



Effect of science virtual laboratory combination with demonstration methods on lower-secondary school students' scientific literacy ability in a science course

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Abstract

Virtual laboratory is computer software that has the ability to perform mathematical modeling of computer equipment presented in the form of simulations. Virtual laboratory is not a substitute for real laboratory, but are used to complement and improve the weaknesses of real laboratory. This study aims to determine the effect of virtual laboratory combination with demonstration methods on lower-secondary school students' scientific literacy ability in a science course. The design of this research is quasi-experimental. The sample in this study was 102 students (12-14 years old) in a lower-secondary school in the city of Yogyakarta, Indonesia, used as experiment 1 group 1 ($n=34$), experiment 2 group ($n=34$), and control group ($n=34$). The three groups (experiment 1, experiment 2, and control) were tested with pretest and posttest. Experiment 1 group used virtual laboratory combination with demonstration methods, experiment 2 group used only virtual laboratory, and the control group used only a demonstration method. Scientific literacy ability was measured using multiple-choice tests before and after treatment. Statistical tests on mixed methods ANOVA were used to determine how effective the use of virtual laboratory combination with demonstration methods was in improving scientific literacy ability. The research result based tests of Within-Subjects Effects showed that there is a difference between the pretest-posttest scores of scientific literacy ability ($F=10.50$; $p<0.05$) in each group. The results based pairwise comparison show that the significance value is <0.05 , and there is a significant increase in the pretest-posttest scores of scientific literacy ability in every group. The result of effect size (partial eta squared) shows that the experiment 1 group to increase scientific literacy ability is 84.5%; experiment 2 group is 78.5%; control group is 74.3%. So, it can be concluded that experiment 1 group (virtual laboratory combination with demonstration methods) provides the most effective contribution to improving scientific literacy ability when compared to experiment 2 group (virtual laboratory only) and control group (demonstration methods only).

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1 Introduction

The era of the twenty-first century is currently marked by the development of science from time to time which has led to significant changes in the development of information and communication technology, where everything can be arranged using technology and has an influence on the teaching and learning process (Serrano-Perez et al., 2021). The implementation of teaching and learning processes, specifically in science course, must be able to answer the challenges of the twenty-first century, namely to create people who can survive with technological developments (Bashoor & Supahar., 2018). The use of technology can support practicum or scientific methods in science so that students have good scientific literacy ability. Through science courses which are methods that involve more students will provide opportunities for students to train and conduct inquiries (Sivamoorthy et al., 2013).

Science practicum can provide positive opportunities for students to get complete knowledge (de Jong et al., 2013). Science practicum is rarely applied for special reasons such as lack of infrastructure facilities and laboratory space. The Ministry of Education and Culture says only 45% of secondary schools in Indonesia have laboratory facilities. Some of the weaknesses of traditional science laboratory include limited access time; cannot accommodate students in one lab at the same time; need more time to prepare and carry out all experiments (Penn & Ramnarain, 2019). In Tanzania, inadequate implementation of science practicum is a major challenge for science subjects due to inadequate or inadequate laboratories, equipment, expertise or reagents (Manyilizu, 2022). This also happens in Thailand, that the most important problem in teaching science in secondary schools is the lack of basic knowledge of students, the laboratories are not properly equipped, and the subject matter is difficult to understand (Klentien & Wannasawade, 2016). Recent trends in education, exacerbated by the COVID-19 pandemic, have seen many schools around the world move from traditional laboratory practicums to online or digital technology (Hu-Au & Okita, 2021).

From the weakness of traditional science practicum, alternative virtual practicum learning tools have been considered through the use of technology. Changes in technology affect laboratories as an integral part of learning science that contains teaching materials, media, facilities, strategies, and assessment systems. According to Supahar and Widodo (2020) to optimize real laboratories, science practicum development must be supported by laboratory models based on virtual instrument systems (Lab-Vis). Although laboratory activities are expensive and time-consuming, virtual laboratory activities can save money, time, and effort (Aljuhani et al., 2018).

Research conducted by Lestari and Supahar. (2020) showed that 94.3% of students need virtual laboratory as a learning media supporting science practicum in real laboratory. Many teachers support the role of virtual laboratory in improving their teaching skills and helping students complete their laboratory practice without compromising the quality of learning (Radhamani et al., 2021). Solikhin et al.

(2019) supported the importance of developing virtual laboratory, who showed that 91.89% of respondents stated that they need integrated virtual laboratories in hybrid learning. Learning in schools through learning science is expected to develop students' ability to deal with the progress of science and technology through learning scientific literacy ability. Science course becomes more meaningful if students have good scientific literacy ability.

Scientific literacy ability is the scientific knowledge that a person has to investigate questions, gain new knowledge, explain questions scientifically, and draw conclusions based on evidence (Ismail et al., 2016). Scientific literacy ability is essential in our modern society because of many problems related to science and technology (Turiman et al., 2012). So that scientific literacy ability students must have in this twenty-first century. Based on the interviews researcher with science teachers at lower-secondary school in the city of Yogyakarta, Indonesia, it is known that science practicum has not been carried out optimally; one of them is on energy material in living systems. Some of the obstacles in carrying out science practicum are the limited time, tools and materials used for science practicum themselves. So, the teacher sometimes only does demonstrations methods. But demonstrations methods have limitations that are only useful for certain activities, and visibility is always a problem when demonstrations are presented.

Based on 2018 PISA data, the achievements of Indonesian students in scientific literacy from 2000 to 2018 have not progressed. In 2018 Indonesia was still in the last rank of 69 out of 77 countries. The data explains that the results of the achievement of scientific literacy of Indonesian students have not progressed even in 2019 Indonesia was ranked 8th lowest (OECD, 2019b). Based on the Indonesian national education system, science learning is explicit and uses a scientific and inquiry approach. But the fact is that in the field this has not been fully implemented in the learning classroom. The scientific literacy ability in PISA was declining because students find it difficult to read and understand the content of the material more precisely and accurately (Fitriani et al., 2018). The results of research conducted by Ristanto et al. (2017) show that the scientific literacy ability of students in Indonesia in the context, content and competence domains is still low. With the low scientific literacy of students in Indonesia, innovation is needed to improve students' scientific literacy abilities.

Based on the problems that have been described, the use of virtual laboratory is essential as one of the learning media to support science practicum such as demonstrations. Virtual laboratory is a simulation method that can be used as alternative learning, such as online learning, learning for schools with inadequate tools and materials for practicum (Oser & Fraser, 2015). The virtual laboratory is also an interactive product that helps students carry out their experimental procedures in stages by providing appropriate learning and expanding limitations (Rajendran et al., 2010). Although a virtual laboratory cannot replace a 100% physical laboratory, as an alternative in the current era of technology-based education, the existence of a virtual laboratory will be beneficial.

Virtual laboratory have the advantage of being able to improve conceptual and inquiry performance (Chien et al., 2015) and improve students' competence in terms of cognitive (mind-on) and psychomotor (Jaya, 2013). The advantages of virtual

laboratories can be an alternative solution to problems in school. This shows that although virtual practicum provides many opportunities for students to explore, direct interaction with the original object is still needed. However, the use of a virtual laboratory is not enough. In schools that usually have limited tools and materials, they typically use demonstrations. According to McKee et al. (2007), laboratories and demonstrations have long been used to complement learning. This is because demonstrations are designed to allow students to make observations through demonstrations methods. Visual demonstration of laboratory procedures is a critical element in teaching pedagogy (Maldarelli et al., 2009). An empirical study conducted by Gurel (2016) shows that science demonstration activities lead to positive motivational outcomes. Research conducted by Toth et al. (2014) states that the use of a virtual laboratory combined with a hand on laboratory or practicum can directly improve the concept of knowledge of students. The results of research conducted by Saputra et al. (2018) show that a virtual laboratory-based inquiry learning model can improve the ability of scientific literacy ability in each domain and aspects of the knowledge of prospective physics teacher students at the University of Samudra Teaching and Education Faculty.

Current technological advances have helped the learning process in the classroom, one of which is in science course and practicum. The high cost of practicum tools and materials and limited time has prevented science practicums from being carried out in the laboratory. Science practicum will be more effective if it uses technology in the form of virtual laboratory that can support science practicum in real laboratory. Research on the effectiveness of virtual laboratory in the science course can assist teachers and students in dealing with limitations in doing science practicum. The results of this study can also help teachers and students that virtual laboratory is very useful for improving students' scientific literacy skills in science course.

2 Literature review

2.1 Theoretical framework

The social constructivism theory (Vigotsky, 1978), is used as a theoretical framework in this study. Vygotsky saw children as active participants in the construction of knowledge. In the theory of constructivism, teachers must be able to direct students to study in groups both during discussions and practicum activities in the laboratory or virtual practicum. This is supported by opinion Dagar and Yadav (2016) that students must construct their own knowledge individually and collectively. Interaction with other people can affect the construction of learning knowledge (Wink, 2006). The existence of discussion activities in this study, carried out by students in their groups, is one of the characteristics of the application of social constructivism theory. When an individual interacts with others, he socially negotiates meanings and develops his own understanding of concepts and behaviors (Schreiber & Valle, 2013).

The use of a virtual laboratory (containing text, images, animation, simulations, videos and quizzes), which is operated via a laptop, is the first experience for students in learning science. This is in accordance with the information provided by

the teacher before the study. Constructivism as an approach to learning emphasizes students building their knowledge from experience gained so that the constructivism approach allows science learning to be effective. The existence of elements (text, images, animation, simulations, videos and quizzes) is the main advantage of the virtual laboratory that researchers use in research, so that it can accommodate the different learning styles of each student. When teachers fully integrate technology into the classroom, constructivist learning environments can develop (Rakes et al., 2006), so that it can facilitate students to be actively involved in the learning process.

2.2 Virtual laboratory

Virtual laboratory is an interactive environment where simulated experiments can be carried out in learning (Wästberg et al., 2019). Virtual laboratory is a computer program to simulate experimental investigations without carrying out activities directly where virtual laboratories can strengthen activities that cannot be practised in real, meaning that virtual laboratories become alternative science practicum media to support practicum if it is not supported to be carried out (Ismail et al., 2016). Furthermore, the virtual laboratory is an interactive virtual space that combines all technology, pedagogics, and human resources to carry out science practicum activities tailored to students' and teachers' needs in a virtual learning environment (Prieto-Blazquez et al., 2009). Virtual laboratory is a laboratory that can be used for practicum without any real tools and materials, where this practicum can be replaced via Android or PC (Solikin et al., 2019). In addition to understanding, we must know what components must be in the virtual laboratory itself.

The completeness of the components in the virtual laboratory can help students understand the concept of the science material being studied (Yusuf & Subaer., 2013). Virtual laboratory that has been developed by Jaya (2013) consists of several parts, namely video tutorials, simulations, practicum modules starting from the initial experiment to the end, and worksheets or practicum worksheets. Components of a science virtual laboratory developed by Ekasari et al. (2018) integrating various media in the form of text, animation, images, sound, and video. Virtual laboratory program contains material complemented by relevant images, animations, and interactive simulations. Virtual laboratory component developed by Yeni and Yokhebed. (2016) consists of essential competencies, instructions for use, materials, simulations, animations, evaluations, and developer profiles. In addition, lab-vis developed by Supahar and Widodo (2020) used as a nature of science course media that utilizes internet-based information and communication technology to improve the quality of science course.

Virtual laboratory has its main parts. Virtual laboratory developed by Tewari and Sukla (2017) has the main part, namely computer equipment connected to the internet network so that students can work directly in a virtual lab anywhere and anytime for conducting experiments electronically; all equipment must be connected to a computer so that communication networks & related hardware must comply with standards because digital communication serves as a link between the user and the

laboratory, simulation refers to the preparation, performance, and evaluation of laboratory experiments, using animation, video, and 3D images to make it more interesting.

Virtual laboratory has the benefit of designing and implementing a software system that has an exact time, reduces limitations, and can be scaled with laboratory equipment to provide students with easy access to laboratory equipment anytime and anywhere via the internet (Fridman & Mahajan, 2014). In addition, the benefits of the virtual laboratory to carry out actual experiments that are expensive and dangerous anywhere and anytime (Ballu et al., 2016). The science virtual laboratory also provided learning opportunities while doing, and also virtual laboratories are designed for hazardous and expensive experimental activities. Besides, students can perform scenarios in the form of simulations that will change the output if changing the input (Rajendran et al., 2010). In addition to having benefits, science virtual laboratories also have advantages.

Virtual laboratory has several advantages: it is easy to use, requires little time, and allows students to carry out several experiments in a limited time (Rajendran et al., 2010). The advantages of the virtual laboratory media, namely (1) during the practicum it does not endanger oneself and others; (2) does not cost much; (4) the experimental results are always the same; (5) can be done independently; (6) presenting teaching materials at the macroscopic, symbolic, and submicroscopic levels (Herga et al., 2016).

2.3 Demonstration methods

Demonstration method is a learning method that is used as a visual aid to illustrate the application of scientific principles, and can help students understand abstract concepts (Lim & Sow, 2019; Hussain, 2020). Demonstration show promotes science and allows students, both the presenters and the audience, to explore phenomena (Fish & Cole, 2020). This strategy can be planned to increase students' interest in a lesson, illustrate a concept or principle, make a point, answer a question, review an idea, initiate inquiry and problem solving, or introduce a unit lesson. Limited time and resources available to conduct practical work in the laboratory, designed to allow students to make observations through demonstrations (McKee et al., 2007).

Teachers prefer demonstration experiments because of time factors, material limitations, and students' lack of required skills (Sever et al., 2010). It is a good idea to practice using laboratory equipment before starting the practicum, it is also good to prepare questions related to the implementation of the practicum that will be carried out (Walsh, 2021). According to Daryanto (2009), the demonstration method presents lesson material by demonstrating or showing students a process, situation, or specific object being studied, either actual or imitation, which is often accompanied by an explanation. Although in the demonstration process, the role of students is only to pay attention, demonstrations can present more concrete lesson materials (Hizbi, 2019).

Demonstration methods have several advantages that make them highly useful in teaching science. The demonstration also has limitations that make them useful

for only certain types of learning situations. Visibility is always a problem when demonstrations are presented. The use of science materials and apparatus and complicated assemblages may cause students to become confused and prevent them from understanding relationships (Collete & Chiappetta, 1994). The demonstration method refers to the teaching method in which the teacher is the principal actor while the learners watch to act later (Daluba & Ekeyi, 2013). The lack of student participation in a demonstration can reduce student interest, understanding, and feeling of involvement (Collete & Chiappetta, 1994).

2.4 Scientific literacy ability

Scientific literacy ability describes efforts to move closer to a more socially beneficial thought of science education (Taylor, 2020). Scientific literacy ability describes efforts to move closer to a more socially beneficial thought of science education (Loughran et al., 2011). Scientific literacy is an ability that must be possessed by individuals to understand the scientific process and fully involve meaning with scientific knowledge in everyday life (Fives et al., 2014). Scientific literacy ability is a person's ability or skill regarding scientific problems such as scientific concepts, methods, and attitudes (Gu et al., 2019). Construction of scientific literacy ability in addition to covering moral values and worldviews must also describe everything that is needed to live in a global society (Mun et al., 2015).

Scientific literacy ability is also a person's ability to understand, communicate, and apply science to solve problems, and can make decisions based on scientific considerations in everyday life (Rajendran et al., 2010). Scientific literacy ability is concerned with thinking about how science and understanding science can be used to solve problems (Techakosit & Wannapiroon, 2015). A person who has good scientific literacy ability has a positive and sensitive attitude towards himself and his surroundings, and he can make decisions based on scientific evidence (Holbrook & Rannikmae, 2009). There are several understandings of scientific literacy ability.

Scientific literacy ability consists of understanding the terminology and concepts of science, scientific inquiry and practice, and the interaction of science, technology, and society (Jarman & Clune, 2007; Cook et al., 2011). Scientific literacy ability consists of knowledge and understanding of scientific concepts (Dani, 2009) and covers literacy in science and technology (Genç, 2015). The most crucial aim of science education is to educate science-literate people who understand the nature of science is also an essential aspect of scientific literacy ability (Ocak, 2018). Every individual must have scientific literacy ability, including scientific knowledge, scientific process skills, and a scientific attitude. Based on this, the development of scientific literacy is important. Fakhriyah et al. (2017) states that the scientifically educated community can use scientific knowledge, identify questions, and draw conclusions based on evidence by understanding and producing decisions related to nature and changes made to nature through human activities.

The development of students' scientific literacy ability is influenced by the understanding of scientific literacy ability used in learning. Smith et al. (2012) state that the assessment of scientific literacy ability does not only consider the curriculum

used but must also consider the age of the students whose abilities will be measured. Pantiwati and Husamah (2019) revealed that scientific literacy ability is very well observed when students are between 10 and 15 years old. Students aged 10-15 years are in a transitional stage from the concrete setting to the abstract location so that students have been able to use their scientific literacy ability. The measurement of students' scientific literacy ability is important to determine students' competence in understanding science knowledge, processes, and applications. Lonigan et al. (2011) stated that using assessment instruments to measure students' scientific literacy ability can help teachers provide an optimal learning experience for students. Vitasari and Supahar (2018) mentions that students who have a high level of scientific literacy ability will quickly find out about everyday conditions or problems. They can relate the issue to a theory or concept they have learned in school.

Scientific literacy in PISA 2018 is determined by three competencies, namely: explaining phenomena scientifically; evaluating and designing scientific investigations; and interpret data and evidence scientifically (OECD, 2019). Based on PISA 2018, measurement of scientific literacy is carried out through item test questions that contain a special stimulus in the form of short writing, or text accompanied by tables, graphs or diagrams. Stimulus material can also include non-static stimulus material, such as animations and interactive simulations. The test items are a series of independently scored questions of various types. The PISA scientific literacy assessment does not assess context, but assesses context-related knowledge and competencies (OECD, 2019a).

3 Research questions

The following research questions guide this research:

1. Is there a difference in each group's pretest-posttest scores for scientific literacy ability?
2. Is there an increase in each group's scientific literacy ability pretest-posttest score?
3. How is the effect size contribution of using virtual laboratory products combined with demonstrations methods in improving scientific literacy ability?

4 Methods

4.1 Settings

This research was conducted at a public lower-secondary school in the city of Yogyakarta, the province of the special region of Yogyakarta, Indonesia. This research was conducted on science subjects, which are compulsory subjects that must be taken by lower-secondary school students. The researcher acted as an observer during the research process in the three treatment groups, and the science teacher who

taught in the classroom. This research was conducted after obtaining permission from the principal of the school concerned.

4.2 Participants

The sample of this study was 102 students of grade VII lower-secondary school in science lessons which were divided into three group consisting of 34 students in a group that used virtual laboratory media, 34 students in a group that used virtual laboratory combination with demonstration, and 34 students as a group that uses demonstration. It should be noted that all students participated voluntarily in this study. Based on information from science teachers, research on the use of virtual laboratory in science course was first conducted at this school. Descriptive statistics about participants can be seen in Table 1.

4.3 Design

The design carried out in this study was a pretest-posttest control group design. Field trials were carried out on three group of students, two group as the experimental group and one other group as the control group, taken at random (cluster random sampling) from a homogeneous population. Before giving treatment, students are given pretest questions (initial test), and at the end of learning, students are given post-test questions (final test). The overall test design is used to determine the increase in students' scientific literacy ability after learning using virtual laboratory. The experimental design of the study is presented in Table 2.

4.4 Materials and procedure

The topic of natural science material used in this research is energy in living systems. This material in Curriculum 13 in Indonesia is taught to seventh grade junior high school students in the first semester. This material discusses learning about energy sources, the concept of energy, various forms of energy, changes in energy forms and their application in life, including in the event of photosynthesis. This material is used as the main topic in the three groups in this study.

Experiment 1 group used virtual laboratory developed by researchers combined with demonstration. Experiment 2 group used virtual laboratory only, and control group used demonstration methods only. Science teachers at this school usually carry out

Table 1 Descriptive statistics about participants

Group	Gender		Total	Age range (years)
	Male	Female		
Experiment 1	15	19	34	12-14
Experiment 2	16	18	34	12-14
Control	16	18	34	12-14
Total	47	55	102	12-14

Table 2 Pre-test-post-test control group design

Group	Pretest	Independent Variable	Posttest
C	Y1	X ₁	Y2
E ₁	Y3	X ₂	Y4
E ₂	Y5	X ₃	Y6

Modification from Ary et al. (2010)

C is control group; E1 is experimental group 1; E2 is experimental group 2; X1 is learning by demonstration group; X2 is learning virtual laboratory media combination with demonstration; X3 is learning with virtual laboratory; Y1, Y3, Y5 are science literacy pre-test; Y2, Y4, Y6 are post-test of scientific literacy

demonstration activities. The demonstration activities in this study can be seen in Fig. 1. Teacher demonstration activities are science teachers who only demonstrate experiments or scientific investigations in front of the class., students acting as observers then students can also ask questions. They are related to the demonstration carried out by the teacher.

An example of the virtual laboratory display is shown in Fig. 2. Virtual laboratory product used in this study has gone through 4-D model development research, defining, designing, developing, and distributing (Thiagarajan et al., 1974). Virtual laboratory validation process was carried out based on media and material aspects by two expert lecturers from internal universities, two science teachers, and three colleagues. Faculty permission is also required to carry out this validation process. The validation results show that the virtual laboratory is feasible to use in science course.

Based on the example of virtual laboratory displayed in Fig. 2, it can be seen that this media consists of two virtual practicum, namely electrolyte and non-electrolyte solutions and photosynthesis (ingenhousz). In addition to being equipped with virtual practicum, this media is equipped with materials, pictures, animations, videos, practice questions and post-test questions of scientific literacy. Virtual laboratory developed by researchers uses Unity 3D software and can be opened via a computer or laptop offline. Teachers have received training and

Fig. 1 Demonstration activities by science teachers



Fig. 2 Example of virtual laboratory display

explanations regarding the use of virtual laboratory media. Learning is carried out in three meetings (ie. 120 minutes, 80 minutes, and 120 minutes).

Students in experimental group 1 learn science using virtual laboratory combined with laboratory demonstrations guided by the teacher during the learning process. First, the teacher gives a demonstration to the students; Then, students practice simulations in virtual laboratory. Each student is given a laptop containing virtual laboratory. The learning process uses a scientific approach. Students are asked to watch videos contained in the virtual science laboratory at the observation stage. After that, the students were asked to ask the teacher. Students are then asked to collect data information by reading material in virtual laboratory. In addition, at this stage students are asked to observe a practical demonstration given by the teacher, then proceed with doing a virtual practicum in virtual laboratory. At the associating stage, students are asked to discuss with their respective groups related to the demonstrations and practicums that have been carried out and the answers on the student worksheets that have been provided. After students conduct discussions, students are asked to communicate the results through presentations. At the end of the lesson, students are guided by the teacher to conclude the learning activities.

Students in experiment 2 group learn science only using virtual laboratory that is guided by the teacher. Each student uses a laptop containing a virtual laboratory. The learning process uses a scientific approach. In the first stage, students are asked to watch the video contained in virtual laboratory. After that, students were asked to ask the teacher about the contents of the video that they did not understand. Students are then asked to collect information by reading material in virtual laboratory. In addition, at this stage students are asked to carry out virtual practicum simulations in virtual laboratory. At the associating stage, students discuss with their group members each question related to the virtual practice that has been done and write down the answers on the provided student worksheet. After students conduct discussions, students are asked to communicate the results through presentations. At the end of the lesson, students conclude the learning activities guided by the teacher.

Students in the control group learn science only by paying attention to the demonstration of science practicum conducted by the teacher in front of the class. Demonstrations are often held at this school due to the limitations of science practicum tools and materials as well as time constraints in the learning process. The learning process in the control group used a scientific approach. First, students were asked to watch a video presented

by the teacher through Powerpoint. After that, students were asked to ask the teacher about the parts of the video content that had not been understood. Students are then asked to collect information by reading the material in the science book. In addition, at this stage students are asked to pay attention to the demonstration of science practicum conducted by the teacher in front of the class. At the associating stage, students discuss with their respective groups related to the demonstration of science practices carried out by the teacher and write their answers on the student worksheets that have been distributed by the teacher. After that, students communicate their results through presentations. At the end of the lesson, students conclude the learning activities guided by the teacher. Table 3 shows the application used in the experiment 1,2 and control groups.

4.5 Research instruments

Scientific literacy ability was measured in this study in the form of a test. The test is given to students, and the scientific literacy test is in the form of multiple-choice questions. The number of questions used is 20 questions. The compiled scientific literacy ability questions were used to carry out the pretest and posttest. Indicators of scientific literacy ability in research are adapted from PISA 2018 (OECD, 2019a). Indicators of scientific literacy ability can be seen in Table 4.

4.6 Data analysis

In this study, the researcher analyzed the data using SPSS 24. The scientific literacy ability profile was analyzed using descriptive statistics. Mixed design ANOVA analysis was used to determine the difference in the pretest-posttest of scientific literacy ability in the virtual laboratory science group with a combination of demonstration, virtual laboratory only, and demonstration only. Prerequisite/assumption tests are needed before the mixed design ANOVA analysis, namely normality and homogeneity, which can be seen in Table 5. After completing the assumption test, students' scientific literacy ability scores from each group showed a normal and homogeneous distribution ($p > .05$). Paired T-test analysis was also carried out to determine differences in the quality of the pretest-posttest students' scientific literacy abilities.

Table 3 Hardware and software applications

	Experiment 1 group	Experiment 2 group	Control group
Classroom Equipment	Laptop, projector, screen, demonstration tools	Laptop, projector, screen	Whiteboard and marker, demonstration tools
Learning Aid	Virtual laboratory	Virtual laboratory	powerpoint, textbooks

Table 4 Indicators of scientific literacy ability

Aspect	Indicators
Explaining Phenomena Scientifically	<ul style="list-style-type: none"> a. Remembering and applying scientific knowledge that is appropriate to certain situations. b. Identify, use, and create simple picture models to explain scientific phenomena encountered in everyday life. c. Make and provide appropriate explanations, predictions.
Identify scientific issues	<ul style="list-style-type: none"> a. Identify issues that might be investigated in a particular scientific study. b. Propose a way of investigating a particular issue scientifically. c. Recognizing the important elements of scientific investigation (what things to compare, variables, work procedures, additional information).
Interpret data and evidence scientifically	<ul style="list-style-type: none"> a. Converts data from one form to another (diagrams, graphs, etc.). b. Analyze and interpret data to draw appropriate conclusions. c. Identify assumptions, evidence, and reasons in texts related to science.

Table 5 The normality and homogeneity test

Group	Pretest		Posttest	
	Normality	Homogeneity	Normality	Homogeneity
Experiment 1	0.20	0.41	0.15	0.82
Experiment 2	0.12		0.09	
Control	0.10		0.12	

$p > .05$ = data are normally and homogeneously distributed

5 Results

Statistical tests on mixed methods ANOVA were used to determine how effective the use of a virtual laboratory was in improving scientific literacy ability. The mixed-methods ANOVA analysis aims to: (a) test whether there is a difference in the pretest-posttest score of scientific literacy ability in each group, (b) test whether there is an increase in the pretest-posttest score of scientific literacy ability in each group, (c) find out the amount of effective contribution the use of virtual laboratory products in improving scientific literacy ability. The results of the mixed methods ANOVA analysis are as follows.

Table 6 Tests of Within-Subjects Effects results on pretest-posttest between the three groups

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time * Group	Greenhouse-Geisser	1017.89	2.00	508.94	10.50	0.00

5.1 Differences in the pretest-posttest scores of each group's scientific literacy ability

The difference in the pretest-posttest scores of scientific literacy ability in the experiment 1, 2, and control groups can be seen in Table 6. The results show a difference between the pretest-posttest scores of scientific literacy ability ($F = 10.50$; $p < 0.05$) in each group. The existence of this difference indicates the change from pretest to posttest in each group is significantly different.

5.2 Increased pretest-posttest scores of scientific literacy ability in each group

The increase in the pretest-posttest scores of scientific literacy ability in experiment 1, 2, and control groups can be seen in Table 7. The results show that the significance value is < 0.05 , and there is a significant increase in the pretest-posttest scores of scientific literacy ability in every group. In the scientific literacy test, the mean differences (MD) in the control group, experiments 1 and 2, were -28.52 , -39.26 , and -32.05 . Based on the MD score from the pretest to the posttest, which was negative in each group, it is known that the average posttest score was higher than the average pretest score. So, there is a significant increase in the pretest-posttest scores of scientific literacy abilities in each group.

Furthermore, to find out which groups are different, it is continued with the Post Hoc test, which can be seen in Table 8. The results show that in the scientific literacy ability of students, the experiment 1 group is significantly different from the control group ($MD = 4.63$; $p < 0.05$), while the experiment 1 and 2 groups were not significantly different ($MD = 3.01$; $p > 0.05$). This shows that experiment 1 group, which used virtual laboratory with demonstration, has a higher effect on scientific literacy ability than the control group.

Table 7 Pairwise Comparisons results on pretest-posttest between the three groups

Group	(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.
Experiment 1	Pretest	Posttest	-39.26	1.68	0.00
Experiment 2	Pretest	Posttest	-32.05	1.68	0.00
Control	Pretest	Posttest	-28.52	1.68	0.00

Table 8 Result of Post Hoc test Bonferroni type between the three groups

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Experiment 1	Control	4.63*	1.54	0.01
	Experiment 2	3.01	1.54	0.16
Experiment 2	Control	1.62	1.54	0.89
	Experiment 1	-3.01	1.54	0.16
Control	Experiment 1	-4.63*	1.54	0.01
	Experiment 2	-1.62	1.54	0.89

5.3 Effect size

The effective contribution from the use of the virtual laboratory combined with demonstration (experiment 1), virtual laboratory (experiment 2), and demonstration (control) on students' scientific literacy ability were obtained from the results of the Multivariate Hotelling's Trace type test on mixed methods ANOVA. This is based on Denis (2019), which states that sig. Obtained is smaller than 0.05, then the data is said to be significant and to see the size of the effect sizes can be seen in the right most column in the Partial Eta-squared statistic. The following results from the Multivariate Hotelling's Trace test can be seen in Table 9.

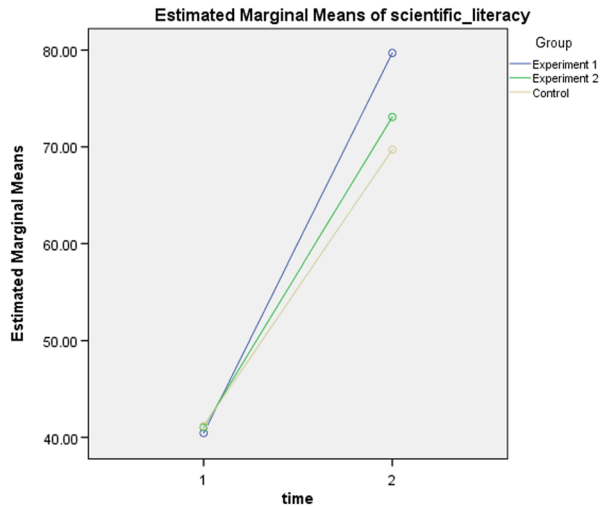
The results from Table 9 show that the effective contribution of experimental group 1 (virtual laboratory combined with demonstration) in increasing scientific literacy ability is 0.84 or 84.50%. The scientific literacy ability of students in experimental 2 group (virtual laboratory only) is 0.78 or 78.50%. The effective contribution of the control group (demonstration) in improving students' scientific literacy ability was 0.74 or 74.30%. So, it can be concluded that experimental 1 group (virtual laboratory combined with demonstration) provides the most effective contribution to improving scientific literacy ability when compared to experiment 2 group (virtual laboratory only) and control group (demonstration only).

The interaction between experimental 1, 2 and control groups can be seen in the Estimated Marginal Means graph on the GLM. The output graph of Estimated scientific literacy ability can be seen in Fig. 3. Figure 3 shows that the increase in scientific literacy in experimental group 1 is higher than in experiment 2 and control groups.

Table 9 Results of Multivariate test Hotelling's Trace test between the three groups

Group	F	Sig.	Partial Eta Squared
Experiment 1	541.18	0.00	0.84
Experiment 2	360.77	0.00	0.78
Control	285.71	0.00	0.74

Fig. 3 Profile Graph Plots of scientific literacy ability



6 Discussion

The effectiveness of virtual laboratory developed in learning is viewed by comparing the increase in the scientific literacy ability of students in the experiment 1, 2, and control groups during the field test. The results of data analysis using ANOVA mixed-methods showed that the effective contribution separately in the experiment 1 group (virtual laboratory and demonstration) in increasing the ability of scientific literacy was 84.5% greater than the experiment 2 group (virtual laboratory) and control group (demonstration).

Virtual laboratory in this research is teaching materials with multiple representations like text, animation, video, a simulation that can be changed variables, exercises, and questions containing scientific literacy. Based on Herianto & Wilujeng (2021), multiple representations can keep students' attention. This is supported by Van Der Meij and De Jong (2006) that multiple representations have benefits such as text and images, which are good representations to present the context of a problem, animation can constrain the interpretation of a graph, and students can understand abstract material. Using virtual laboratory gives students science practicum advantage in accepting the basic concepts of the material being taught and then followed by direct practice, making students get a deeper and more complex understanding (Toth et al., 2014). Using virtual practicum in classrooms makes it time-efficient (de Jong et al., 2013). Animation, videos, and images in the virtual laboratory can enhance students' interest and involvement in learning (Alneyadi, 2019).

Virtual experiments have a disadvantage because they do not provide direct experience to individuals because experiments are carried out virtually through computer hardware or laptops. In traditional laboratories, students learn about the complexities of science practicum that will deal with unexpected events, such as measurement errors, while virtual experiment research variables are programmed by the manufacturer (Serrano-Perez et al., 2021). A virtual laboratory is more suitable to

supplement science practicum and can not be replied to for actual practicum (Burkett & Smith, 2016; Corter et al., 2011). In addition, virtual teaching methods are combined with traditional methods; this method increases effective student learning (Paxinou et al., 2020). This is supported by research conducted by Kapici et al. (2019) that using virtual laboratories together with science practicum simultaneously can increase students' knowledge compared to using just one type of science practicum. According to Moore et al. (2020), science practicum is at the heart of teaching and learning in science classrooms..

Practicum virtual and traditional activities like the demonstration have become the core element of science education globally and locally (Alneyadi, 2019). The virtual practicum implementation accompanied by direct experience such as demonstration is a form of manifestation and learning strategy that requires students to be able to use the knowledge gained by the scientific process. That is why the scientific process is closely related to aspects of the concept of scientific literacy found in virtual laboratories. The results of research support this by Hurtado-Bermúdez and Romero-Abrio (2020), which shows that the use of direct laboratory tools combined with virtual ones can benefit students' knowledge of abstract and complex concepts. Virtual laboratory, whether combined with the demonstration or not combined, can increase the ability of scientific literacy ability, although the best is a virtual laboratory combined with a demonstration.

The low scientific literacy ability in the control group (demonstration) is supported by research by Odom and Bell (2015), which states that demonstrations do not provide sufficient opportunities for students to develop an understanding of the scientific process. This is reinforced by research Frago and Janer (2020) which shows that through laboratory demonstrations, science teachers only demonstrate experiments or scientific investigations that only explain science lessons in front of the class using a set of laboratory equipment and materials. Naturally, students in the classroom act as listeners and observers. Although students are also encouraged to ask lesson-related questions, the activities demonstrated by the laboratory make them passive compared to direct laboratory instruction.

So basically, virtual laboratory can't replace the essential role of laboratory. Still, science virtual laboratories are used to support and complement the lack of laboratory equipment in schools. Demonstration laboratory is not enough, so technology is needed to support it, such as virtual laboratory. Based on the overall trial results of virtual laboratory product combined with effective demonstrations can improve students' scientific literacy ability.

7 Conclusion

The results show that difference between the pretest-posttest scores of scientific literacy ability in each group. There is a significant increase in the pretest-posttest scores of scientific literacy ability in each group. Virtual laboratory learning media combination with demonstration was more effective in improving students' scientific literacy ability than virtual laboratory and demonstrations only. The combination virtual laboratory with demonstration methods can be a solution to overcome limitations in conducting science

practicum, such as the high cost of practicum tools and materials and the limited time to do the practicum. In addition, the combination virtual laboratory with demonstration methods can also solve the problem of students' scientific literacy ability.

This research still requires further research. Among them are the limitations of the small research sample size. Future research is expected to increase the sample size by implementing interventions in several classrooms to reveal the combination of virtual laboratory with demonstrations to improve students' scientific literacy ability and other abilities. The virtual laboratory also needs to be made an online version that can be accessed via smartphones and laptops to make it easier for students to learn. Based on the results of this study, it is better if virtual laboratory combination demonstration is more often used in classrooms or schools that have limitations in carrying out science practicum in the laboratory because it is proven to be able to improve students' scientific literacy in science course.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Consent to participate All collected data is used only for research purposes, and the teachers and students voluntarily participated in this study.

Conflict of interest The author have no conflicts of interest to declare that are relevant to the content of this article.

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