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Enhancing Students' Scientific Literacy using Virtual Lab Activity with Inquiry-Based Learning

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ABSTRACT Laboratory activity is closely related and yet is essential in the process of science teaching-learning. The hands-on laboratory experiment is the one normally used in school. Particularly with the state of online schooling, it is quite challenging to perform a hands-on laboratory activity. The combination of inquiry-based learning with virtual lab activity can be an alternative to developing a more alluring yet meaningful learning process within online learning. This research aims to analyze virtual lab activity with inquiry-based learning on students' scientific literacy in light and optics topics. Participants were taken from junior high school students in the 8th-grade in Bandung, Indonesia. It includes 40 students with 14 males and 26 females with ages range 13-14 years old who have not yet studied light and optics. A pre-experimental research method with a one-group pre- the post-test design was used. The finding indicates that students' scientific literacy was significantly increased with a medium category (N-Gain score 0.441). Based on this research, virtual-lab activity with inquiry-based learning could be considered an alternative to conducting a meaningful online learning activity, especially in science education.

Keywords Science Education, Light and Optics, Virtual Laboratory, Inquiry-Based Learning, Scientific Literacy

1. INTRODUCTION

The students considered physics as a challenging subject to be comprehended (Lee & Sulaiman, 2018). There is also a lack of urgency for studying physics by the students where they do not play an active role during the learning process (Afriani & Agustin, 2019). Consequently, in the Program for International Student Assessment (PISA) 2018, which the Organization for Economic Co-operation and Development (OECD) held, Indonesia shows a low result in science. From the year 2000 to 2018, the highest score for science is 403 points in 2015, which is always below the average score (500). The latest PISA result is in 2018, where Indonesia earned 396 points in which is far lower than the average score from the participating countries (OECD, 2018). PISA was being used as global, comparable data of schools performance in the standard of the quality in the education sector, whereby countries with better PISA score average results have better school performance (Agasisti & Zoido, 2018). This condition indicates low achievement in science education. Besides that, the global Covid-19 pandemic may impact the performance of science teaching-learning activities to be held through online learning. There are several limitations on the online science teaching-learning process, such we cannot conduct experiments directly and the limitation of group work.

One of the aspects measured in science achievement in PISA is students' scientific literacy. Scientific literacy is a thoughtful citizen that has the capacity to deal with science-related concerns and the concepts of science (OECD, 2018). Thus, the scientifically literate person can understand the main conceptualization and theories that shape the foundation of science and technical thinking, the derivation process of the knowledge, and the extent of how evidence or theoretical explanations can justify such knowledge (OECD, 2017). Fives, Huebner, Birnbaum, & Nicolich (2014) describe scientific literacy as the capacity to grasp and work with scientific information in a practical

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way on a regular basis. The low score that Indonesia gained in PISA 2018 can be one indicator that there is a problem in science teaching in Indonesia. Hurd (2000) stated that science education needs to pursue students to fit the living in the 21st-century. Furthermore, Turiman, Omar, Daud, & Osman (2012) state that scientific literacy and comprehension of science concepts are needed to face the digital era. As shown by Halliday, Resnick, & Walker (2013) physics can enrich students' 21st-century skills by relying on experimental observations and quantitative measurements.

Laboratory activity is closely related and yet is important in the process of science teaching-learning. Practicum activity emphasizes that students acquire new experience, anticipation, curiosity, motivation, confidence, and the greatest significant aspect because they have a deeper learning understanding (Lee & Sulaiman, 2018). The hands-on laboratory experiment is the one normally used in school. But unfortunately, the conventional hands-on laboratory needs high costs in the procurement of the equipment, room, and maintenance staff. Particularly with the state of online schooling, it is quite challenging to perform a hands-on laboratory activity. Here, as a result, students cannot continue to undertake hands-on laboratory activities. Attempting to implement an appropriate learning activity to study science to access internet connection to take part in this situation is essential. In which they may also do self-guided learning and allows them to work at their place.

The cycle of science teaching and learning must require a number of approaches, strategies, and models to accomplish the learning objective to address these obstacles. However, there is a shortage of practical facilities and resources for hands-on laboratory experiments and a concern that still limits the full realization of long-distance learning. In online learning, the virtual laboratory might be helpful (Daineko, Dmitriyev, & Ipalakova (2016) Potkonjak et al., 2016). The virtual lab has been used widely in science teaching because of its ability to permit students to obtain expertise in modifying variables and studying scientific phenomena. We may also carry out laboratory experiments in the context of online schooling (Daineko, Dmitriyev, & Ipalakova (2016) and Potkonjak et al., 2016). However, in Indonesia, the teacher has not been used computer technology such as virtual lab as a learning tool maximally (Ismail, Permanasari, & Setiawan, 2016).

Furthermore, the virtual laboratory's usefulness in teaching relies on the teachers' pedagogic skills, the ability to design the learning process, and the ability to apply the curricula during the learning process (Daineko, Dmitriyev, & Ipalakova (2016)). A virtual laboratory activity can also be used as a piece of inquiry-based learning (Ifthinan & Atun (2019). Wolf & Fraser (2007) describe inquiry-based learning as a student-centered, focused on discovering how to learn, and immersive learning approach. A virtual laboratory activity integrated with inquiry-based learning poses students construct their experiment rather than follow predefined experiment procedures to formulate their explanation of the scientific phenomena that establish their higher-order cognitive skills (Ural, 2016). Besides, the study done by Wolf & Fraser (2008) has shown that inquiry-based laboratory activity strengthens the cohesion amongst students and has felt the inquiry-based laboratory activity is efficient for the learning activity. Nevertheless, the incorporation of virtual lab activity and inquiry-based learning is seldom performed in Indonesia Prima, Putri, & Rustaman (2018). Hence, combining virtual laboratory activity with inquiry-based learning to be implemented in the science teaching-learning process positively impacts students' scientific literacy.

The topic chosen in this research is light and optics topic, where students can engage with scientific phenomena in daily life, which is one of the scientifically literate students' requirements. Generally, for both students and teachers, the light and optics teaching and learning process is challenging (Tural, 2015). Students consider this topic is abstract and have difficulties in understanding the concept. Research conducted by Kroothkaew & Srisawasdi (2013) revealed that the students' poses a greater conceptual comprehension after completing the class. Chiu, DeJaegher, & Chao (2015) also find that a virtual science laboratory can permit students to explain abstract science subjects and light and optics topics.

Preceding research on virtual laboratory activity with inquiry-based learning was undertaken. Beck, Butler, & Burke da Silva (2014) have done research that positively affects students' learning gains after applying inquiry-based teaching in biology laboratory courses. Wang, Guo, & Jou (2015) examined the learning efficacy of scientific inquiry skills in high school students by utilizing the Virtual Physics Lab (VPL). The result shows that Model-Based Inquiry-VPL were far more significant in comprehensive skills and process skills. Blumer & Beck (2019) further analyzed whether students with varying degrees of previous experience have reacted differently to laboratory courses where a guided-inquiry module was implemented. Former research by Galan, Heradio, de la Torre, Dormido, & Esquembre (2017) reported that inquiry-based learning had been shown to enhance students' enthusiasm and interest, allowing higher-level cognitive skills to be established. Ifthinan & Atun (2019) presented that students' confidence, creativity, and critical thinking can be promoted by implementing inquiry-based virtual laboratories. Following Hermansyah, Gunawan, Harjono, & Adawiyah (2019) substantial influence on students' conceptual comprehension was noticed after implementing virtual laboratories in guided inquiry learning.

Such research introduces the benefits of virtual laboratory activity and focuses mainly on conceptual comprehension. Besides that, most of the previous results

Table 1 One group pretest-posttest design

	Pre-test	Inquiry Virtual Lab Activity	Post-test
One Class	X	X	X

Table 2 Initial scientific literacy test blueprint

The aspect of Scientific Literacy	Questions	Total	Percentage
Scientific Competencies	2, 3, 4, 5, 6, 7, 8, 9, 12, 15, 16, 18, 19, 20, 22, 23, 29, 30	18	60%
Scientific Knowledge	1, 10, 11, 13, 14, 17, 21, 24, 25, 26, 27, 28	12	40%
Total		30	100%

were emphasizing on senior high school students. In contrast to these studies, this research was prompted to analyze the impact of virtual laboratory activity with inquiry-based learning on junior high school students. This research also focuses on students' scientific literacy, which is highlighted as a science education problem. Therefore, this research is contemplated to carry out a study titled 'Enhancing Students' Scientific Literacy Using Virtual Lab Activity with Inquiry-Based Learning in Light and Optics Topic.

2. METHOD

2.1 Research Design

This study utilizes the pre-experimental method with one group pre-test and post-test design. It helps the researchers with an ability to analyze the impact of a treatment on a specific group (Cresswell, 2012). There is only one class that was treated by using virtual lab activity with inquiry-based learning. Table 1 defined the research design.

2.2 Participant

In this research, the population consisted of 8th-grade students attending an International Junior High School in Bandung, Indonesia. This school is using Indonesia Curriculum 2013 (*Kurtilas*). The convenience sampling technique was used as the sampling technique, in which the sample taken are the groups or individuals that were (conveniently) eligible for the study (Fraenkel, Wallen, & Hyun, 2012). The sample is 40 students consisting of 26 females and 14 males with an age average of 12-13 years old who have not yet learned the topic of light and optics.

2.3 Research Instrument

The instrument utilized to assess the students' scientific literacy either in the pre and post-test was made referred to PISA's Assessment on students' scientific literacy that focuses on light and optics topics. The Scientific Literacy test was also adjusted to fit Kurikulum 2013. The initial test

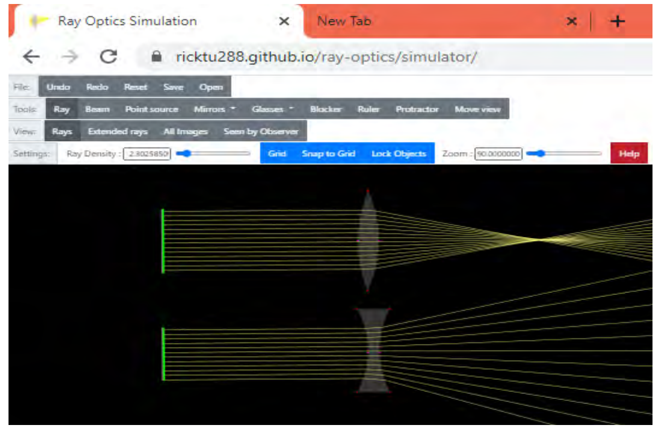


Figure 1 Ray and Optics Simulation

consisted of 30 questions. The initial test blueprint can be seen in Table 2. After the construction process, the test was analyzed and judged by the expert. After revising the test based on the expert's suggestion, the test was given to 9th-grade students who have learned the topic. There are 49 students from a different school. The difficulty level, discriminating power, validity, reliability, and distractor of the test were measured using SPSS ver.25. The most qualified questions were then sorted out. There are 15 questions on the final scientific literacy test. The scientific literacy test blueprint can be seen in Table 3. The pre-test is conducted before the treatment to assess students' initial scientific literacy, and after the treatment, a post-test is conducted to assess final students' scientific literacy.

2.4 Data analysis

The data gained was then analyzed by utilizing Ms. Excel for calculation and SPSS IBM ver.25 for statistical analyses. The first data analysis was calculating the students' score with the maximum score is 100. After that, the average from the pre and post-test data was also calculated. After the average was calculated, the normality test, homogeneity test, and the N-Gain score were done. Lastly, either if the data were normally distributed and homogeneous, a paired sample t-test will be used. Meanwhile, if one of the data was not normally distributed or homogeneous, a non-parametric Wilcoxon signed-rank test would be carried out.

2.4 Research Procedure

The treatment given in this research is virtual lab activity with inquiry-based learning. The learning method phases are the ones defined by Joyce, Weil, & Calhoun (2004). There are five phases of inquiry-based learning. It consists of confrontation with the problem, data gathering (verification, data gathering (experimentation), formulating an explanation, and analyzing the inquiry process. Meanwhile, for the virtual laboratory, there are two virtual labs used with different functions. The first one is 'Ray Optics Simulation,' in which the layout can be seen in Figure 1. This virtual lab offers geometric optics simulation

Table 3 Final scientific literacy test blueprint

Sub-Topic	Aspect		Level	Science Competence	Question Number	Percentage
	Competency	Knowledge				
Properties of light	Explain phenomena scientifically	-	1b	Personal	4	33,3%
	Explain phenomena scientifically	-	1a	Global	5	
	Evaluate and design scientific inquiry	-	5	Personal	6	
	Evaluate and design scientific inquiry	-	4	Personal	3	
	-	Epistemic	1a	Global	7	
Flat mirror	Evaluate and design scientific inquiry	-	5	Personal	1	13,3%
	Interpret data and evidence scientifically	-	1b	Personal	2	
Concave mirror	Evaluate and design scientific inquiry	-	2	Personal	9	20%
	-	Procedural	4	Personal	10	
	Interpret data and evidence scientifically	-	3	Personal	11	
Convex mirror	Explain phenomena scientifically	-	1a	Global	8	20%
	-	Epistemic	2	Personal	12	
	Evaluate and design scientific inquiry	-	5	Personal	13	
Concave lens	-	Content	3	Personal	14	6,7%
Convex lens	-	Content	4	Personal	15	6,7%
Total					15	100%

such as the reflection, refraction, and convergent and divergent of mirror and lens. The second one is 'Lens and Mirrors Lab' that the layout can be seen in Figure 2. Differ with the first virtual lab, and it stimulates the forming of image concave mirror and concave and convex lens. All virtual labs are available online on the website and can be accessed without paying any penny. The treatment was done in 7 meetings within online learning. In the first and the last meeting, the pre-test and post-test were conducted. And the remaining meeting was used to give the treatment.

3. RESULT AND DISCUSSION

After the pre-test and post-test using the Scientific Literacy test were conducted, the data obtained was then calculated and analyzed. The answer to the 40 students is calculated, to sum up the correct answer. Figure 3 shows the comparative data of the pre and post-test average scores. The initial scientific literacy average score of the students obtained from the pre-test was 63.27. Then we can pose an enhancement since the post-test gain 81.25 scores.

After the average score was calculated, the homogeneity, test normality test, N-Gain, and non-parametric Wilcoxon signed-rank test was then carried out to further investigate the data more deeply by using SPSS ver.25. The result is described in Table 2. The normality

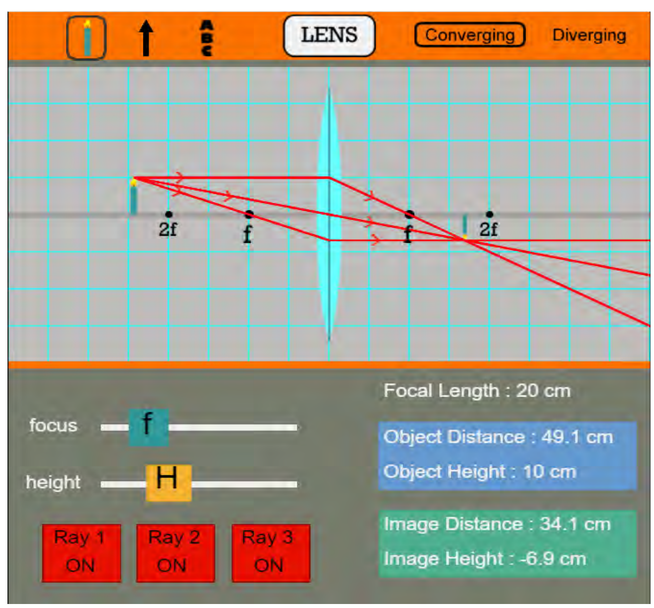


Figure 2 Lens and mirrors lab

test, the pre-test gets sig. 0.181, and the post-test gets 0.001 as seen in Table 4. Therefore, since the prerequisite of normally distributed data is sig. Value> 0.005, the pre-test is considered normally distributed; whereas, the post-test was not normally distributed. After that, the homogeneity

Table 4 The Summary of students' scientific literacy

Component	Signification	Description
Normality		
Pre-test	0.181	Normally distributed
Post-test	0.001	Not Normally distributed
Homogeneity	0.517	Homogeneous
Hypothesis (Wilcoxon signed-rank test)	0.000 Asymp. sig. (2-tailed)	There is a significant difference (H_1 accepted, H_0 rejected)
N-Gain	0.441	Medium

test displayed a sig. value 0.903, showing sig. value > 0.005 and characterized as homogeneous. Despite this, a non-parametric test was carried out. The hypothesis test, Wilcoxon signed-rank test, was implemented. Asymp. sig. (2-tailed) gained was 0.000, which means it suggests that students' scientific literacy significantly affected after implementing the virtual lab activity with inquiry-based learning since the asymp. sig. (2-tailed) value is less than 0.005. Inevitably, the N-Gain was calculated. The N-Gain score was 0.441 that further classified into medium efficiency on students' scientific literacy (Hake, 1998).

3.1 Implementation of learning activities

The learning process was conducted throughout seven meetings. In which every meeting has 2x30 minutes allocated. Because of the global COVID-19 pandemic, the topic was addressed by online learning in which utilizing some online learning portal. Zoom conference was used as the meeting site, Edmodo organized the assignment, learning material, and launched the announcement, and lastly, it is Google Form to conduct gain the data. Google Form to conduct gain the data. Meanwhile, the treatment itself was conducted by the usage of virtual lab activity with inquiry-based learning. Two virtual labs were utilized in this research, Ray Optics Simulation and Lens and Mirrors Lab, available online on the website and freely accessed.

Ural (2016) observed that executing a guided inquiry laboratory experiment trigger a substantial enhancement in students' academic achievement and attitude toward chemistry laboratory and decreased laboratory anxiety. Galan, Heradio, de la Torre, Dormido, & Esquembre (2017) further researched that inquiry-based learning has been shown to increase students' curiosity and interest, allowing higher-level thinking skills to be established. Kroothkaew & Srisawasdi (2013) outlined a significantly increased students' conceptual understanding after implementing simulation-based inquiry learning.

A scientifically literate person can understand the central concept and theories that form the foundation of science and technical thinking, the derivation of the knowledge, and the extent to how evidence or theoretical

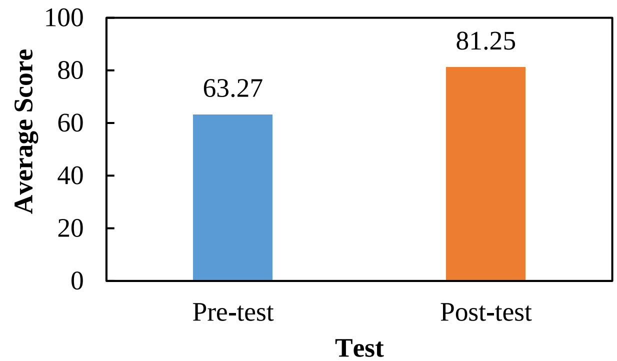


Figure 3 The average score of pre-test and post-test for students' scientific competency

explanations can justify such knowledge (OECD, 2017). Fives, Huebner, Birnbaum, & Nicolich (2014) describe scientific literacy as the capacity to grasp and work with scientific information in a practical way on a regular basis. Furthermore, students with high scientific literacy can perceive questions of scientific investigation that pose an individual's understanding of the nature of science, scientific methods, and what stands as evidence in science. These skills will involve students' knowledge and scientific conceptual comprehension and procedures necessary for individual decision making, participation in political and cultural sector, and economic development (NRC, 1996).

The teacher will improve students' aspects to be scientifically literate by utilizing virtual lab activities with inquiry-based learning. The usage of a virtual lab encourages students to learn about modifying variables to get the data to seek as evidence of their conclusion in the end. Integrating virtual lab activity with inquiry-based learning brings more meaningful learning. The students may develop their knowledge and understanding by actively engaging in the learning process by posing and answering questions scientifically, which was essential to boost their critical thinking. Similarly, the students can investigate any potential result by deciding their experimental procedure and the teacher's guidance. They will, therefore, assess whether the data can be counted as credible evidence or not.

Two virtual labs were used in this research, and the first one is Ray optics simulation. It was established by Rick Tu and can be accessed freely from the following link https://ricktu288.github.io/ray-optics/simulator/. In operating this virtual lab, the user was encompassed to create the components needed, including mirrors, lenses, and rays or beams. The user can also decide the location, size, and the focal point of the elements they could learn by inquiry learning by consulting the teacher for the right arrangement. The elements provided in this virtual lab can be seen in Figure 4, which includes the ray, beam, point source, mirrors, glasses, blocker, ruler, and protractor. This

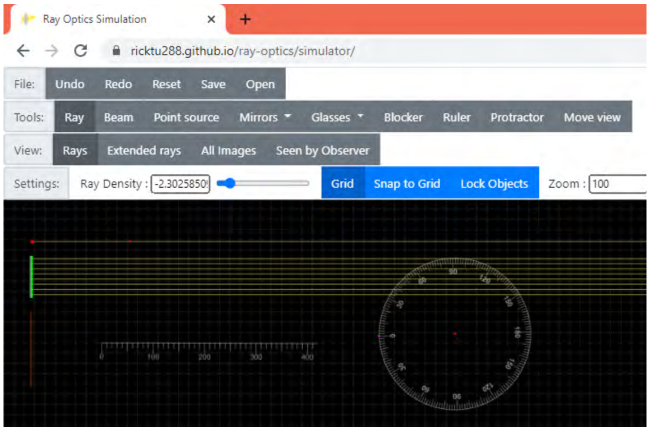


Figure 5 The element that can be used in ray optics simulation

virtual lab can perform much variety of optical geometry experiments. For this research, the virtual lab was utilized to refract light, reflect light, and converge and divergent from mirror and lens.

The next virtual lab utilized was Lens and Mirrors Lab. This virtual lab was developed by simbucket.com and can be freely accessed in the link provided https://simbucket.com/lensesandmirrors/. The contrast from Ray Optics Simulation that encompassed the user to create the elements by themselves, the element has already been provided. To use this virtual lab, the user can just drag the object back and forth to observe the image formed by the mirror or the lens. The element consists of concave mirrors and a concave and convex lens.

In comparison, the image formation of the convex mirror cannot be observed through this virtual lab. However, the functionality of this virtual lab may be viewed as a complete kit. We can also visualize the image formation by the mirrors and lens. We can also see the special ray, which allows a simpler way to visualize the image formation process. There is a feature where we can switch the special ray to be on and off such we can see which special ray it is. We may even alter the gap between the object and image and even modify the mirror's focus and lens. Candle, arrow, and alphabet are available as the object. The design of the Lens and Mirrors Lab is shown in Figure 5. After all, further checking was done by the researcher to make sure the appropriateness of these virtual labs to be implemented in the teaching-learning process, which uses Kurikulum 2013. There is no misconception found, and it is completely can be used as a learning media in a school that is using Kurikulm 2013 as their curriculum.

Even if the students have not been faced with the real equipment, such virtual labs managed to help students visualize the phenomena that occur when the light ray strikes the mirror or the lens, enhancing students' conceptual understanding of the light and optics topic. By using those virtual labs, they could improve their scientific literacy.

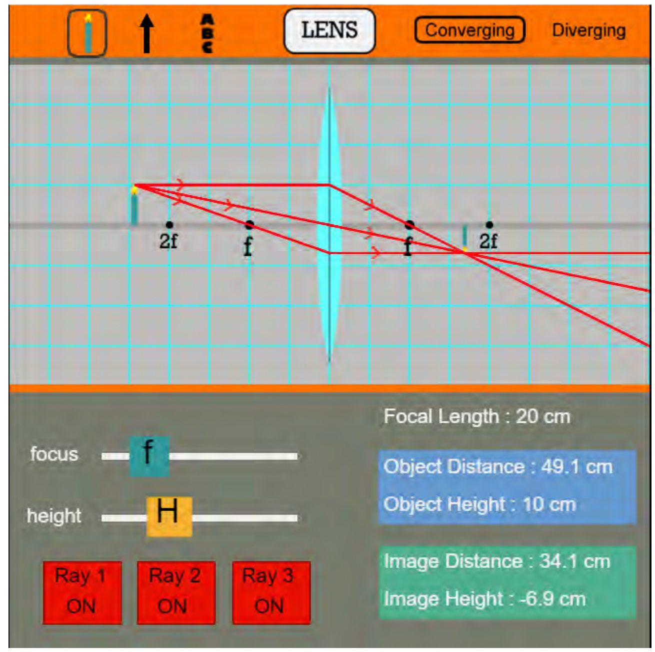


Figure 4 The layout of lens and mirrors lab

Furthermore, in this research, it is considered that there is a significant effect of the treatment on students' scientific literacy with the N-Gain score of 0.441 and categorized into a medium improvement on students' scientific literacy. Following Zhang (2016), which notes that inquiry-based learning models "do in fact" encourage students to improve their science content knowledge and investigative activities. Students' scientific literacy was not quite as high as anticipated. One of several factors that can affect this situation would be that the learning process has been entirely done through online learning. The teacher could not verify that the five phases of inquiry-based learning were correctly executed by the students.

The five phases of inquiry-based learning by Joyce, Weil, & Calhoun (2004) are adopted in conducting the learning process. The first phase is a confrontation with the problem. The teacher delivers the procedures of inquiry learning to acquainting students with the concept of inquiry-based learning. The students were provided text about everyday phenomena relevant to the studied subject. Based on the text, students are asked to deliver a scientific question in the worksheet. Such questions were then discussed together to point out the subject that will be learned. By this point, students are supposed to be acquainted with science-related topics surrounding them. Yet when this phase undergoes, some students are not willing to read the text given. In the term of delivering questions, just a few students counted. There are still some students who have not taken part in the conference for a variety of reasons. The solution to this issue is to place the text on the worksheet and allow students to pose a question. As seen in Figure 6, one of the texts in the worksheet was shown.

1. Convergent and Divergent

Picture 1. Flashlight

Flashlight is known as a device that were used to light the room. Generally, Flashlight is a tube with a small light bulb at the peak.

Do you know that concave mirror is used in a flashlight? Why is it?

The answer of this question can be find in the following experiment!

Figure 6 The passage stated in the worksheet

Basic Theory

Look for information about what you want to know or prove. You can add various sources such as books and the internet. Then write in the column below!

Curved mirror is a mirror whose surface is curved like the surface of a sphere. This mirror is distinguished by a concave mirror and a convex mirror. The incident ray on the concave mirror faces the reflected surface which is shaped like the inner surface of a sphere, while in the convex mirror the incident ray is facing the reflected surface which is the outer surface of the sphere. Concave mirrors is a converging mirror, where they collect light sources into a single focal point (focus light). Convex mirrors is a diverging mirror, where they break up light sources from a single focal point

Figure 8 Student's answer on basic theory

The next phase is data gathering (verification). After reading the text and asking questions centered on the text, they ought to compose the subject's basic theory. Websites and books can be used as the source to construct the basic theory. It could allow them to be aware of the basic concept that they must apply to the experiment. Figure 7 shows the example of student-made basic theory.

The third phase is data gathering (experimentation). The virtual lab activity with inquiry-based learning forces students to construct their self-made procedure with the teacher hint in the form of questions. The example is the question, 'What should you do if you want to measure the distance of the image formed? Where can you observe that?' this will help them consider what they are going through in the experiment yet still on the right guidance. We must not compel them to obey a rigid procedure to establish students' scientific inquiry—one sample of students' data The Figure 8.

However, while many evidential studies have shown that virtual lab may establish students' conceptual understanding, certain students still have difficulty learning when utilizing a virtual lab Chiu, DeJaegher, & Chao (2015). The virtual lab utilized in this study can be freely accessed via the website, but then there was a shortage of exposure to such virtual labs by using a PC. Having that in mind, certain students who cannot access the virtual lab since they do not have laptops were excluded from the sample. But they can still join the class by watching the video of the experiment on youtube.

The fourth phase is formulating an explanation. After the data was obtained by experimenting, it is evaluated to formulate an explanation. Again, the teacher-guided the students by questioning. In this phase, they may openly state their understanding of the phenomena that occur. Since the discussion was taken at an online meeting, unfortunately, several of the students were absent. About 2-3 students were absent in every meeting. A personal approach was used to handle this situation. The teacher can talk to the students through social media, discuss the reason for their absence, and encourage them to join the next meeting. The meeting process is illustrated in Figure 9.

E. **Result**

Fill the table below based on your observation!

- Give a sign (x) in the convergent or divergent column according to the image properties resulted by each mirror.
- Adjust the length of the photo to 5 cm before inserting the photo to the table!

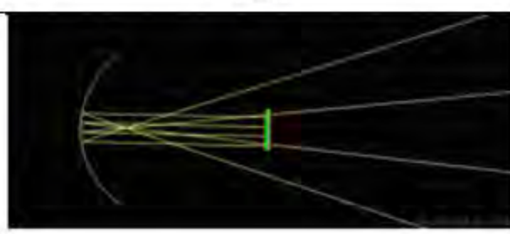
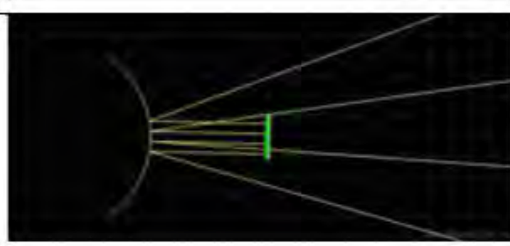
Mirror	Photo	Convergent	Divergent
Concave		x	
Convex			x

Figure 7 Students' result after conducting the experiment by using the virtual lab

Table 5 Observation Sheet Result

Subtopics	The phase of virtual lab activity with inquiry-based learning	Implementation		Score	Category
		Yes	No		
Properties of light	Confrontation with the problem	√		100	All activity has done
	Data gathering (verification)	√			
	Data gathering (experimentation)	√			
	Organizing, formulating an explanation	√			
	Analysis of the inquiry process	√			
Image formation of the mirror	Confrontation with the problem	√		100	All activity has done
	Data gathering (verification)	√			
	Data gathering (experimentation)	√			
	Organizing, formulating an explanation	√			
	Analysis of the inquiry process	√			
Image formation of the lens	Confrontation with the problem	√		100	All activity has done
	Data gathering (verification)	√			
	Data gathering (experimentation)	√			
	Organizing, formulating an explanation	√			
	Analysis of the inquiry process	√			

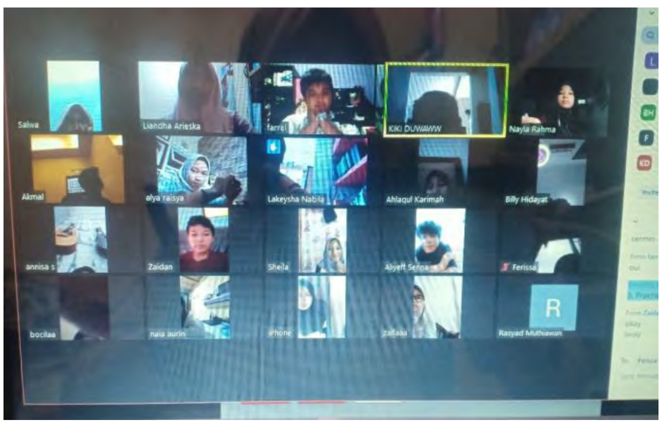


Figure 9 The discussion process was held online through Zoom Conference

The final phase is the analysis of the inquiry process. The whole learning process was assessed by verifying the conclusions of the students. If there are still misconceptions found in conclusion, the teacher should clarify and deliver more explanation of the concept to prevent more misconceptions. Here, the teacher ought to make sure each of the students comprehends the topic's basic idea. Eventually, the finished worksheet was compiled through Edmodo. Sadly, copying a friend's work was often found, and even some students did not submit the worksheet right on time.

Both the students and the teacher ought to carry out the whole phases properly. Although the researcher has indeed performed the phase right, it is difficult to determine whether the students follow precisely the right phases due to online learning. Furthermore, to mitigate the risk of a missed phase, it would be better to collaborate with the students' parents to ensure that they carry out all of the phases. The researcher carried out additional analyses by asking the students about their impression of using virtual lab activity with inquiry-based learning in the learning process. The virtual lab used in this research was found to be easy to use, but many students often find it challenging to operate the virtual lab at first because this is the first time they have encountered a virtual lab through an online course. The researcher notes that the video tutorial was handy to help the students understand the virtual lab procedure. Still, the students admit they did not face any further problems in the next trial.

There are seven meetings with 2x30 minutes of time allocation in every meeting. The short time requires the teacher to teach the entire content in such a compressed time. This situation has been modified to suit the school's condition and might exacerbate the students' difficulties. They said they had to attempt to do many assignments other than science in school, which made it much tougher to learn the subject. It may contribute to outcomes that are not as good as anticipated, where students still low on conceptual comprehension so that the N-Gain value was classified into the medium. The pre-test results were also considered high, despite that they have not known much about this topic. It may have arisen because the test was administered through Google Form, so the teacher could not be sure that the students were truthful. They might access the internet, books, or asking people around them to search for the answer.

A science teacher observed the whole learning activity to ensure that the researcher follows the five phases of inquiry-based learning. In the observation sheet, the observer can give a checklist sign on each activity. The summary of the observation sheet result is shown in Table 5. We can conclude that all of the Virtual Lab Activity with Inquiry-Based Learning phases was conducted 100% without any phases being left. It indicates that the learning process using Virtual Lab Activity with Inquiry-Based Learning was carried out correctly by the researcher.

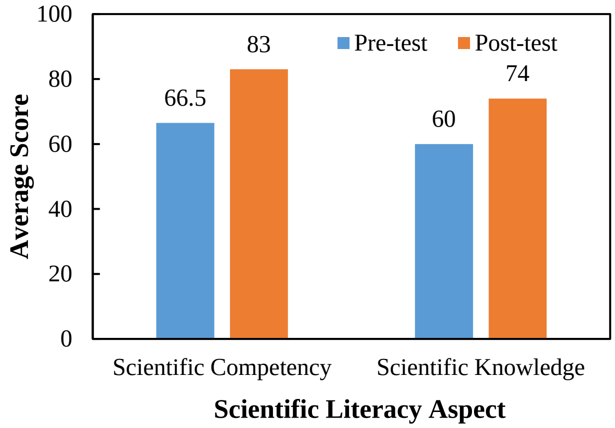


Figure 10 The comparison of the average score in the pre-test and post-test on each scientific literacy aspects

Table 8 N-gain for each scientific literacy aspect

Component	The Aspect of Scientific Literacy	
	Scientific Competency	Scientific Knowledge
Pre-test	66.50	60
Post-test	83	74
N-Gain	0.420	0.314
Category	Medium	Medium

Promoting scientific literacy is one of the learning process requirements in a science curriculum Fives, Huebner, Birnbaum, & Nicolich (2014). The usage of virtual lab activities with inquiry-based learning will also be one of the forms in which students improve their scientific literacy. The students stated that it is challenging to grasp the subject's abstract theories through an online explanation by using video and online meetings. Still, the virtual lab usage greatly allows the students to improve their understanding by observing the phenomena that arise after the experiment has been carried out. The combination of inquiry-based learning with the virtual lab activity allows the learning process to be more active. Students will ask questions and deliver their thought to generate their knowledge.

3.2 Students' Scientific Literacy on Each Aspect

In this research, there are two scientific literacy aspects measured: scientific competency and scientific knowledge. The data analyses gained for each aspect can be seen in Table 6. We can point out the average score of both aspects was increasing. For scientific competency, the average score for the pre-test is 66.50, while the post-test is 83.00. We can highlight the difference of 16.50 points, where the post-test average score results are higher than the pre-test. Comparing each scientific literacy aspect average score in pre-test and post-test can be seen in Figure 10.

Furthermore, the data gained was calculated to measure its Normalized Gain. As we can see from Table 3, the N-Gain value of scientific competency was 0.42 and 0.314 for

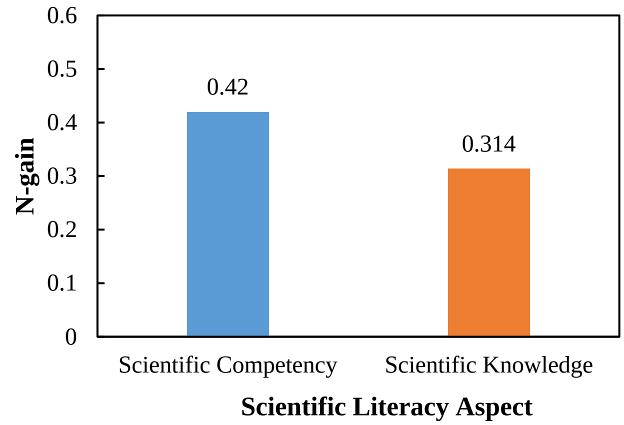


Figure 11 Comparison of N-gain in each scientific literacy aspects

Table 6 Scientific competency aspect blueprint

The aspect of Scientific Competency	Questions	Total
Explain phenomena scientifically	4, 5, 8	3
Evaluate and design scientific inquiry	1, 3, 6, 9, 13	5
Interpret scientific data	2, 11	2
Total		10

Table 7 The Summary of students' scientific competency

Component	Signification	Description
Normality		
Pre-test	0.013	Not Normally distributed
Post-test	0.061	Normally distributed
Homogeneity	0.061	Homogeneous
Hypothesis (Wilcoxon signed-rank test)	0.000 Asymp. sig. (2-tailed)	There is a significant difference (H_1 accepted, H_0 rejected)

scientific knowledge. The N-Gain score for scientific competency is higher by 0.106 points. Figure 11 draws the comparison of the N-Gain of each scientific literacy aspect.

3.2.1 Students' scientific competency

Scientific competency is one of the scientific literacy aspects evaluated in this research. Out of 15 questions, ten questions assess students' scientific competency. The distribution of the question can be seen in Table 7. The average score of pre-test and post-test was calculated to evaluate students' enhancement in scientific competency. As shown in Table 8, the normality test reveals the pre-test is not normally distributed with a score of 0.013, and the post-test is usually distributed with a score of 0.061. The homogeneity test shows a result of 0.061 and is categorized as homogeneous. Since one of the variables is not normally

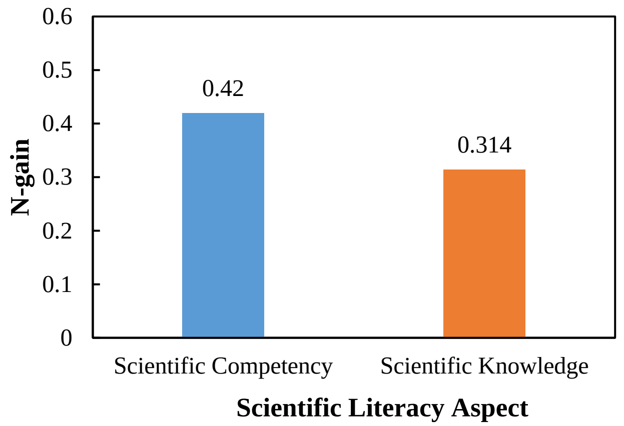


Figure 12 Comparison of N-gain in each scientific literacy aspects

distributed, A non-parametric test was done by using Wilcoxon signed-rank test, and the result is Asymp. sig. (2-tailed) 0.000. It can be concluded that students' scientific competency has a significant difference after implementing virtual lab activity with inquiry-based learning (H_1 accepted, H_0 rejected). In advance, the implementation of virtual lab activity can be used to improve students' scientific competency. Since virtual lab activity with inquiry-based learning actively involves students' participation in every phase of inquiry learning.

3.2.2 Students' scientific knowledge

The following scientific literacy aspects assessed are scientific knowledge. There are five from 15 questions to measure students' scientific knowledge. The distribution of the question can be seen in Table 9. The pre-test and post-test average scores were calculated to evaluate students' scientific knowledge enhancement. The data indicates that the average pre-test score is 60.00, whereas the post-test average score is 74.46. We can note that the post-test is greater than the pre-test. As seen in Table 10, the normality for pre-test scored 0.014 and 0.000 for post-test, making both of the data categorized as not normally distributed. The next test is the homogeneity test that resulted in sig. 0.061 and categorized as homogeneous. A non-parametric test was done by using Wilcoxon signed-rank test, and the result is Asymp. sig. (2-tailed) 0.000. It can be drawn that students' scientific knowledge poses a significant difference after implementing virtual lab activity with inquiry-based learning.


Bacalah teks di bawah ini untuk menjawab pertanyaan no. 5-7!

Laghi De Fusine, danau jernih di Italia!

Laghi De Fusine, sebuah glasial yang lokasinya berada satu mil dari perbatasan Italia dan Slovenia. Air di danau ini cukup dalam, namun karena danau ini memiliki air yang jernih, jika dilihat dari permukaan airnya akan terlihat dangkal. Saking beningnya, kamu bisa menyaksikan biota bawah air dengan jelas. Namun jika kamu tidak kuat dingin, jangan sesekali mencoba berenang di sini ya, karena danau ini memiliki suhu air yang sangat dingin.

(tripadvisor.com)

Figure 13 The example of the passage on the objective test

Table 9 Scientific knowledge aspect blueprint

The aspect of Scientific Knowledge	Questions	Total
Content	14, 15	2
Procedural	10	1
Epistemic	2, 7	2
Total		5

Table 10 The Summary of students' scientific knowledge

Component	Signification	Description
Normality		
Pre-test	0.014	Not Normally distributed
Post-test	0.000	Not Normally distributed
Homogeneity	0.822	Homogeneous
Hypothesis (Wilcoxon signed-rank test)	0.000 Asymp. sig. (2-tailed)	There is a significant difference (H_1 accepted, H_0 rejected)

The five phases of inquiry-based learning affect students' scientific knowledge as they learned light and optics topics. Students' ability to enhance inquiry thinking where they can read and develop some information based on the passage given. As the students did the five phases of inquiry-based learning, they can formulate questions based on daily phenomena. They can do experimentation to prove their hypothesis, and finally, they can conclude an explanation based on the data gathered. These aspects help to improve students' scientific knowledge significantly.

In the objective test, the question format is that there is a passage that consists of the daily phenomena that happen related to the sub-topic. The students can get indirect information to answer the questions given, then several questions related to the passage will be given. One of the examples of the passage can be seen in Figure 12. Following the passage, the questions were constructed to measure whether students' scientific knowledge or scientific competency. There are three sub-aspects of scientific competency: interpreting data scientifically, evaluating and designing scientific inquiry, and explaining phenomena scientifically. Scientific knowledge also has

Berdasarkan informasi di atas, pernyataan manakah yang paling tepat mendeskripsikan fenomena tersebut?

Figure 14 Example of the question that measures students' scientific competency

Sharon ingin mengetahui sifat bayangan yang dibentuk oleh cermin cekung. Ia melakukan sebuah percobaan dengan menggunakan sebuah cermin cekung, sebuah layar, dan sebuah lilin yang disusun seperti gambar berikut.

Sharon ingin mengetahui perbesaran bayangan yang dihasilkan cermin cekung bila ditempatkan di ruang berbeda. Apa yang harus dilakukan?

Figure 15 Example of the question that measures students' scientific knowledge

three sub-aspects, which are epistemic, content, and procedural knowledge. The example of the question that measures students' scientific competency and scientific knowledge can be seen in Figures 13 and 14.

The two aspects of scientific literacy that were measured in this research include scientific knowledge and scientific competency. In the objective test, the question that measures students' scientific competency requires them to think about the theory and implement the content itself. They have to think scientifically. Meanwhile, scientific knowledge questions can be answered directly by knowing the theory behind the passage itself. Further analysis of each aspect shows that the average score gained in the pre-test and the post-test for both aspects increased. But, students' scientific competency increased slightly higher than students' scientific knowledge. The implementation of virtual lab activity with inquiry-based learning that emphasizes students' ability to experiment and make an explanation on their own may be the cause of this condition. Students' ability to explain scientific phenomena, design and evaluate scientific inquiry, and interpret data and evidence scientifically increase students' ability in procedural, epistemic, and content knowledge.

Hermansyah, Gunawan, Harjono, & Adawiyah (2019) revealed that students' understanding of the concept of heat enhanced significantly in both the cognitive aspect and subtopic of heat by the use of guided inquiry model with virtual laboratories in the research titled "Guided inquiry model with virtual labs to improve students' understanding of heat concept." The research entitled "Laboratory courses with guided-inquiry modules improve scientific reasoning and experimental design skills for the least-prepared undergraduate students" Blumer & Beck (2019) observed that integrating the courses with guided-inquiry laboratory activities shows a promising outcome on students' basic scientific reasoning and experimental design skill. Then, Chiu, DeJaegher, & Chao (2015), with the research "The effects of augmented virtual science laboratories on middle school students' understanding of gas properties," possess that students can construct complex scientific explanations by connecting molecular-level visualizations to observable, macroscopic phenomena in which the augmented virtual science laboratories have high potential in helping them. The students can explain the molecular-level explanation of gas behavior after conducting the treatment. Lastly, the research conducted by (Wardani & Winarno, 2017) also found a positive enhancement on students' understanding of Nature of Science (NOS) in light and optic topics after implementing inquiry-based laboratory activity.

4. CONCLUSION

The implementation of virtual lab activity with inquiry-based learning on light and optics topics was done with a sample that consists of 40 8th grade Junior High School students. After calculating the data, students' scientific literacy was increased by the pre-test score was 68.27, while the post-test was 81.25. Furthermore, the N-Gain value that scored 0.441 indicated a medium improvement in students' scientific literacy. There are two aspects of scientific literacy that were measured in this research. The first one is scientific competency that scores 66.50 for the pre-test and 83 for the post-test.

Meanwhile, the N-Gain score is 0.420. The second aspect is scientific knowledge, with a pre-test score of 60 and a post-test score of 74. The N-Gain value is calculated to be 0.314. This data indicates that the implementation of virtual lab activity with inquiry-based learning emphasizes scientific competency that focuses more on the way students think and act like scientists.

Furthermore, this research is perhaps one reference to conduct online learning, particularly in science education. Other than that, the implementation of virtual lab activity with inquiry-based learning can enrich the variety of learning methods used in science teaching and learning. For future research, it is suggested to combine physical and virtual laboratories to underlines students' conceptual comprehension.

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