THE IMPACT OF INQUIRY-BASED ONLINE LEARNING WITH VIRTUAL LABORATORIES ON STUDENTS' SCIENTIFIC ARGUMENTATION SKILLS

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ABSTRACT

Scientific argumentation is a higher-order thinking skill that is a major focus in education in the 21st century. This is a skill that plays an important role in knowledge construction which in reality is rarely implemented in science learning. The facts show that most students have low scientific argumentation skills and still need to be improved. In improving scientific argumentation skills, the learning design used must give students more opportunities to build and criticize arguments, make claims, and use evidence in the process of reasoning based on inquiry activities. Based on the results of previous research, it is known that inquiry-based learning has extraordinary potential in developing students' scientific argumentation skills. Interestingly, no research has been found that reveals the effect of inquiry-based online learning on students' scientific argumentation skills. Therefore, this study aims to determine the impact of inquiry-based online learning with a virtual laboratory on students' scientific argumentation skills. This study uses a one-group pretest-posttest design with n-gain analysis. The results of this study indicate that the application of inquiry-based online learning with a virtual laboratory can improve students' scientific argumentation skills. Uniquely, this only significantly impacts the claim, evidence, and reasoning components, but not the counterclaim and rebuttal components.

Keywords: Scientific argumentation skills, online learning, inquiry-based online learning, virtual laboratory.

INTRODUCTION

The era of disruption confronts students with the realities of 21st-century life which are full of volatility, uncertainty, complexity, and ambiguity. Educational institutions need to produce students who are ready and able to adapt to such an environment (Seow et al., 2019). Therefore, students must be equipped with the skills and competencies needed, one of which is scientific argumentation skills (Haug & Mork, 2021; Lobczowski et al., 2020; Noroozi et al., 2020; Noviyanti et al., 2019).

Scientific argumentation is a higher-order thinking skill that is the main focus of education in the 21st century (Guilfoyle & Erduran, 2021; Noviyanti et al., 2021). This is also one of the core practices that must be implemented in science learning (Loper et al., 2019; Mao et al., 2018; Mikeska & Lottero-Perdue, 2022). This is because scientific argumentation skills affect conceptual understanding (Greene et al., 2018; Jin & Kim, 2021; Larrain et al., 2019; Ping et al., 2020; Rahayu et al., 2020), are related to critical thinking skills (Convertini, 2021; Giri & Paily, 2020; Hong & Talib, 2018; Kuhn, 2019), can promote scientific literacy (Archila et al., 2018; Chen, 2019; Yacoubian & Khishfe, 2018), can improve scientific reasoning (Sari & El Islami, 2020), can develop analytical thinking skills (Perdana et al., 2019), can develop reflective thinking skills (Gulen & Yaman, 2019), can develop innovative thinking (Turabova, 2021), can support social collaboration (Henderson et al., 2018), can increase awareness of the surrounding environment (Faize & Akhtar, 2020), and is needed in expressing opinions, making decisions, and solving problems in everyday life (Songsil et al., 2019).

Scientific argumentation is a skill used to make, support, challenge, or enhance scientific claims that lead to validation and credible conclusions based on empirical data and evidence (Evagorou & Osborne, 2013; Lin & Mintzes, 2010; Songsil et al., 2019). This is described as what scientists do in building and defending their scientific ideas (Roviati & Widodo, 2019). Where scientific arguments are used by scientists to identify, resolve, and reduce uncertainty through debate and rejection of claims and evidence to build a collective understanding of a phenomenon fenomena (Bricker & Bell, 2008; Y.-C. Chen, 2020; Grooms et al., 2018; Lee et al., 2014). This is done through the use of language rhetorically or dialogically with most analytic frameworks focusing on claims, evidence, reasoning, counterclaims, and rebuttals (see Figure 1) (Schen, 2013; Xing et al., 2020).

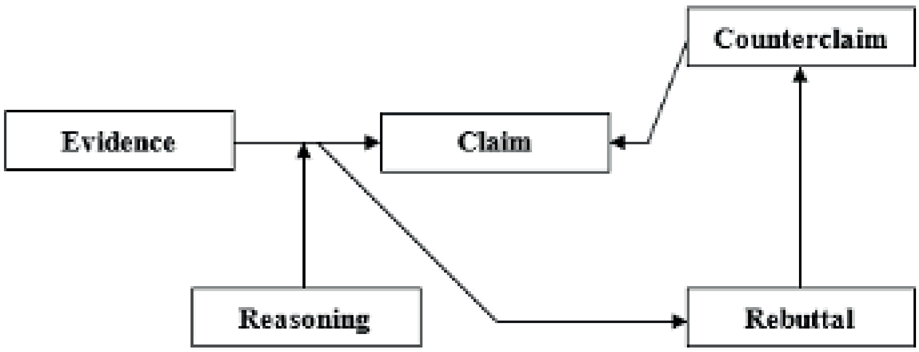

Figure 1. The Structure of Scientific Argumentation

Scientific argumentation is a skill that plays an important role in science, which is rarely applied in the science learning process (Kurniasari & Setyarsih, 2017; Muna & Rusmini, 2021; Rahayu et al., 2020). This resulted in the dominant quality of students' scientific argumentation skills at level 1, namely arguments consisting of simple claims and students sometimes making claims based on inaccurate conceptual understanding (Wardani et al., 2018). This statement is also reinforced by findings based on a preliminary study conducted at a public senior high school in Surabaya, Indonesia, which shows that the majority of students have scientific argumentation skills that are in the low category. Where, most students have been able to make claims quite well, but are not good enough at constructing evidence, reasoning, counterclaim, and rebuttal.

The findings from previous researchers and the results of preliminary studies indicate that students' scientific argumentation skills still need to be improved. In improving scientific argumentation skills, the learning design used must give students more opportunities to build and criticize arguments, make claims, and use evidence in the process of reasoning based on inquiry activities (Mikeska & Howell, 2020). Inquiry-based learning is defined as a multifaceted construction, which in the learning process integrates various components such as conceptual, social, procedural, and epistemological activities (Forbes et al., 2020) which can ultimately affect students' scientific argumentation skills.

Based on the results of previous research, it is known that inquiry-based learning has extraordinary potential in developing students' scientific argumentation skills (Akili et al., 2022; Andrews-Larson et al., 2019; Conn et al., 2020; Hendratmoko et al., 2016; Mariam et al., 2020; Muntholib et al., 2021; Nam & Chen, 2017; Pitorini et al., 2020; Psycharis, 2016; Rohayati et al., 2022; Roja et al., 2020; Sandhy et al., 2018; Septyastuti et al., 2021; Stanford et al., 2016). Where most of the research was conducted in the implementation of inquiry-based offline learning. In other words, there has not been any research that reveals the effects of inquiry-based online learning on students' scientific argumentation skills.

Online learning is a form of distance education that involves the use of technology as a mediator in the learning process and learning is fully delivered via the internet (Heng, 2021; Siemens et al., 2015). Online learning has proven to be quite helpful in carrying out learning in various conditions, such as disasters and pandemics such as Covid-19 (Dhawan, 2020). This shows that online learning offers effectiveness and flexibility in learning activities. Where online learning is also quite effective in supporting student inquiry activities (Williams et al., 2017), this is done with the help of a virtual laboratory. According to Romano et al. (2021), a virtual laboratory can be seen as a technologically enriched environment to support students' scientific argumentation skills.

Based on the previous explanations, it is known that inquiry-based online learning with virtual laboratories seems to be able to provide convenience, flexibility, and effectiveness in improving students' scientific argumentation skills. Therefore, this study aims to reveal the impact of inquiry-based online learning with a virtual laboratory on students' scientific argumentation skills.

Purpose of Study

This study used a one-group pretest-posttest design. According to Ventura et al. (2021), one-group pretest-posttest design is a study conducted in one group, internal validity is limited and there is no control group. According to Sugiyono (2014), the one-group pre-test-posttest design is described as shown in Figure 2.

METHOD

Design

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Figure 2. Research Design

The pretest is used to determine students' initial scientific argumentation skills before being given treatment. While the posttest is used to determine students' final scientific argumentation skills after being given treatment. The pretest and posttest scores are then used as a reference in measuring and determining the increase in students' scientific argumentation skills after being given treatment.

The treatment given is the implementation of inquiry-based online learning with a virtual laboratory in science learning. The implemented learning activities are adapted from the inquiry-based lesson (Arends, 2012) which are integrated with the virtual laboratory of PhET Interactive Simulations. The learning activities are divided into three main activities, that is opening online learning, inquiry with a virtual laboratory, and discussion and reflection. The learning steps carried out are presented in Table 1.

Table 1. The Steps of Inquiry-Based Online Learning with a Virtual Laboratory

Phase	Sub Phase	Activity
Opening online learning	Preparation and explanation of the inquiry process.	The teacher opens virtual learning activities through video conferencing by conveying the objectives and learning process.
	Giving problems to be investigated	The teacher divides students into several groups and provides problems related to science and its implementation through student worksheets.
Inquiry with virtual laboratory	Formulate hypotheses	The teacher divides the video conference into several breakout rooms according to the student groups and encourages students to formulate hypotheses or claims for the problems given. Claims that are formulated will direct students to inquiry activities.
	Collecting data	The teacher encourages students to design and conduct experiments using the virtual laboratory of PhET Interactive Simulations to obtain evidence to support the claims that have been made.
	Formulate reasoning and/or conclusions	The teacher asks students to formulate reasoning and/or conclusions based on experimental data. The reasoning made must show the connection between claims and evidence based on related scientific concepts/laws/theories.
Discussion and reflection	Discussion	All students are directed to return to the main video conference room. The teacher guides students to discuss the conclusions of the experiments that have been carried out. In this phase, it is directed to bring up counterclaims and rebuttals based on arguments from the conclusions that have been made.
	Reflection	The teacher asks students to rethink what they have learned. In these steps, the teacher makes students think about their thinking processes and reflect on the inquiry process.

Participants

This study was conducted on science classroom students using a relatively small sample. This was done to optimize the treatment given during the study. The participants were randomly selected using a simple random sampling technique. According to Acharya et al., (2013), the use of simple random sampling allows each individual to have the same opportunity to be selected as the research sample and has the advantage of the ease of data analysis.

The participants of this study were 16 students of grade XII at a public senior high school in Surabaya, Indonesia. The students consisted of 6 male students and 10 female students aged between 16-17 years old. These students will take part in inquiry-based online learning with a virtual laboratory for 6 meetings. Where the first and last meetings were used as a pretest and posttest of scientific argumentation skills.

Data Collection and Analysis

The data collected and analyzed in this study were the pretest and posttest scores of students' scientific argumentation skills. The pretest scores of students' scientific argumentation skills were measured before students took inquiry-based online learning with a virtual laboratory. The posttest scores of students' scientific argumentation skills were measured after students participated in inquiry-based bold learning with a virtual laboratory. Scientific argumentation skills are measured based on a written scientific argumentation test which includes 5 components, that is claims, evidence, reasoning, counterclaims, and rebuttals. The score obtained from each indicator is used as the basis for determining the final score of scientific argumentation skills. The assessment of the student's scientific argumentation skills test is based on the rubric of the assessment of the scientific argumentation skills test with a range of 0 – 3. The method of calculating the final score is written as follows.

$$\text{Final score} = \frac{\text{total score of all components}}{\text{max score}} \times 3$$

The final score obtained by students is then used as the basis for determining the category of students' scientific argumentation skills. The categories of students' scientific argumentation skills are presented in Table 2.

Table 2. Category of Students' Scientific Argumentation Skills

Score	Category of Students' Scientific Argumentation Skills
0.00 – 0.75	Beginner
0.76 – 1.50	Intermediate
1.51 – 2.25	Advanced
2.26 – 3.00	Proficient

The scientific argumentation skill scores obtained from the pretest and posttest were then analyzed using normalized gain (n-gain). N-gain can be calculated using the following equation.

$$n - gain = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Max Score} - \text{Pretest Score}}$$

N-gain is used to determine the increase in students' scientific argumentation skills after being given treatment. According to Hake (1999), the results of the n-gain calculation are then converted with the following criteria (see Table 3).

Table 3. Category N-Gain Students' Scientific Argumentation Skills

Score	Category of n-gain
$0.70 < \text{n-gain}$	High
$0.30 \leq \text{n-gain} \leq 0.70$	Medium
$\text{n-gain} < 0.30$	Low

The treatment given, that is inquiry-based online learning with a virtual laboratory is said to have a positive impact if the average n-gain score is at least in the medium category. The use of n-gain can also be used to analyze the improvement of each indicator of scientific argumentation skills before and after participating in inquiry-based online learning with a virtual laboratory.

FINDINGS

Students' scientific argumentation skills were assessed using a scientific argumentation skill test given before and after participating in inquiry-based online learning with a virtual laboratory. The results of the scientific argumentation skills test, both pretest, post-test, and n-gain scores of scientific argumentation skills are presented in Table 4.

Table 4. The Results of Student's Scientific Argumentation Skills Test

Student	Pretest							Posttest							Enhancement	
	C	E	R	Cc	Rb	FS	Category	C	E	R	Cc	Rb	FS	Category	<g>	Category
1	2	2	1	0	0	1	Intermediate	3	3	3	1	1	2,2	Advanced	0,6	Medium
2	2	2	2	1	1	1,6	Advanced	3	3	2	2	1	2,2	Advanced	0,43	Medium
3	2	2	1	1	0	1,2	Intermediate	3	3	2	1	0	1,8	Advanced	0,33	Medium
4	2	2	1	1	0	1,2	Intermediate	3	3	1	1	0	1,6	Advanced	0,22	Low
5	3	3	1	1	0	1,6	Advanced	3	3	3	1	0	2	Advanced	0,29	Low
6	1	1	1	0	0	0,6	Beginner	2	2	2	1	1	1,6	Advanced	0,42	Medium
7	2	1	1	0	0	0,8	Beginner	3	3	2	0	0	1,6	Advanced	0,36	Medium
8	3	2	1	0	0	1,2	Intermediate	3	3	2	1	0	1,8	Advanced	0,33	Medium
9	2	2	1	1	1	1,4	Intermediate	3	3	1	2	1	2	Advanced	0,38	Medium
10	1	1	1	0	0	0,6	Beginner	3	3	3	2	1	2,4	Proficient	0,75	High
11	2	2	2	1	0	1,4	Intermediate	3	3	2	1	1	2	Advanced	0,38	Medium
12	2	2	2	0	0	1,2	Intermediate	2	2	2	1	0	1,4	Intermediate	0,11	Low
13	3	1	1	0	0	1	Intermediate	3	2	1	1	0	1,4	Intermediate	0,2	Low
14	2	1	1	2	1	1,4	Intermediate	3	3	3	2	1	2,4	Proficient	0,63	Medium
15	2	1	1	1	1	1,2	Intermediate	3	2	2	1	0	1,6	Advanced	0,22	Low
16	1	1	1	0	0	0,6	Beginner	3	3	3	0	0	1,8	Advanced	0,5	Medium
Ave.	2	1,6	1,2	0,6	0,3	1,1	Intermediate	2,9	2,8	2,1	1,1	0,4	1,9	Advanced	0,38	Medium

Note: C = Claim; E = Evidence; R = Reasoning; Cc = Counterclaim; Rb = Rebuttal; FS = Final Score; <g> = n-gain Score

Based on the data in Table 4 it is known that the average score of students' initial scientific argumentation skills is in the intermediate category. Then after being given treatment the average score of students' final scientific argumentation skills is in the advanced category. This shows an increase in students' scientific argumentation skills after being given treatment. This increase is also reinforced by the average n-gain score which is in the medium category. The majority of the n-gain scores for students' scientific argumentation skills are also in the medium category, as presented in Figure 3. This shows that the treatment given has an impact on improving students' scientific argumentation skills.

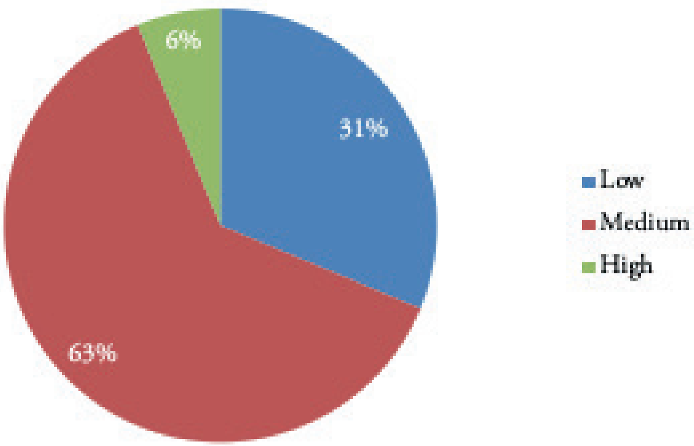

Figure 3. The N-gain Scores for Students' Scientific Argumentation Skills

Furthermore, the scientific argumentation skills test from the pretest and posttest were analyzed for each component. The results of the analysis of the scientific argumentation skills test for each component, that is claim, evidence, reasoning, counterclaim, and rebuttal are presented in Table 5.

Table 5. The Score of Each Component of Students' Scientific Argumentation Skills

Component	Pretest		Post-test		Enhancement	
	Average Score	Category	Average Score	Category	n-gain Score	Category
Claim	2.00	Advanced	2.875	Proficient	0.875	High
Evidence	1.625	Advanced	2.75	Proficient	0.82	High
Reasoning	1.1875	Intermediate	2.125	Advanced	0.52	Medium
Counterclaim	0.5625	Beginner	1.125	Intermediate	0.23	Low
Rebuttal	0.25	Beginner	0.4375	Beginner	0.07	Low

The counterclaim and rebuttal components have a fairly poor average score compared to the other three components. This is also reinforced by the average n-gain score which is only in the low category. The comparison of average pretest and posttest scores for each component of students' scientific argumentation skills is presented in Figure 4.

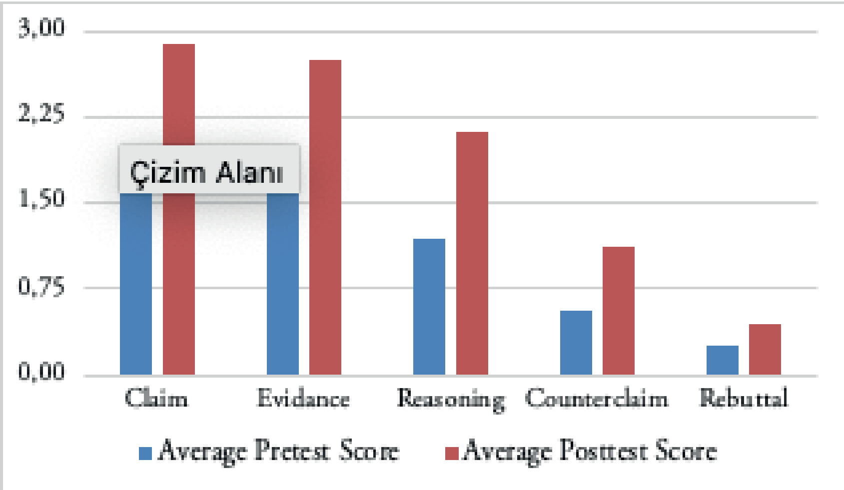

Figure 4. Comparison of Each Component of Students' Scientific Argumentation Skills

DISCUSSIONS AND CONCLUSION

Scientific argumentation is a key component in developing students' knowledge (Ho et al., 2019), especially in science learning practices (Osborne et al., 2019). Where one of the focus points of learning science is to develop students' skills to actively participate in discussions and build scientific argumentation (Tsai, 2018). These skills emphasize the importance of students' social and epistemic interactions for the purpose of developing and critiquing knowledge (Grooms et al., 2018).

Since ancient times, when philosophers started looking for reasons for things, argumentation reached a fundamental position in the construction of knowledge and public debate (Torres & Cristancho, 2018). The concept of scientific argumentation has subsequently become an attraction among policymakers in various countries (Admoko et al., 2021; Henderson et al., 2018). Scientific argumentation has also become a central issue in various studies and research related to science learning in recent years (Kim & Roth, 2018; Nazidah et al., 2022; Valero Haro et al., 2019; Wang et al., 2022; Wulandari et al., 2019). These studies mostly focus on implementing effective learning designs or strategies in improving students' scientific argumentation skills (Ault et al., 2015; Henderson et al., 2018; Osborne et al., 2019; Ping et al., 2020; Sampson et al., 2011). This is what was done in this study, which is investigating the impact of inquiry-based online learning with a virtual laboratory on students' scientific argumentation skills.

Inquiry-based online learning with a virtual laboratory has been proven to improve students' scientific argumentation skills (see Table 4). This is evidenced by the average n-gain score for students' scientific argumentation skills which is 0.38 or is in the medium category. In addition, the majority of the n-gain scores for students' scientific argumentation skills are also in the medium category (see Figure 3). According to (Hake, 1999), a treatment is said to have a positive impact if the n-gain score is at least in the medium category.

Online learning is defined as a learning experience in a synchronous or asynchronous environment using different devices (eg, mobile phones, laptops, etc.) with internet access (Dhawan, 2020). Learning activities that offer this flexibility have developed rapidly over the last decade in most parts of the world (Adnan, 2020; Bayrak et al., 2020; Pei & Wu, 2019). This is also due to the effectiveness of online learning on student learning outcomes (Maness et al., 2023; Panigrahi et al., 2018; Pei & Wu, 2019; Purba, 2020) and the acquisition of higher-order thinking skills (Coman et al., 2020; Dumford & Miller, 2018; Fiock, 2020), especially scientific argumentation skills (Y.-R. Lin et al., 2020; Yeh & She, 2010) as the results of this study.

Inquiry-based online learning with a virtual laboratory which is the focus of this study was developed by adapting inquiry-based lessons (Arends, 2012). Learning is carried out through 3 main activities, namely opening online learning, inquiry with a virtual laboratory, and discussion and reflection (see Table 1). Where learning activities are carried out through video conferences and inquiry activities in the learning process are facilitated with a virtual laboratory from PhET Interactive Simulations. These learning activities are illustrated in Figure 5.

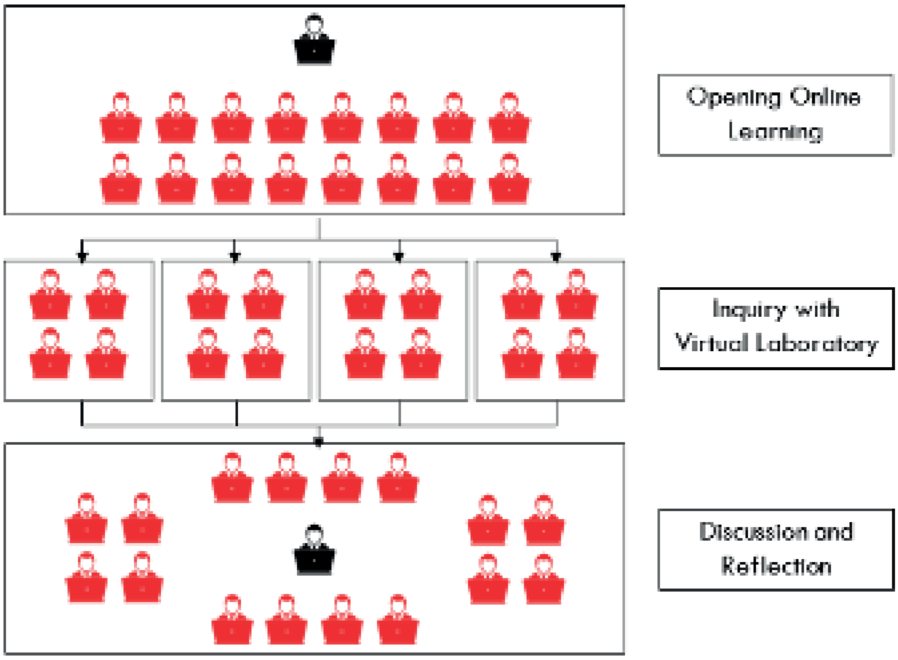

Figure 5. The Design Inquiry-Based Online Learning with Virtual Laboratory

Online learning activities begin with the teacher opening virtual learning via video conferencing. The activity is directed at preparing students and providing an explanation regarding the inquiry process that will be carried out. The teacher conveys the objectives and the learning process that will be carried out. The results of the study show that the delivery of learning objectives can provide a focused mindset for students who are involved in learning (Mitchell & Manzo, 2018). This is the earliest strategy that must be carried out by every teacher because the benchmark for the learning interaction itself departs from the opening learning strategy (Ginting, 2017). In addition, in this initial activity, the teacher also conveyed apperception and motivation to students. Providing apperception and motivation is important for the teacher to do so that students are interested in learning more about the context and content of learning (Rakhmawati, 2016). This is reinforced by the theory of learning motivation which states that for students to be successful in learning, students must be able to take strong initiatives and generate persistence in learning (Arends, 2012). Students must also focus on mental resources, focus on the stimulus provided, and pay attention to the instructions given by the teacher (Moreno, 2010; Santrock, 2011; Woolfolk, 2016). Therefore, focusing and motivating students at the beginning of learning activities is a must to optimize students' scientific argumentation skills.

After students are ready to participate in learning activities, the teacher then divides students into several groups and provides problems related to science and its implementation through student worksheets. The problems given are contextual. Previous findings show that giving problems before the learning process can improve student readiness and learning outcomes (Jayadiningrat et al., 2017). Providing contextual problems at the beginning of learning can help students solve problems with strategies they understand, this is because they can see the relevance of the material being studied to their daily lives and use initial knowledge that is appropriate to the problems at hand (Mulyati, 2016). The problems given are used as a stimulus in encouraging students to carry out inquiry activities. Where inquiry activities are directed at facilitating and improving students' scientific argumentation skills consisting of claims, evidence, reasoning, counterclaims, and rebuttals.

The next step is an inquiry activity with a virtual laboratory. At this step, students are guided to formulate hypotheses, collect data, and formulate reasoning and/or conclusions. Where in this activity, the teacher divides the video conference into several breakout rooms according to student groups. Students carry out inquiry activities through virtual laboratories from PhET Interactive Simulations.

Inquiry activities begin with students formulating hypotheses on the problems given. The formulated hypothesis will direct students to inquiry activities. Formulation of hypotheses is also directed at facilitating students in making claims about a problem. Just as in constructing hypotheses, understanding the learning material is one way for students to be able to make good claims (Ariyanti et al., 2021). In making claims students need to carry out discussions in their groups. Discussion is a way of presenting learning materials in which educators provide opportunities for students or groups of students to hold scientific discussions in order to collect opinions, make claims, make conclusions, or compile various alternative problem-solving (Junita & Siregar, 2018).

The treatment given in the hypothesis formulation activity proved effective in improving students' scientific argumentation skills on the claim component (see Table 5). The average pretest and posttest scores for the claim component have a significant difference (see Figure 4). The increase in the claim component is in the high category with an average n-gain score of 0.875. The final average score of students on the claim component is in the proficient category. This shows that in scientific argumentation, students have been able to make good claims about the problems given.

The treatment given in the hypothesis formulation phase guides students to explore and use prior knowledge that they already have in making claims on the problems given. In addition, an understanding of the problem can also affect the resulting claims. Therefore, students are directed to discuss making claims. Through discussion activities, there is a process of exchanging information and knowledge between students regarding the problems given.

Based on the claims that have been formulated, students are directed to activities to collect data. Students are encouraged to carry out inquiry activities by designing and conducting experiments with virtual laboratories. Inquiry activities have a positive effect on students to control their learning process through experimentation (Rutten et al., 2015), in this case, scientific argumentation skills. In addition, the positive impact of inquiry activities in the learning process can also arouse student activity in participating in learning and can increase student interest in learning (Pardimin et al., 2021). On the other hand, virtual laboratories make learning more meaningful by enabling the concretization of abstract subjects, supporting interest, bringing joy, and motivating students towards learning science (Yildirim, 2021). Inquiry-based virtual laboratories provide opportunities for students to construct conceptual understanding through simulation activities and virtual practicum. Learning using inquiry-based virtual laboratories can foster self-confidence and develop students' creative thinking skills and critical thinking (Junaidi et al., 2016). Critical thinking skills are the basis for building scientific arguments.

Falk & Brodsky (2013) stated that inquiry activities can support students in building scientific argumentation. Scientific inquiry is an important part of scientific argumentation which is intended to produce evidence and rational justification (Muntholib et al., 2021). Inquiry activities through experiments using virtual laboratories are carried out to collect data as evidence to strengthen claims. Evidence is the second component of scientific argumentation skills. Based on the research results, it is known that inquiry activities through experiments with virtual laboratories can improve students' scientific argumentation skills on the evidence component. The evidence component experienced an increase in the high category with an average n-gain score of 0.82 (see Table 5). The average pretest and posttest scores for the evidence component have a significant difference (see Figure 4). The average student's final score for the evidence component is in the proficient category. This shows that in scientific argumentation, students have been able to provide strong evidence to substantiate their claims.

Data or scientific evidence that has been collected based on inquiry activities with a virtual laboratory is then analyzed by students. An analysis is part of an important cognitive ability, analysis is used to identify actual intentions and conclusions between sentence relationships, questions, structures, concepts, descriptions, opinions, reasons, information, and explanations (Facione, 2011). Data analysis was carried out to produce reasoning which is the third component of scientific argumentation skills.

Reasoning is one of the basic forms of simulated thinking, and the process of inferring new judgments (conclusions) from one or several existing judgments (premises) (Y.-C. Chen, 2020). According to Lawrence & Reed (2020), the task of understanding argument reasoning requires a system to use the given premises and conclusions to distinguish between two given alternative possibilities (there is also further contextual information available, with explicitly identified topics and backgrounds). In the context of scientific argumentation, the reasoning is used to show the relationship between claims and evidence based on related science concepts/laws/theories.

Based on the research results, it is known that the reasoning component has increased to the medium category with an average n-gain score of 0.52 (see Table 5). The average pretest and posttest scores for the reasoning component have a not-too-significant difference (See Figure 4). The average student's final score for the reasoning component is in the advanced category. This shows that in arguing scientifically students have been able to provide reasoning, but the reasoning given is not good enough. This also indicates that students have been able to show the connection between claims and evidence, but have not provided enough support with related science concepts/laws/theories.

Not enough good reasoning is produced by students because compiling reasoning requires a complex level of thinking, students must use higher-order thinking skills, such as critical thinking skills. Therefore, the teacher must guide students so they can make good reasoning. The guidance given can be in the form of an explanation regarding the structure of reasoning in scientific argumentation. Where in scientific argumentation, the reasoning is an explanation that shows the connection between claims and evidence based on related science concepts/laws/theories. Understanding of learning materials and interest in reading needs to be developed by students so that they can improve their ability to make a reasoning. Therefore, the teacher's role is very important to guide and direct students so that they want to develop an interest in reading and understand the learning material well (Ariyanti et al., 2021).

The next step of inquiry-based online learning activities with a virtual laboratory is discussion and reflection. This is the final phase of the learning activity. At this step, all students are directed to return to the main video conference room. The teacher guides students to discuss the conclusions of the experiments that have been carried out. This class discussion activity is expected to be able to facilitate counterclaim and rebuttal components.

The discussion process begins with the teacher asking one of the representatives from the student group to submit a claim to the problems given at the beginning of the lesson. The other groups were then asked to respond to these claims. In the activity of responding to each other, a claim that is contrary to the initial claim is known as a counterclaim. However, the results of this study indicate that the increase in the counterclaim component is in a low category with an average n-gain score of 0.23 (see Table 5). The average pretest and posttest scores for the counterclaim component have a not-too-significant difference (See Figure 4). The final average score of students on the counterclaim component is in the intermediate category. This means that the average student has not been able to produce a counterclaim that is in direct conflict with the initial claim so the arguments produced are at a low level. This is as stated by Erduran et al. (2004) who state that, when there is a debate among students but the debate consists only of unrelated counterarguments, this is considered a low-level argument.

As is the case with a counterclaim, students' skills to produce rebuttals have increased in the low category with an average n-gain score of 0.07 (see Table 5). The average pretest and posttest scores for the rebuttal component have a not significant difference (See Figure 4). The final average score of students for the rebuttal component is at the beginner level. This shows that students have not been able to produce rebuttals to the arguments given.

Counterclaims and rebuttals are key elements in argumentation, this is a skill to oppose arguments by presenting counterarguments. This is a significant component for determining the quality of an argument (Erduran et al., 2004) and when it is added, the argument becomes more complex (Anisa et al., 2019; Capkinoglu et al., 2020). It is an important skill, not easy to learn, and valued in many fields such as politics and science (Orbach et al., 2019).

Counterclaims and rebuttals are indicators of argumentation skills that are more complex than other components, so they require special treatment to experience optimal improvement. The low-quality improvement of counterclaims and rebuttals in this study indicates that discussion activities are not sufficient to facilitate this. Therefore, to produce a good counterclaim and rebuttal quality, it is necessary to present a debating method in the learning process. Debate in learning activities encourages students to convey, refute, and defend ideas or opinions (Al Giffari et al., 2021; Darman, 2022; Wagu & Riko, 2020). This is the practice of speaking skills and intelligent behavior in dealing with various points of view which are proven to be able to develop students' abilities to think critically, rationally, argumentatively, and creatively (Pudjantoro, 2015). The application of the debate method in science learning activities is proven to improve students' scientific argumentation skills (Dawson & Carson, 2017; Felgenhauer & Xu, 2019; Lytos et al., 2022; Martini et al., 2021; Mohammed et al., 2019; Suraya et al., 2019; Turabova, 2021).

The final step of inquiry-based online learning activities with a virtual laboratory is reflection. At this step, the teacher asks students to rethink what they have learned. Teachers get students to think about their thought processes and to reflect on inquiry processes. Although it does not contribute directly to students' scientific argumentation skills, reflection activities still need to be presented at the end of the lesson. According to Listiyani (2018), reflection activities are one of the basic process skills of students in concluding the learning process that is used to determine the extent of students' knowledge and achievements in understanding the material after participating in learning and conducting inquiry activities. Reflection in learning is needed for students to review what they have learned for improvement and deep learning. This allows students to document their learning journey and provide references and suggestions for the future (Chang, 2019).

In conclusion, the application of inquiry-based online learning with a virtual laboratory can be used to improve students' scientific argumentation skills. The increase in students' scientific argumentation skills on average is in the medium category with an average n-gain score of 0.38 (see Table 4). This means that inquiry-based online learning with virtual laboratories has a positive impact on increasing students' scientific argumentation skills. Students' scientific argumentation skills increased with a high category on the claim and evidence components. The reasoning components increased with the medium category. However, counterclaims and rebuttals increased with the low category. This means that the treatment given during the learning activities is not sufficient to facilitate counterclaim and rebuttal components. This is to the findings from Hendratmoko et al. (2016) which state that the implementation of inquiry-based learning has no significant impact on the counterclaim and rebuttal components. This is because these two components are components of more complex scientific argumentation skills that require higher critical thinking skills and reasoning processes. In addition, the stages in inquiry-based learning also cannot facilitate the development of counterclaim and rebuttal components.

The essence of scientific argumentation is to support claims with evidence and reasoning and then refute or refute the opponent's claims and evidence (Woolfolk, 2016). As this study concludes, supporting claims with evidence and reasoning can be facilitated through inquiry-based learning. However, to produce a counterclaim and rebuttal of the opponent's claims and evidence it is not enough just to apply the discussion method to learning activities. To facilitate these two components, it is necessary to present a debating method in learning activities. Where the debate method is proven to be able to improve students' scientific argumentation skills (Dawson & Carson, 2017; Felgenhauer & Xu, 2019; Lytos et al., 2022; Martini et al., 2021; Mohammed et al., 2019; Suraya et al., 2019; Turabova, 2021). Therefore, as a follow-up to this study, it is suggested to integrate inquiry-based learning with the debate method to optimally improve students' scientific argumentation skills.

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