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Implementation of Interactive Learning Media Based on Virtual Laboratory to Improve Students Science Literacy Skills

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Abstract: Virtual laboratories based on computers allow students to conduct practical work or experiments with real phenomena or laboratory equipment sets. This study aims to test the implementation of interactive learning media based on virtual laboratories on the topic of substances and their changes to students' scientific literacy skills. This study was conducted in class VII of SMP Negeri 1 Tilongkabila and SMP Negeri 4 Tilamuta in the 2024/2025 Academic Year. The research design used A one-group pre-test and a post-test design involving three classes as samples. The study results showed a significant increase in students' scientific literacy skills after treatment using virtual laboratory media based on PhET Simulation. PhET Simulation media allow students to conduct experiments virtually, improving students' understanding of abstract concepts and thinking skills. The results indicate this through the hypothesis testing criteria where T-count ≥ T-table with a level of $\propto$ = 0.05 for the experimental and replication classes 1 in each school; therefore, H0 is rejected, and H1 is accepted. So, it can be concluded that there is an effect of implementing interactive learning media based on a virtual laboratory on the scientific literacy skills of junior high school students on the topic of substances and their changes. Meanwhile, normalized gain for all sample classes, both experimental and replication, which are in the high category, in the experimental class at SMP Negeri 1 Tilongkabila (0.75), the experimental class at SMP Negeri 4 Tilamuta (0.79) and the replication class 1 (0.83). So, it can be concluded that there is an effect of implementing interactive learning media based on a virtual laboratory on the scientific literacy skills of junior high school students on the topic of substances and their changes.

Keywords: Learning Media; Scientific Literacy; Substances; Virtual Laboratory.

Introduction

In 21st-century learning, learning media are developing quite rapidly in digital form. Even other changes, namely the rapid development of Science and Technology, result in changes in the learning process. According to [1], 21st-century education differs from the previous century. 21st-century education is constructivist and utilizes information and communication technology, whose learning must develop critical thinking and problem-solving skills, creativity and innovation, communication, and collaboration. Therefore, teachers must be creative and innovative in creating learning that fosters high-level thinking in students. One of them is selecting varied and digital-based learning media by developing 21st-century education. Learning media is an essential factor in the teaching and learning process, where teachers often use various tools and sources to convey material in a way that is easier for students to understand [2]. The use of learning media can not only increase students' interest and desire to learn but can also generate motivation and provide a positive psychological impact on their learning experience [3]. In addition, teachers must also be able to develop skills in creating engaging and interactive learning media [4].

The school has used an independent curriculum based on the observations conducted at SMP Negeri 4 Tilamuta and SMP Negeri 1 Tilongkabila. Although it has used the independent curriculum, the learning still uses the lecture method, where the teaching is centered on the teacher, so some students feel bored, especially in science learning, which requires a lot of practice. From the results of observations at this school, there are still some incomplete facilities, one of which is the tools and topics in the science laboratory, so students can only imagine without having to practice when science learning requires practice or experiments. This problem can also have an impact on students' science literacy in schools, so teachers are expected to be able to find solutions to these problems to improve students' science literacy. Science learning cannot be achieved by memorizing or passively listening to the teacher's explanations. Still, students themselves must learn through experiments, observations, or active experiments, which ultimately lead to creativity and can maintain awareness and improve natural phenomena. The formation of a scientific attitude, which in turn actively seeks to preserve the stability of nature appropriately and sustainably. Science learning is essential because students can discover and prove their scientific theories, which are learned through a direct inquiry process both in the laboratory and the environment, so that they can develop or improve their scientific process skills [5].

Several obstacles often occur when learning science, including in practical activities and when doing practicals; the barriers that often occur are the lack of adequate supporting facilities and practical materials [6]. Then there are also other obstacles during the learning process in class,

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namely that some students have a kinesthetic learning style, some like audio learning, and some like visual learning media [7]. Students who have a kinesthetic learning style prefer physical movement in order to remember something, whereas students who like audio use their sense of hearing to capture the material explained, while those who are visual can learn optimally by using their sense of sight. Regarding the limitations of science laboratory tools and materials, it is necessary to implement interactive media based on virtual laboratories. A virtual laboratory is a laboratory that displays tools in the form of computer software based on interactive multimedia. Virtual laboratories are operated with software, computers, or other electronic devices that can demonstrate activities in the laboratory so that users feel like they are working in a real laboratory [8]. Computer-based virtual laboratories allow students to conduct practical work or experiments with real phenomena or laboratory equipment sets. In addition, virtual laboratories are also able to improve students' scientific literacy skills [9].

Science literacy is a skill used to define scientific phenomena or phenomena. It focuses on how students use their knowledge to develop new ideas or concepts for a scientific problem. The ability to use scientific knowledge, identify questions, and draw conclusions based on evidence to understand and make decisions about nature through human activities [10]. Indonesian students have low levels of science literacy for several reasons. One is teacher-centered learning, a lack of positive student attitudes towards science learning, and a lack of basic understanding of content, processes, and context. Therefore, lessons become boring, and students do not understand them [11].

In the learning process, there are several problems, for example, in the media, methods, and learning models, which will affect students' science literacy skills in class. Students are more interested in participating in learning, especially in science learning, depending on the media used during the teaching and learning process. So, the more interesting the media used in the learning process, the more students are interested in participating in learning, especially science learning.

So, the student learning process depends on the model, media, and topic used by the teacher during the learning process, especially in science learning, which can cause low scientific literacy skills of students in the classroom. To create good and conducive scientific literacy in order to achieve above average, teachers must be more careful and creative when choosing learning media used in the classroom because learning media can also attract students' enthusiasm in the teaching and learning process in the classroom and learning media can also affect students' scientific literacy skills. Based on the problems related to media and the low scientific literacy skills in schools, the researcher wants to know the effect of implementing interactive learning media based on virtual laboratories on students' scientific literacy skills in the material of substances and their changes. This study is expected to help improve students' scientific literacy skills by using interactive virtual laboratory media so that students can more easily understand the topic of substances and their changes.

Research Methods

This study uses a quasi-experimental method, namely a research method that aims to determine the effect of treatment on research subjects but does not fully use randomization to determine the experimental group. The research design used in this study is a one-group, pre-test-post-test design. This study uses the quasi-experimental method, and the research design used in this study is a one-group, pre-test-post-test design. This study was conducted in class VII of SMP Negeri 1 Tilongkabila and SMP Negeri 4 Tilamuta in the 2024/2025 Academic Year. The subjects of this study were 22 students at SMP Negeri 1 Tilongkabila as the experimental class and two classes at SMP Negeri 4 Tilamuta, namely the experimental class and replication 1, each class consisting of 27 students. The sampling technique used is cluster random sampling based on random groups. The instrument used in this study was a test instrument in the form of 10 essay questions given before learning (Pre-test) and after participating in learning (Post-test). The instrument used has been validated by two validators and is classified as very valid and reliable. In this study, the data were analyzed using several statistical techniques, namely the normality test, which was used to determine whether the pre-test and post-test data were normally distributed. A normality test is essential as a requirement before conducting parametric statistical tests [12]. Then the hypothesis test was carried out to determine the significant difference between the pre-test and post-test scores of students after treatment, and the n-gain test was used to determine the increase in students' conceptual understanding after treatment [13]. In addition to the essay test, this study was supported by an observation sheet for implementing learning, an observation sheet for student activities, and a student questionnaire on learning.

Results and Discussion

Students' scientific literacy skills are obtained through tests designed based on scientific literacy indicators, according to PISA. The questions given have been arranged to contain three scientific literacy indicators according to PISA: Identifying problems scientifically, explaining scientific phenomena clearly, and using scientific evidence. Then, the average percentage of students' scientific literacy skills from the experimental and replication classes 1 in each school will be calculated in Table 1.

Table 1. Percentage of Achievement of Science Literacy Level at SMP Negeri 1 Tilongkabila

Class	Identifying problems scientifically (%)		Explaining scientific phenomena clearly (%)		Using scientific evidence (%)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Experimental	64	97	70.42	93.76	60.57	92.39

Based on Table 1, it can be seen that students' scientific literacy skills obtained from the pre-test percentage in the experimental class at SMP Negeri 1 Tilongkabila which were analyzed based on three indicators of scientific

literacy according to PISA showed that indicator 1 had a percentage of 64%, indicator 2 had a percentage of 70.42%, and indicator 3 had a percentage of 60.57%, and for the post-test value in the experimental class at SMP Negeri 1 Tilongkabila, the percentage of indicator 1 increased to 97%, indicator 2 increased to 93.76%, indicator 3 increased to 92.39%. Based on the percentage of achievement of the level of scientific literacy of students in the experimental class at SMP Negeri 1 Tilongkabila, Indicator 1 has a higher percentage than Indicators 2 and 3. This happens because, in the questions of indicator 1, namely about identifying problems scientifically, students understand better and find it easier to do them in the questions of indicator 2, namely about explaining scientific phenomena, where there are still some students who do not understand the scientific phenomena that often occur in everyday life, and indicator 3, namely about using scientific evidence, where there are several questions that require calculation answers so that many students are confused. Based on research conducted by [14], the low ability of scientific literacy is influenced by students' understanding, which is still lacking because students are not yet mature enough to use the concept, so they do not build aspects of scientific literacy abilities in Table 2.

Table 2. Percentage of Achievement of Science Literacy Level at SMP Negeri 4 Tilamuta

Class	Identifying problems scientifically (%)		Explaining scientific phenomena clearly (%)		Using scientific evidence (%)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Experimental	70.24	98	67.37	96.42	59.29	91.93
Replication 1	61	93	70.62	97.37	56.77	90.80

Based on Table 2, it can be seen that students' scientific literacy skills obtained from the pre-test percentage in the experimental class at SMP Negeri 4 Tilamuta, which were analyzed based on three indicators of scientific literacy according to PISA showed that indicator 1 had a percentage of 70.24%, indicator 2 had a percentage of 63.73%, and indicator 3 had a percentage of 59.29%. For the post-test value in the experimental class, the percentage of indicator 1 increased to 98%; indicator 2 increased to 96.42%, and indicator 3 increased to 91.93%. Based on the percentage of achievement of the level of scientific literacy of students in the experimental class, indicator 1 has a higher percentage than indicators 2 and 3. This is due to the lack of students' understanding of scientific phenomena and mastery of concepts regarding the use of scientific evidence, so some students are still confused in answering questions in indicators 2 and 3. This is in line with research conducted by [15], which shows that students often have difficulty understanding scientific phenomena, especially those related to social scientific issues. They are also less able to evaluate and use scientific evidence in their arguments critically.

The students' scientific literacy skills obtained from the pre-test percentage in replication class 1 at SMP Negeri 4 Tilamuta, which were analyzed based on three indicators of scientific literacy according to PISA showed that indicator 1 had a percentage of 61%, indicator 2 had a percentage of 70.62%, and indicator 3 had a percentage of 56.77%, and for the post-test value in the experimental class showed that the percentage of indicator 1 increased to 93%, indicator 2 increased to 97.37%, indicator 3 increased to 90.80%. Based on the percentage of achievement of students' scientific literacy level in replication class 1, indicator 2 has a higher percentage than indicators 1 and 3. In contrast to the experimental class, this happened because students in replication class 1 understood more about working on indicator 2 questions, which contained scientific phenomena. Students in replication class 1 had less understanding of identifying problems scientifically and still lacked in finding scientific evidence. Based on research conducted by [16], most students can answer questions based on scientific phenomena or concepts but have difficulty explaining or drawing conclusions from the data or evidence provided.

Researchers use the arithmetic average from each sample group to find out how the quantitative data is distributed in each sample group and to see if there is an increase in students' scientific literacy after using interactive media based on virtual laboratories. The average value for each school is calculated using the Excel application program, as shown in the Table 3.

Table 3. Results of Calculation of Average Pre-test and Post-test Scores of SMP Negeri 1 Tilongkabila

Class	Average	
	Pre-test	Post-test
Experimental	57.44	88.64

Based on the data presented in Table 3, it is known that the average pre-test score in the experimental class at SMP Negeri 1 Tilongkabila reached 57.44. After implementing learning using interactive media based on virtual laboratories, the average post-test score showed a significant increase of 88.64. These data illustrate a significant increase in students' average scientific literacy skills in the experimental class at SMP Negeri 1 Tilongkabila, which shows the success of the learning media applied in improving students' scientific literacy skills. The success of learning media is not only measured from the aspect of student perception but is also proven in real terms through an increase in post-test scores, which are higher than the pre-test. This shows that the learning media used have succeeded in improving students' scientific literacy in terms of conceptual understanding, critical thinking skills, and skills in using scientific evidence. Interactive media, including virtual laboratories, can significantly improve students' understanding of concepts and scientific literacy because they support active and experience-based learning [17].

Table 4. Results of Calculation of Average Pre-test and Post-test Scores of SMP Negeri 4 Tilamuta

Class	Average	
	Pre-test	Post-test
Experimental	59.72	91.20
Replication 1	58.06	91.85

Based on the data presented in Table 4, it is known that the average pre-test score in the experimental class at SMP Negeri 4 Tilamuta reached 59.72, while in replication 1, it was 58.06. After implementing learning using interactive media based on a virtual laboratory, the average post-test score showed a significant increase, with the experimental class reaching 91.20 and the replication class 1 at 91.85. These data illustrate a significant increase in students' average scientific literacy ability in the experimental and replication classes 1 at SMP Negeri 4 Tilamuta, which shows the success of the learning media applied in improving students' understanding of scientific literacy. A high increase in post-test scores indicates that the learning media have achieved learning objectives. Learning success can be measured by students' abilities, as seen by comparing pre-test and post-test scores [18]. When there is a high increase in scores after learning treatment, this shows that the media used has succeeded in helping students understand the topic better.

The learning implementation data was analyzed to systematically review and interpret data obtained through various methods, such as direct observation of learning activities in the classroom. Meanwhile, the analysis of student activities aims to measure and understand the different actions or activities carried out by students during the learning process. The results of observations of learning implementation by science teachers of class VII SMP Negeri 4 Tilamuta and SMP Negeri 1 Tilongkabila can be seen in Figures 1 and 2.

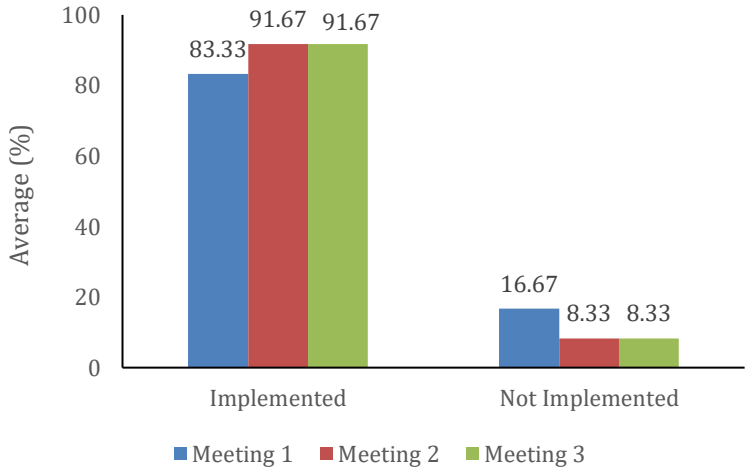

Figure 1. Analysis of Learning Implementation Results at SMP Negeri 1 Tilongkabila.

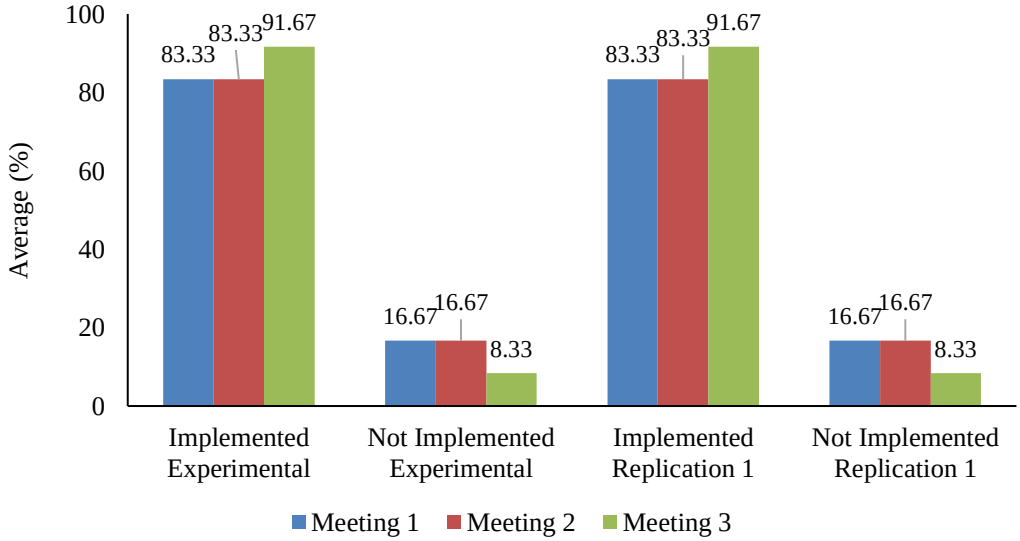

Figure 2. Analysis of Learning Implementation Results at SMP Negeri 4 Tilamuta

The primary purpose of this analysis is to obtain a clear picture of the extent to which the learning process has been carried out according to the plan and objectives set. In addition to measuring learning implementation data, this study also measures learning activity data. The achievement of the level of success of student activities in the experimental and replication classes 1 in each school from the first to the third meeting is included in the high category. This study also measures student questionnaires regarding student responses to learning that implement interactive learning media based on virtual laboratories. The questionnaire is used to collect information desired to be obtained from respondents (students), and the questionnaire data can be obtained in qualitative and quantitative forms.

The questionnaire supports data in data collection, learning implementation, and student activities in the classroom. The average achievement of student questionnaires per indicator in the experimental class at SMP Negeri 1 Tilongkabila is included in the good category, and then for the experimental and replication classes 1 at SMP Negeri 4 Tilmuta. The percentage is included in the good category. The good category is determined based on the assessment guidelines used in the questionnaire analysis, namely by using the criteria interval based on the Likert scale. According to [19], Likert scale-based questionnaire assessments can be categorized by converting the average score into a percentage and then matching it to a specific category. The data obtained were then analyzed by covering three tests, namely the normality test, hypothesis test, and n-gain analysis.

Data Normality Test

Normality testing was carried out on student data from three classes in 2 different schools, namely the experimental class at SMP Negeri 1 Tilongkabila, the experimental class, and replication class 1 at SMP Negeri 4 Tilamuta, all of which received treatment in the form of learning using interactive media based on Virtual Laboratory. Data from the normality test results of the three classes. The statistical test data obtained from the Kolmogorov-Smirnov analysis are summarized and presented in Table 5, which specifically shows the results of the data normality test from this study.

Table 5. Normality Testing at SMP Negeri 1 Tilongkabila

Class	Fi	K	Status
Experimental	0.47	0.28	Normally distributed

Based on Table 5, the results of the data normality test at SMP Negeri 1 Tilongkabila, it is known that Fi ≥ K for the real level α = 0.05. This shows that the research data for the experimental class at SMP Negeri 1 Tilongkabila is normally distributed.

Table 6. Data Normality Tests at SMP Negeri 4 Tilmuta

Class	Fi	K	Status
Experimental	0.48	0.25	Normally distributed
Replication 1	0.48	0.25	Normally distributed

Based on Table 6, the results of the data normality test at SMP Negeri 4 Tilamuta, it is known that Fi ≥ K for the real level α = 0.05. This shows that the research data for the experimental and replication classes 1 at SMP Negeri 4 Tilmauta are normally distributed. According to [20], a normal distribution means that the research variable data is evenly distributed above and below the average, thus allowing parametric statistical techniques in hypothesis testing.

Hypothesis Testing

After the prerequisite test is carried out and the data is stated to be normally distributed, the next step is a hypothesis test. According to [21], hypothesis testing is a statistical process used to test the truth of a claim or statement regarding population parameters.

The hypothesis was tested using a parametric hypothesis test with a paired sample t-test. The data from the hypothesis test results were for both the experimental class at SMP Negeri 1 Tilongkabila and the experimental class and replication 1 at SMP Negeri 4 Tilamuta. The results of the hypothesis test are in the following Table 7.

Table 7. Hypothesis Testing Results

Class	T-count	T-table	Status
Experimental	17.71	2.079	H_1 accepted

Based on Table 7, it is obtained that T-count ≥ T-table with a level of $\propto = 0.05$ for the experimental class. The t count is 17.71. Therefore, H0 is rejected, and H1 is accepted. This shows that there is an effect of implementing interactive learning media based on virtual laboratories on the topic of substances and their changes on students' scientific literacy skills in the experimental class, at SMP Negeri 1 Tilongkabila. The effect of implementing interactive learning media based on virtual laboratories can be seen from the results of scientific literacy and a significant increase in students' post-test scores after carrying out the pre-test.

Table 8. Hypothesis Testing Results

Class	T-count	T-table	Status
Experimental	12.27	2.055	H_1 accepted
Replication 1	16.74	2.055	H_1 accepted

Based on Table 8, it is obtained that T-count ≥ T-table with a level of $\propto = 0.05$ for the experimental class, which obtained a t count of 12.27, and for the replication class 1, which obtained a t count of 16.74. Therefore, H0 is rejected, and H1 is accepted. This shows the effect of the application of interactive learning media based on virtual laboratories on the topic of substances and their changes on students' scientific literacy skills in the experimental and replication classes 1 at SMP Negeri 4 Tilamuta. According to [22], if the T-count value ≥ T-table at a certain level, then H0 is rejected, and H1 is accepted. This means that the treatment given in the study, in this case, the use of virtual laboratory-based learning media, significantly affects the variables being measured, namely, students' scientific literacy.

N-Gain Test

The n-gain test was conducted to measure the improvement in students' scientific literacy skills by comparing the pre-test and post-test scores. The n-gain analysis was performed using the course average normalized gain method for each class to provide a more objective picture of the effectiveness of the learning process. The results of this n-gain analysis reflect how learning has improved students' understanding of the topic being taught. Complete data on the results of the n-gain test can be seen in Table 9.

Table 9. The N-Gain Test of SMP Negeri 1 Tilongkabila.

Class	N-gain	Criteria
Experimental	0.75	High

Based on Table 9, the n-gain value for the experimental class at SMP Negeri 1 Tilongkabila (0.75) is included in the high category. This shows a significant

increase in students' scientific literacy skills on the topic of substances and their changes by using interactive media based on virtual laboratories.

Table 10. The N-Gain Testing at SMP Negeri 4 Tilamuta

Class	N-gain	Criteria
Experimental	0.79	High
Replication 1	0.83	High

Based on Table 10, the n-gain value for the experimental (0.79) and replication classes 1 (0.83) at SMP Negeri 4 Tilamuta is included in the high category. This shows that there is a significant increase in students' scientific literacy skills in the topic of substances and their changes using interactive media based on virtual laboratories. Virtual laboratories can be used as an alternative means in the learning process to overcome the lack of tools and topics in practical activities. According to [23], Virtual laboratories can be used as an alternative to focus students' attention on teaching and learning activities and to train students to do real practicums, practical activities can be trained using the virtual world. Thus, the limitations of practical facilities and infrastructure, the level of insecurity and financing for practicums are no longer obstacles to the failure to fulfil practical activities for students in learning, especially in the topic of substances and their changes. In line with research conducted by [24], which states that virtual laboratories greatly influence students' scientific literacy skills and are also able to provide a real picture of physical phenomena.

The advantage of this virtual laboratory is that users can access the virtual laboratory from anywhere, anytime, without physical location restrictions; then, it can reduce the risk of accidents and exposure to hazardous materials, allowing users to repeat experiments as many times as desired without restrictions. Several advantages were also put forward by [25]. Virtual Laboratories have several benefits, including explaining abstract concepts that cannot be explained through verbal delivery; virtual laboratories can also be a place to conduct experiments that cannot be done in conventional laboratories. Research on the application of interactive learning media based on virtual laboratories to the scientific literacy skills of junior high school students has been proven in real terms, where, by using interactive learning media based on virtual laboratories, the scientific literacy skills of junior high school students in science subjects, specifically the topic on substances and its changes, are higher.

Conclusion

Based on the results of the study, it can be concluded that there is an effect of implementing interactive learning media based on virtual laboratory on students' scientific literacy skills on the topic of substances and their changes at SMP Negeri 4 Tilamuta and SMP Negeri 1 Tilongkabila in the experimental and replication classes. The results indicate this through the hypothesis testing criteria where T-count ≥ T-table with a level of $\propto = 0.05$ for the experimental and replication classes 1 in each school; therefore, H0 is rejected, and H1 is accepted. So, it can be concluded that there is an effect of implementing interactive learning media based on a virtual laboratory on the scientific literacy skills of junior high school students on the topic of substances and their changes. Also supported by the acquisition of the course average normalized gain for all sample classes, both experimental and replication, which are in the high category, in the experimental class at SMP Negeri 1 Tilongkabila (0.75), the experimental class at SMP Negeri 4 Tilamuta (0.79) and replication class 1 (0.83). This shows that interactive learning media based on virtual laboratories affects students' scientific literacy skills on the topic of substances and their changes at SMP Negeri 4 Tilamuta and SMP Negeri 1 Tilongkabila.

Author's Contributions

Manda Nur Aisia Daud: Conceptualization, writing-original draft preparation, methodology; Tirtawaty Abdjul: Conceptualization, methodology; Citron S. Payu: Curation, writing-original draft preparation; Nova Elysia Ntobuo: Writing-review and editing; Abdul Haris Odja: Formal analysis, methodology; Nurhayati Nurhayati: Validation.

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