge (Chin & Brown, 2000). This process is directly related to open-ended laboratory activities. In confirmatory laboratory activities, students do the experiments by following the teacher's plan and the results of the experiment are predetermined but in open-ended laboratory activities students construct the experimental process and the results are not known by the students (Katchevich et al., 2013). Confirmatory laboratory activities are an obstacle for argumentation (Kind et al., 2011) because they do not have a chance to discuss the problem and construct their knowledge. They only try to complete the task instructions given to them in the laboratory. Inversely, as students work with their peers both in planning experimental process and doing the experiment, they will use claim, data, warrant, rebuttal that are the key components of argumentation (Toulmin,1990) so that open-ended laboratory experiments develop the students' argumentation abilities (Katchevich et al., 2013; Kind et al., 2011; Sampson& Gelim, 2009; Walker et al., 2019).

Several studies emphasized the effects of argumentation in science laboratory (Author, 20xxa; Author, 20xxb; Burke et al., 2005; Hosbein et al., 2021; Katchevich et al., 2013; Kelly et al., 1998; Uzuntiryaki et al., 2021; Walker et al., 2019; Watson et al., 2014; Yaman, 2020). Most of these studies found that open-ended inquiries support and develop students' argumentation. Katchevich et al. (2013) found that the number of arguments of high school students' and level of them in the open-ended inquiry experiments were higher than in the confirmatory-type experiments. Uzuntiryaki et al. (2021) investigated the development of argumentation ability in the laboratory and they found that pre-service chemistry teachers' argumentation ability developed over time. Hosbein et al. (2021) investigated argumentation abilities in a general chemistry laboratory that involved the Argument Driven Inquiry (ADI) instructional method. This study revealed that an increase occurred in the total Assessment of Scientific Argumentation in the Classroom (ASAC) observation protocol scores for the experiments. But most of that studies were conducted in the chemistry laboratory and there are few studies conducted in the physics laboratory. Also, the previous studies reported inconsistent findings compared to each other. The results of Author, (20 xxa) indicated that the ADI method was more effective in developing the argumentation ability compared to the traditional laboratory method. Author xxb (2015) examined the effect of (ADI) based laboratory instruction on pre-service science teachers' argumentation ability in General Physics Laboratory III. They did not find a significant difference between argumentation quality of the experimental and control group students' arguments at the beginning and the middle of the treatment. However, there was a significant difference at the end of the treatment. Conversely, in Watson et al.'s study (2014) conducted with two teachers and two groups of students (Age 12-13), the quality and quantity of argumentation of the inquiry were low. Also, Kelly et al. (1998) reported that students did not support most of their arguments with warrants in laboratory practices on electrical circuits. These studies shows that additional research needs to be conducted on argumentation abilities in physics laboratory.

Traditionally laboratory instruction requires students to work in groups by following the teacher instructions without group discussions (Katchevich et al., 2013; Kind et al. 2011). Designing argumentation in science classes and the laboratory is difficult (Hofstein, Kipnis, & Kind, 2008) because of the limited time, pedagogical challenges

(Author, 20xxb; Hofstein & Lunetta, 2004; Sadler et al., 2007), meeting curriculum targets. As a results of these most of the science educators do not use discussions, argumentation and open-ended experiments in the laboratory (Newton et al., 1999; Watson et al., 2014). Conducting some of the activities of open-ended type experiments in an online environment could be a promising solution.

1.2. Online Argumentation

Over the years, several studies indicate that online environments, synchronized and asynchronous communication, can support argumentation and have many benefits (Chen & She, 2012; Choi & Hand, 2020; Clark, & Sampson, 2007; Clark et al., 2010; Sandoval & Reiser, 2004; Yeh & She, 2010). Participating in online learning environments provide students more opportunity to engage in discussions and to learn science rather than face-to-face settings (Clark & Sampson, 2007; Hsi & Hoadley, 1997; Schellens & Valcke, 2006; Tsai, 2015). The online synchronous discussion provides students simultaneous consideration and coordination when they work together on a task (Janssen, et al., 2006). Students see the arguments used by other students on the screen and they have time to propose, read, understand, evaluate, refute and refine these arguments typed in written in online argumentation (Clark et al., 2007; Schellens & Valcke, 2006). Students feel free and express their thoughts in more equal opportunities in online asynchronous discussions (Wang & Woo, 2007). Instead of the discussions conducted by dominant students in the classroom, low-achieving students also get the chance to express their thoughts, develop a logical and critical perspective, and put forward well-structured arguments in asynchronous discussions (Nussbaum et al., 2007; Yeh & She, 2010). In this way, online argumentation enables task-oriented discussions and student knowledge construction (Schellens & Valcke, 2006; Lin et al., 2011). Although the benefits of online argumentation in knowledge construction, conceptual change and development in science learning, still there is no consensus about the effectiveness of online learning over traditional instruction on students' academic achievement (Chen & She, 2012). Chen and She (2012) examined the effect of online synchronous argumentation learning in physical science context on 8th-grade students' argumentation ability and conceptual change. They found that the quality of arguments of the students in experimental group developed significantly in all topics. Additionally, the students in the experimental group generated more correct conceptions from pre- to post-argumentation questions in all topics. They also proved that the online synchronous scientific argumentation group significantly performed than the traditional group on the Physical Science Conception Test. In Choi and Hand's study (2020), the grade 5 students used evidence to justify their arguments, evaluated evidence, revise their claims and critiqued the arguments in the online asynchronous discussion and the in-class wrap-up discussion. Yeh and She (2010) concluded that the 8th-grade students in the experimental group engaged in online argumentation significantly performed than the control group on chemical reaction achievement. Thay also revealed that the quantity and quality of scientific arguments that 8th grade students used in a series of argumentation questions developed and their conceptions were changed across all topics. Kirtman (2009) stated conversely that students in the traditional instruction group significantly outperformed better than the students in the online instruction group, in mid-term and final exams. Larson and Sung (2009) revealed that there were no significant differences in achievement between face-to-face, blended and online instruction. Lim et al. (2008) found a positive significant difference between the levels of achievement of the online learning group and the traditional face-to-face learning group.

Therefore, this study aims to investigate whether online argumentation in open-ended physics experiments affects academic achievement and argumentation abilities of preservice science teachers.

The research questions guiding the study are:

1) Is there a difference between the academic achievement of the students engaged in an on-line argumentation in open-ended physics experiments and students participated in traditional physics experiments?

2) How do the argumentation abilities of students who engaged in on-line argumentation in open-ended physics experiments change during the study?

2. Method

2.1. Research Design

Quantitative and qualitative research methods were used in this study. In the quantitative parts of the study, the non-equivalent groups design within quasi experimental design was used. In this design, group members are not randomly selected, however they are randomly assigned to the control or experimental groups (Cohen et al., 2000). Qualitative data were collected through online argumentation to determine the change in argumentation abilities of students.

2.2. Participant characteristics

A total of 55 preservice science teachers (43 females and 12 males) participated in this study. 29 of them were assigned in the experimental group and 26 were in the control group. These participants consisted of students studied in a public university. Their grade point average ranged from 1.54 to 3.42 over 4.00. The students were from middle or low socioeconomic status families.

The study was conducted in General Physics II Laboratory Course (GPLC II). The students took (GPLC II) when they took General Physics II Course (GPC II) at the same time.

Along with the description of subjects, give the mended size of the sample and number of individuals meant to be in each condition if separate conditions were used. State whether the achieved sample differed in known ways from the target population. Conclusions and interpretations should not go beyond what the sample would warrant.

2.3 Intervention

In the study, experimental group and control group students participated in five different laboratory activities for a total of 7 weeks, two hours a week. Both in experimental and control group students were divided into heterogeneous groups of four people before the GPLC II. The participants were regrouped with different peers to make them work in different groups prior to each experiment. One of the researchers of the current study conducted the intervention both in the experimental and control group. The experiments named in GPLC II were; 'Resistance measurement, Series and parallel connection, Factors affecting resistance, Ohm's Law, Lamp Circuits'.

2.3.1 Laboratory Activities in Experimental Group

For the experimental condition, in the first week of the GPLC, both the experimental and control group students were informed about the intervention and pre-tests were administered. The experimental group students were also informed about argumentation and the Toulmin argument model. In the second week, the experimental group students were registered to the OLIVES and were informed about the use of the system. OLIVES is a learning management system developed by the Distance Education Research and Application Center of the university where the research was conducted. For the next 5 weeks, a day and time were agreed with the students before coming to the course, and whole-class discussions were made on OLIVES with argumentation about the subject of the experiment to be done that week. In this process, the researcher gave the students a case about the subject of the experiment or asked a question that would enable the students to participate in discussion at the determined day and time. The students discussed the case given by the researcher, the theoretical knowledge about the case and how would be the experiment done. During the discussion, the researcher asked questions such as "What do you think about your friend's opinion?" "Why do you think so?", "How do you know?" to help students engage in argumentation and encourage them to support their claims and justifications (Erduran et al., 2004). The students were also able to continue the discussion asynchronously outside the determined time. In the course time, the students performed the related experiment with groups of four students in line with the online discussions. The activities performed by the students in open-ended experiments are given in Figure 1. The students uploaded the lab reports they prepared individually within a week to the OLIVES. Then the researcher announced the evaluations of these reports and provided feedback to the students through the system. After the intervention both the experimental and control group students took the post-test.

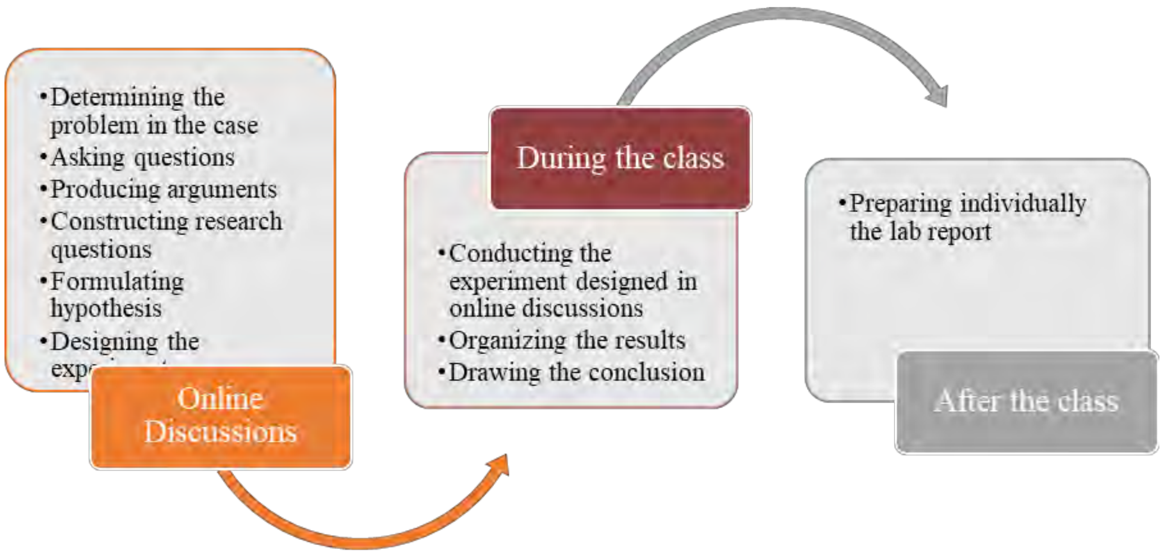

Figure 1. The activities in open-ended experiments

2.3.2 Laboratory Activities in Control Group

The control group students engaged in traditional laboratory instruction. They did their experiments following the handouts given by the researcher. The name of the experiment, the objectives and the research questions, the materials to be used, how to use them, the steps of the experiment were explained in the handouts. The students individually prepared their lab reports within a week after the experiment. The activities performed by the students in the traditional laboratory instruction are given in Figure 2.

The researcher assessed the reports and provided feedback to the students.

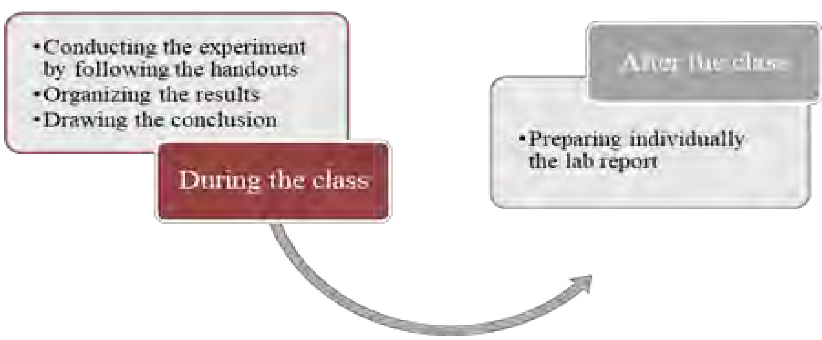

Figure 2. The activities in the traditional laboratory instruction

2.4 Data Collection

The achievement of pre-service science teachers in laboratory course was measured by the Basic Electricity Achievement Test (BEAT). The test was developed by the researcher in the following steps:

A test include 19 multiple-choice questions related to the subjects in experiments GPLC was developed. Later, three academicians in science education department reviewed the questions of the test and they examined the content validity of the test. Changes were made according to the suggestions of the experts. The test was given 67 pre-service science teachers previously taken GPC and GPLC. ITEMAN software was used for item analysis for the pilot test. Problematic questions were excluded. The final version of the test included 14 items. The Kuder Richardson-20 (KR-20) value of the test is .68.

To determine the argumentation abilities of the students, the arguments related to experiments produced during the online argumentation were analyzed.

2.5 Data Analysis

Independent-Sample t-test was used to determine whether there was any significant difference between the mean scores of control group and the experimental group regarding the achievement in laboratory course.

The change in the argumentation abilities of the students in experimental group was analyzed through qualitative data analysis software, NVivo 11. The Toulmin argument model (Toulmin, 1990) was used firstly to divide the arguments produced during the online argumentation into components. Data, claim and warrants were the basic items in the Toulmin Model. Rebuttals, backing and qualifiers are subsidiary items of the argument (Toulmin, 1990). Secondly, the arguments produced by the students were put into levels based on the framework for the assessment of the quality of argumentation developed by Erduran et al. (2004). The arguments generated in each online argumentation session (total of 5 weeks) were examined. The framework for the assessment of the quality of argumentation is given in Table 1.

Table 1. The analytical framework for the assessment of the quality of argumentation (Erduran et al., 2004; pp. 928)

Levels	Description
Level 1	Consists of arguments that are a simple claim versus a counterclaim or a claim versus claim
Level 2	Arguments consisting of claims with either data, warrants, or backings, but do not contain any rebuttals.
Level 3	Arguments with a series of claims or counterclaims with either data, warrants, or backings with the occasional weak rebuttal.
Level 4	Arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counterclaims as well, but this is not necessary.
Level 5	Displays an extended argument with more than one rebuttal.

3 Results

3.1 Effects of the online argumentation in open-ended physics experiment on achievement

The students' pre-test and post-test mean scores of BEAT were analyzed using the independent sample t-test. There was no significant difference between the pre-test mean scores of the groups ($X_{experimental} = 3.41$, $X_{control} = 3.73$, $t_{53} = -.77$, $p > .05$). The results of the independent sample t-test indicate that there was a significant difference between the experimental group and control group in the post-test mean scores of the BEAT (Table 2).

Table 2. Independent-sample t-test results from post BEAT

Groups	N	Mean	SD	t	df	p
Experimental	29	9.34	1.26	3.97	53	.00
Control	26	7.73	1.73			

3.2 The change in argumentation abilities of experimental group students

The students' each argumentation sessions were divided into two parts according to their arguments in online argumentation. In the first part, the students engaged in argumentation to find a solution to the problem in the case about the subject of the experiment. In the second part they engaged in argumentation about how to design the experiment to find a solution to the problem.

The arguments produced by the experimental group students in two parts of the online argumentation sessions were classified into levels; Level 1, 2, 3, 4, 5 respectively. There were no arguments in Level 1 and Level 4. Examples of the arguments in levels are given below:

Level 2:

S 27: "*The colors and bands on the resistor show the value of the resistor. From left to right, the first and the second color gives the first two digits of the resistance value. The* *third band represents the multiplier or the exponential number, and the fourth color signifies the tolerance or error percentage. We can solve the problem with the help of this information."* (Data)

S 11: "*When we try to find the resistance of 44 ohms by calculating according to the codes of the colors, the value of the resistor with colors; yellow-purple-orange-gold is 47, so the closest result to our 44 is 47*." (Data-Warrant-Claim)

S27: "*I found the value 40 with the colors; "grey-gold-gold-gold" with tolerance %5*" (Claim-Warrant)

S12: "*I calculated and found 47 ohms with the resistor that have the colors "yellow-purple-orange- gold*". (Claim-Warrant)

S25: *From where do I start reading the value of the resistor?*

S24: *We read the resistor from left to right band.* (Data)

S18: *If a resistor has a band with a gold or silver color we have a tolerance %5 or %10. The value of the resistor with the colors yellow-yellow-orange-gold is 44*" (Data- Claim)

Level 3:

S9: *I think that thick wire should be used for good conductivity the material to be used should be copper. It should be copper because copper is a good conductor of electricity, as well as a material that bends easily and is resistant to corrosion*. (Claim-Data-Warrant)

S6: *There is a direct relationship between the length of the wire and the amount of the resistance. If the length of the wire increases, the amount of the resistance increases. If the length of the wire decreases, the amount of the resistance also decreases. For the amount of the resistance to be low, the length of the wire must be short*. (Data-Warrant)

There is an inverse proportion between the cross-sectional area and the resistance. If the cross-sectional area of the wire is wider, there will be the lower amount of resistance. Therefore, the cross-sectional area must be wider. (Data-Warrant-Claim)

If we want the resistance to be low, the wire should be thick and the length of the wire should be short. In addition, the resistivity is directly proportional to the resistance. Copper wire should be chosen since it is the copper wire with the lowest resistivity among the written materials. (Claim-Data-Warrant)

S20: *I also think that copper should be used because it is low in cost, easy to form and copper is the best in terms of conductivity after silver*.

I think that the length of the wire to be used for the resistor should be short and the cross-sectional area thin.

S27: *Thin??? The cross sectional area should be wide, not thin. (Claim-Rebuttal)*

S20: Sorry dear friends, I wrote thin for the cross-sectional area of the wire, it should be wide. (Rebuttal)

S17: *Dear friends, actually, we say copper, but it also writes copper-tin alloy in the question, I think tin can affect the conductivity of copper*. (Rebuttal)

S10: *Bronze is an alloy that contains copper and tin, harder and more durable than copper*. (Data)

This Level 3 argumentation is more complex than Level 2 argumentation example. Because it contains rebuttals. The claim "I think that the length of the wire to be used for the resistor should be short and the cross-sectional area thin." is weakly rebutted with a counterclaim. And another rebuttal is used by S17 about the material and the conductive ability of that material.

Level 5:

In the last argumentation session, the students produced arguments about what they would do when they wanted to create different lighting environments in their rooms at different times. The Level 5 argumentation example about this problem is below:

S2: *For example, there is a bulb called Alba, and this bulb gives off light in cold and natural white tones in the first hours of the morning, and gradually transitions to warmer tones during the day. it starts to give light with the help of various sensors on it, for example, the motion sensor...* (Data-Claim)

S8: *Arzu, you said that this light bulb turns off when there is no noise and in the moment of inactivity, but how will this work while studying*? (Rebuttal)

S2: *While studying, there is movement in the environment, you write or turn the pages. And there are people who study aloud.* (Warrant- Rebuttal)

S8: *It varies from person to person. Therefore, this is not suitable for everyone.* (Warrant-Rebuttal)

S11: *The Alba bulbs are very suitable for this situation, but their cost is very high. Instead, we can use dimmer switches, and they are more suitable economically than Alba bulbs. A dimmer switch is installed instead of the existing switch on the wall, and we can use our lighting at the brightness setting we want, thanks to this. Dimmers are used with standard filament bulbs. According to my research, some brands also have dimmer-enabled energy saving bulbs, but these are also expensive in terms of cost.* (Claim-Rebuttal-Data)

In this example of Level 5 argumentation, the students used several rebuttals and they supported their rebuttals with data and warrants.

The argument levels of experimental group students' arguments in the argumentation sessions of the experiments are given in Table 3.

Table 3. The argument levels of experimental group students' arguments

Experiments	Part 1 Argument Levels	Part 2 Argument Levels
Resistance Measurement	Level 2	Level 2
Series and parallel connection	Level 2	Level 2
Factors affecting resistance	Level 3	Level 3
Ohm's Law	Level 3	Level 2
Lamp Circuits	Level 5	Level 2

4 Discussion and Conclusion

According to the results of the Basic Electricity Achievement Test (BEAT), we found that the students in the experimental group engaged in online argumentation in open-ended experiments had higher scores of achievement test than the control group students participated in traditional laboratory activities and that difference was significant. In addressing the first research question, we would indicate that online argumentation in open-ended physics experiments increased the students' academic achievement in the physics laboratory. Similar results were reported in relevant literature (Chen & She, 2012; Lim et al., 2008; Yeh & She, 2010; Zengin, Keçeci & Kırılmazkaya, 2011). There are many reasons for the positive impact of online argumentation in open-ended physics experiments on achievement. Simultaneous consideration and coordination occur in the work on the task when the students synchronously engaged in argumentation (Janssen et al., 2006). During the discussions, the students had a chance to gain a different viewpoint when their peers made counter arguments. They searched on the web about the theoretical background of the knowledge of the subject in the case given or the question asked by the instructor to support their arguments and they acquired new information and data about the subject. That enabled them to evaluate the validity and reliability of the claims and evidence. They also had a chance to change their misconceptions about the subject. Because, when they mentioned something incorrect about the theoretical background of the subject, their peers refuted that argument with the warrants and data. The students had time to understand the counter arguments and reflect their contributions when they asynchronously engaged in argumentation. That helps students construct individual knowledge (Schellens & Valcke, 2006). In the traditional laboratory method, students conducted their experiments by following the handouts given to them and the theoretical background of the subject of that experiment given in the handouts directed them to the result. Meaningful science learning occurs when students determine the problem related to a phenomenon, identify the things that they know and they do not know, search for solutions to solve the problem and reconstruct their scientific knowledge (Chin & Brown, 2000). In confirmatory experiments, the students did not have a chance to discuss the problem and determine the things that they know or do not know, explain what they think, and why they think that way and construct their knowledge. They only measured, recorded the data and proved the conclusion of the experiment given in the handouts.

The results demonstrate that students' argumentation ability improved throughout the intervention in the first part of the argumentation sessions when the students discussed the solution to the problem. This result is consistent with relevant literature (Cheh & She, 2012; Choi & Hand, 2020; Clark & Sampson, 2007; Yeh & She, 2010). Students' argumentation levels increased from level 2 to level 5 throughout the experiments. The students determined the problem in the case given by the researcher, constructed claims about it, read and evaluated the claims constructed by their peers, used evidence for their arguments and counter arguments during online argumentation. The synchronous discussion allowed students to get quick feedback on argumentation (Clark et al., 2010) and they reconstructed their arguments. High-quality argumentation includes rebuttals (Aufschnaiter et al., 2008; Erduran et al., 2004). Level 3 and level 5 arguments of the students includes rebuttals. This is the indicator of the positive change in the quality of students' arguments from the first subject to the fifth. The students had more time to produce well thought of and higher quality arguments during asynchronous argumentation. There are also inconsistent results with the results of the current study (Kelly et al., 1998; Watson et al., 2014). A difference in the sample might be the reason for different results. Kelly et al. (1998) studied with high school students and Watson et al. (2014) with 8th-grade students. And, the most important difference is that this study was conducted with online argumentation. Kelly et al. 's (1998) study and Watson's (2014) study were conducted with face-to-face discussions. Participating in online learning environments provide students more opportunity to engage in discussions and to learn science rather than face-to-face settings (Clark& Sampson, 2007; Clark and Sampson 2008; Hsi & Hoadley, 1997; Schellens & Valcke, 2006; Tsai, 2015).

However, our results indicate that students' argumentation ability do not develop throughout the intervention in the second part of the argumentation sessions when they discussed the design of the experiment. A possible explanation for that situation might be the working mode of the task. The modes are 'experimenting', 'hypothesizing', and 'co-ordination and evaluation' in an experiment, students strictly work in one mode, and it is difficult to change the mode from one to another (Kind et al., 2011). In our study, similarly, students spent most of the time discussing the problem in the task and the theoretical background of the subject. Although the instructor asked them to discuss the design of the experiment they continued to produce arguments in the first part of the argumentation session until a time. Another finding of Kind et al. (2011) is that generating claims, supporting them with data, and using rebuttals decline at a time before arriving at a plateau. That time for our study might be when students engage in the argumentation in planning about the design of the experiment.

5 Limitations and Future Research

This was a small-scale research to investigate the effectiveness of online argumentation in open-ended physics experiments on academic achievement and argumentation abilities therefore the generalization of the result could be limited. The other limitation of this study was that only the arguments of the students in online argumentation were analyzed and only before doing the experiment. Future research can be conducted to examine the argumentation ability of students by analyzing the arguments of students both in face-to-face and online argumentation in open-ended physics experiments. Also, comparative research examining the effect of online argumentation on argumentation abilities both before and after doing the experiment would be useful.

It was concluded that students' argumentation ability did not develop throughout the intervention in the second part of the argumentation sessions when they discussed about the design of the experiment in our study. Examining the arguments about the design of the experiment in-class time would be recommended for the researchers to implement this process.

The change in the argumentation abilities of students engaged in online argumentation in open-ended physics experiments was examined in the current study. Students' arguments were analyzed through Erduran et al.'s (2014) analytical framework for the assessment of the quality of argumentation. A follow-up study that includes additional assessment tools, for example; a subject dependent argumentation test to determine the quality of argumentation can be conducted. In this way, the argumentation ability of the students both in the experimental group and control group could be compared. In addition, it would be useful to perform a study that contains the groups participated in the online argumentation in open-ended physics experiments instruction and argumentation in open-ended physics experiments without online argumentation sessions.

In the current study, the students took General Physics II Course (GPC II) when they took GPLC II at the same time. The importance of content knowledge in the quality of arguments was highlighted in different studies (Cross et al., 2008; Kelly et al., 1998, Sampson & Clark, 2011). Finally, further research can be conducted both before and after the GPC II to determine the quality of arguments.

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