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Assessing of Science Literacy Skills of Natural Science Pre-Service Teachers Through Virtual Laboratory-Based Scientific Approach

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Abstract

This study aims to assess the science literacy skills of science: 1) the activity of natural science pre-service teachers; 2) the improvement of science literacy skills of groups A and B; 3) whether there is a difference in the average score and the improvement of science literacy skills before and after learning in group A and B; 4) whether there is no difference in the average score of the n-gain of science literacy skills of group A and B; and 5) how big is the effect size of the science literacy skills of group A and B. Pre-experimental research method, the number of samples of each group A and B (n = 29) were determined by purposive sampling. Data analysis was descriptive and inferential. The research instrument, a science literacy test, consisted of 20 multiple-choice questions with a value range of 0-100, which were valid (Vc = 1) and reliable (100%). Prospective science teachers who participated in the virtual laboratory-based scientific approach demonstrated an average score increase of 48% in science literacy skills for group A and 46% for group B. There was a difference in the average score of science literacy before and after learning in both groups. However, there was no significant difference in the average n-gain score between the two. The effect size in group A was in the high category (1.0), while group B was in the medium category (0.4). These results indicate that the science literacy skills of prospective teachers still need to be improved through training that combines the scientific approach and virtual laboratory so that they can be directly involved in the development of science literacy.

Keywords: scientific, laboratory, virtual, science literacy skills, assessing

INTRODUCTION

The knowledge and understanding of scientific concepts and processes necessary for personal decision-making, participation in civic affairs, culture, and economic productivity is the ability to read, write, think, and talk about real-world science issues(Abeldina et al., 2018; Adriyawati et al., 2020; Afnan et al., 2023; Agustia et al., 2021; Alatlı, 2020; OECD, 2019).

In Indonesia, people are not science literate. One only has to look at international studies of educational performance to see that students in Indonesia rank at the very bottom in science and math, quite unlike what would be expected if schools were doing their job well. Recent international math studies report, for example, that Indonesian students are well below international levels in problem-solving, and a recent study of the National Education Progress Assessment found that despite some recent progress, their average performance was 17 (Amin et al., 2021; Aruta, 2023), few primary school teachers have basic education in science and math, and many science and math teachers in junior and senior high schools do not meet reasonable standards of preparation in these areas.

Science and math teachers have such a heavy teaching load that it is almost impossible for them to perform well, regardless of how well-prepared they are. This burden is compounded by the almost complete absence of modern support systems to back them up (Avikasari et al., 2018; Ayu et al., 2021).

Current science textbooks and teaching methods, rather than promoting progress, often hinder the achievement of science literacy. They emphasize learning answers over exploring questions, prioritizing memory over critical thinking, and focusing on chunks of information rather than understanding in context, favoring reading over arguments, and even using reading as a substitute for hands-on experience (Aliyana et al., 2019; Allum et al., 2018).

The 2013 science and math curriculum, which was later revised into the current independent curriculum, is overly content-heavy and lacks science and numerical literacy skills. For decades, they grew unimpeded, overwhelming teachers and students and making it difficult for them to know what really matters in science, math, and technology. Some topics are taught repeatedly in unnecessary detail; some equally or more important for science literacy, often from the physical and social sciences as well as from technology are absent from the curriculum or reserved for only a few students Hernawati et al., 2019; Hestiana & Rosana, 2020).

"*...... science education, meaning science, math, and technology education, should help students develop the understanding and habits of mind they will need to become compassionate human beings capable of thinking for themselves and facing life head-on.*" (Aliyanaetal, 2019; Allumetal, 2018; Amin et al., 2021; Anazifa & Djukri, 2017; Archilaetal, 2021; Ardianto & Rubini, 2016; Aruta, 2023). Science fosters an intelligent respect for nature that should inform decision-making in the use of technology; without that respect, we are in danger of wantonly destroying our life support systems.

According to the American Project 2061, science for everyone is based on the belief that a scientifically literate person realizes that science, mathematics, and technology are interdependent human endeavors with strengths and limitations; understands key concepts and principles of science; is familiar with nature and recognizes its diversity and unity; and uses scientific knowledge and scientific thinking for individual and social purposes; is required to participate in a Digital Age society; can ask, discover, or determine answers to questions that stem from his or her curiosity about everyday experiences; have the ability to describe, explain, and predict natural phenomena; be able to read with understanding articles about science in popular media and engage in social activities; have conversations about the validity of conclusions; be able to identify scientific issues that underlie national and local decisions and state positions that are based on scientific and technological information; be able to evaluate the quality of scientific information based on its source and the methods used to produce it; have the capacity to propose and evaluate arguments based on evidence and apply the conclusions of those arguments appropriately; have knowledge and understanding of scientific concepts and processes(Ashari et al., 2023; Handayani & Saputra, 2023; Hendriana et al., 2018; Hernawati et al., 2019; Hestiana & Rosana, 2020).

Students need to understand how to evaluate data sources. Students need to understand where data is collected, how it is collected, and what it represents. Like scientists in the lab or in the field, scientists in the classroom must learn that it is important to consider multiple sources of data to analyze and draw conclusions (Atmojo et al., 2021; Avikasari et al., 2018; Ayu et al., 2021; Hendriana et al., 2018).

Based on this problem, several research results reported that the average score of science literacy skills is still very low, around 45.89 by applying various learning models, including problem-based learning, project-based learning, and models of guided discovery, in elementary schools, junior high schools, high schools, and even students in universities (Aliyana et al., 2019; Amin et al., 2021; Conner et al., 2019; Dewi et al., 2021; Dignam, 2023; Erman et al., 2020; Eugenio-Gozalbo et al., 2022).

To overcome these problems, this study applies a scientific approach based on a virtual laboratory. This approach directly involves students conducting investigations and discoveries through the practicum of virtual science experiments. This is where this research differs from other research. Originality is that students carry out scientific activities to test hypotheses that have been formulated to solve problems. That means students are involved in understanding how to evaluate data sources, understanding where data is collected, how it is collected, and what it represents.

Virtual laboratories can reduce the simulation of student experiments. Through virtual laboratories, students conduct experiments, and the experimental results obtained will be the same as the results of manual laboratory experiments. Virtual laboratories can overcome some of the shortcomings of manual laboratories. (Wong et al., 2020) found that with the application of virtual laboratories and microcomputers, students understand the purpose of the experiment and increase student interest. Combined with Android smartphones, the quality of learning is very good (Fortus et al., 2022; Fuad & Hamid, 2019; Goodwin et al., 2023).

There are six steps of the virtual laboratory, namely: observing, questioning, constructing, conducting experiments, analyzing results and conclusions, reporting results (Grabau et al., 2022; Guo et al., 2022; Hairida & Junanto, 2018; Hariyadi et al., 2023; He et al., 2021; Herlina & Abidin, 2024; Husniyyah et al., 2023; Hwang et al., 2018). The practicum topic is to investigate the relationship between wave deviation to amplitude, wave number, angular acceleration, and phase. Wave interference on wave number, angular acceleration, wave superposition on wave phase, wave number.

Science literacy is defined as the capacity to use scientific knowledge, identify questions, and draw conclusions based on facts to understand the universe. Based on this definition, science literacy has four domains: scientific knowledge, scientific process, scientific context, and attitude toward science (Ichsan et al., 2024; Jalil et al., 2019; Jannah et al., 2023; Jumanto et al., 2024; Kadir et al., 2024).

Science literacy as scientific knowledge will always be needed by every human being. Everyone needs to use this scientific information in their lives. Therefore, learning that is identified with scientific literacy needs to be taught early to children at school. At the primary, secondary, and tertiary levels of education, learning with an emphasis on the process of science literacy is seen as better equipping students with scientific abilities such as observation, inference, experimentation, and inquiry. The scientific method is the core of student science literacy learning. There are many ways that teachers can teach science literacy. For example, in classroom learning, teachers can apply cooperative learning models with a scientific method approach, such as by applying the Jigsaw learning model, inquiry, and other models. Competencies that can support the achievement of these goals are science attitudes and science literacy skills. Based on the results of the study, it was found that the average score of the two competencies was still very low (Amelia et al., 2019; Good et al., 2018; Kang, 2022; Kaya & Elster, 2019; Kelp et al., 2023; Putri et al., 2020; Tawil & Dahlan, 2021). As an effect of these problems, the *Program for International Student Assessment* (PISA) and *Trends in International Mathematics and Science Study* (TIMSS) rankings are still low compared to other countries (Marôco et al., 2024; Muhibbuddin et al., 2020; Mun et al., 2015; Murti et al., 2024; Nasor et al., 2023; Nasution et al., 2023; Nazri, 2019; Norambuena-Meléndez et al., 2023).

The novelty of this study is the discovery of a way to assess scientific literacy skills for pre-service teachers through a virtual laboratory-based scientific approach that has never been studied. This is important because there will always be a need for more sophisticated research. From the findings of this study, it is hoped that more information, an overview, and a map of scientific literacy research that has been carried out in Indonesia will be obtained. This will provide direction in conducting further research and policies. The results of the study reported that the assessment of scientific literacy skills is very important to measure to assess analytical skills in the application of science to solve problems (Osborne et al., 2003; Paristiowati et al., 2019; Pebriani1 et al., 2022; Picardal & Sanchez, 2022; Ploj Virtič, 2022; Purnomo et al., 2023).

METHODS

The Research Model

This study is a pre-experiment using a one-shot case study design (Qadar et al., 2022; Rahman et al., 2023; Ramli et al., 2022). The design is shown in TABLE 1.

TABLE 1. Research Design

Group	Pretest	Treatment (X)	Post test
A	O_1	X	O_2
B	O_3	X	O_4

Pre-experimental research method. Both groups (A and B) were given the same treatment, namely a virtual laboratory-based scientific approach. Before the treatment was given, a pretest was conducted, and after the treatment, a posttest was conducted, which aimed to 1) analyze the effect of the treatment on improving the science literacy skills of pre-service teachers, 2) improve the science literacy skills of groups A and B, 3) whether there was a difference in the average score of science literacy skills before and after learning in groups A and B, 4) whether there was a difference in the average score of science literacy skills of groups A and B, and 5) how big the effect size was on improving the science literacy skills of groups A and B.

Participants

The sample of this study was natural science pre-service teachers education, Faculty of Mathematics and Natural Sciences, Univesitas Negeri Makassar, totaling 58 people, each consisting of groups A and B ($n = 29$). The sampling technique used purposive sampling. The sampling technique of the study used purposive sampling. This was done because it was adjusted to the reason that there were only two groups.

Data Collection Tools

Data were collected using a science literacy skills test consisting of 20 multiple-choice questions, with one point awarded for each correct answer and zero for each incorrect one. The analysis of the internal consistency coefficient of the test used Gregory's analysis, and the data analysis used descriptive and inferential with the SPSS version 25.0 application. Science literacy skills is the total score obtained by natural science pre-service teachers after completing the science literacy skills test.

Validation and Reliability of Research Instruments

The science literacy skills test consists of 10 items and was validated by three science education experts. The validation was analyzed using Gregory's method (Romli et al., 2024; Rosnelli & Ristiana, 2023; Rusilowati et al., 2021; Tawil et al., 2024), as shown in TABLE 2. The coefficient of internal consistency (internal validation) was calculated using Equation (1), and its category was determined based on TABLE 3. The validation results show that the internal validation value exceeds 0.75, which falls into the high category, indicating that the test is suitable for use in research.

$$\text{Internal Consistency Coefficient (Internal validation)} = \frac{\text{D}}{\text{A+B+C+D}} \quad (1)$$

TABLE 2. Gregory's validation analysis tabulation

	Expert Assessment	
	(1 or 2) score	**(3 or 4) score**
weak relevance expert assessment (item is worth 1 or 2)	A	B
strong relevance expert assessment (item is worth 1 or 2)	C	D

with remarks:

A = Both experts give weak relevance
B = The first expert gives strong relevance
The second expert gives weak relevance
C = The first expert gives weak relevance
The second expert gives strong relevance
D = Both experts give strong relevance

TABLE 3. Gregory-Based Content Validity Classification

Content Validity	Criteria
0.80 – 1.00	Very high validity
0.60 – 0.79	High validity
0.40 – 0.59	Medium validity
0.20 – 0.39	Low validity
0.00 – 0.19	Very low validity

Based on the calculation results above, the instrument is declared valid with the category "very high" because Vc = 1.

Analysis of the reliability of the SPS diagnostic test to calculate the level of percentages of agreements between the two raters stating "yes" or "no" used Equation (2) (Tawil et al., 2024). The results of the reliability analysis are 100%, which is greater than the lower limit of the reliability coefficient of 0.75, meaning that all research instruments are reliable.

$$R = \left(\frac{\overline{d(A)}}{d(A)+\overline{d(D)}}\right) x100\% = \left(\frac{3.86}{3.86+0}\right) x100\% = 100\% \quad (2)$$

In this study, the science literacy skills aspects assessed include indicators: scientific knowledge, scientific process, scientific context (Suhirman & Khotimah, 2020; Supahar & Widodo, 2021). Because the value is > 75%, the scientific literacy test instrument is reliable.

TABLE 4. Content validation category

Interval	Category
> 0.8	High
0.4 – 0.79	Medium
< 0.4	Low

Data Analysis and Interpretation

The data obtained were then analyzed descriptively and inferentially. Descriptive analysis will provide an overview of the science literacy of prospective natural science pre-service teachers. The results of this analysis are displayed in the form of the highest score, lowest score, average score, standard deviation, and variance. N-Gain analysis was obtained using Equation (3), and the categories are in TABLE 5.

$$g = \frac{skorposttest - skorpretest}{nskorideal - skorpretest} \quad (3)$$

TABLE 5. N-Gain level categories

Average N-gain (g)	Category
g > 0.7	High
0.3 ≤ g < 0.7	Medium
0 ≤ g < 0.3	Low
g ≤ 0	Failed

Effect size analysis used is Cohen's d effect size analysis. The effect size value is obtained using Equation (4).

$$d = \frac{\bar{\bar{x}}_2 - \bar{\bar{x}}_1}{\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2}}} \quad (4)$$

TABLE 6. Interpretation of Effect Size Value

Value d	Category
d ≥ 1.00	High
0.5 ≤ d < 1.0	Medium
0.2 ≤ d < 0.5	Low
d < 0.2	Failed

Tests of inferential satatistical requirements and hypothesis testing were analyzed with SPSS 25.

RESULTS AND DISCUSSION

Results of Descriptive Statistical Analysis

Class A Science Literacy Skills

An overview of the pre-test of science literacy skills of natural science pre-service teachers in group A before being given treatment is presented in the form of descriptive statistics in TABLE 7.

TABLE 7. Statistical Data of Pre-Test Score of Science Literacy skills of Class A

Descriptive Statistics	Statistical Results
Sample Quantity	29
Average	45.89
Standard Deviation	4.99
Variance	24.95
Minimum Score	35
Maximum Score	56

The pre-test results for science literacy skills in Class A show that among 29 participants, the average score was 45.89, indicating a moderate level of initial science literacy. The standard deviation of 4.99 and variance of 24.95 suggest relatively low variability, meaning most students scored close to the average. The minimum score was 35, and the maximum score was 56, resulting in a range of 21 points. This relatively narrow range implies a fairly homogeneous level of initial ability among the students.

TABLE 8. Frequency Distribution of Class A Science Literacy Pre-Test Score

Range	Frequency	Relative Frequency (%)
55 – 59	1	3.45
51 – 54	5	17.24
47 – 50	5	17.24
43 – 46	11	37.93
39 – 42	5	17.24
35 – 38	2	6.90
Total	29	100.00

Most students in Class A scored between 43 and 46 on the pre-test, making it the most common score range (37.93%). Several students also scored between 39-42, 47-50, and 51-54, each with about 17% of the class. Only one student scored in the highest range (55-59), and two students were in the lowest range (35-38). This shows that most students had average science literacy skills, with only a few scoring very high or very low.

An overview of the post-test scores of science literacy skills of natural science pre-service teachers in group A before being given treatment is presented in the form of descriptive statistics in TABLE 9.

TABLE 9. Statistical Data of Post-Test Score of Science Literacy skill of Class A

Descriptive Statistics	Statistical Results
Sample Quantity	29
Average	71.31
Standard Deviation	5.0
Variance	25.0
Minimum Score	60
Maximum Score	81

The post-test results for Class A show a clear improvement in science literacy skills, with an average score of 71.31, significantly higher than the pre-test average. The standard deviation of 5.0 and variance of 25.0 indicate that the scores were fairly consistent, with most students scoring near the average. The minimum score was 60 and the maximum was 81, showing a range of 21 points, similar to the pre-test, but at a higher overall level. These results suggest that the students' science literacy skills improved after the intervention, with performance shifting to a higher and more uniform level. The following is the distribution of post-test data of group A science literacy skills scores in the frequency distribution TABLE 10.

TABLE 10. Frequency Distribution of Class A Science Literacy Post-Test Score

Range	Frequency	Relative Frequency (%)
80-83	2	6.90
76-79	4	13.79
72-75	6	20.69
68-71	10	34.48
64-67	5	17.24
60-63	2	6.90
Total	29	100.00

The post-test results show that most students in Class A scored between 68 and 71, making it the most common score range (34.48%). A significant number also scored between 72-75 (20.69%) and 64-67 (17.24%). Higher score ranges like 76-79 and 80-83 had fewer students, at 13.79% and 6.90% respectively. Only two students (6.90%) were in the lowest range of 60-63. Overall, the scores are spread across higher ranges compared to the pre-test, indicating an improvement in science literacy skills after the learning intervention.

Class B Science Literacy Skills

An overview of the pre-test score of science literacy skills of natural science pre-service teachers in group B before being given treatment is presented in the form of descriptive statistics in TABLE 11.

TABLE 11. Statistical Data of Pre-Test Score of Science Literacy Skills of Class B

Descriptive Statistics	Statistical Results
Sample Quantity	29
Average	42.59
Standard Deviation	8.50
Variance	71.90
Minimum Score	7
Maximum Score	52

The pre-test results for Class B show an average score of 42.59, indicating a moderate level of science literacy before the intervention. The standard deviation of 8.50 and variance of 71.90 suggest a wider spread of scores compared to Class A, meaning there was greater variation in students' initial abilities. The minimum score was 7, which is very low, while the maximum was 52, giving a wide range of 45 points. This shows that students in Class B had more diverse starting points, with some performing very poorly and others moderately well before instruction. The following is the distribution of pre-test data on group B science literacy scores in TABLE 12.

TABLE 12. Frequency Distribution of Class B Science Literacy Pre-Test Score

Range	Frequency	Relative Frequency (%)
47-54	9	31.03
39-46	16	55.17
31-38	3	10.34
23-30	0	0
15-22	0	0
7-14	1	3.45
Total	29	100.00

The pre-test scores for Class B show that more than half of the students (55.17%) scored in the 39-46 range, making it the most common performance level. Another 31.03% of students scored between 47–54, while only 10.34% were in the 31-38 range. Very few students scored very low, with only one student (3.45%) in the 7-14 range, and none in the 15-30 range. These results indicate that although most students had moderate pre-test scores, there was still a wide spread in performance, with one student showing a very low level of science literacy.

An overview of the post-test scores of science literacy skills of natural science pre-service teachers in class B before treatment is presented in the form of descriptive statistics in TABLE 13.

TABLE 13. Statistical Data of Post-Test Score of Science Literacy Skills of Class B

Descriptive Statistics	Statistical Results
Sample Quantity	29
Average	68.24
Standard Deviation	7.35
Variance	53.97
Minimum Score	40
Maximum Score	77

The post-test results for Class B show an average score of 68.24, indicating a significant improvement compared to the pre-test scores. The standard deviation of 7.35 and variance of 53.97 suggest that the students' scores are still somewhat varied but more evenly distributed than before. The minimum score increased to 40, and the maximum score reached 77, showing that all students improved, including those who initially had very low scores. This data reflects an overall enhancement in science literacy skills across Class B after the learning intervention. The following is the distribution of post-test data on group A science literacy skills scores in the frequency distribution TABLE 14.

TABLE 14. Frequency Distribution of Class B Science Literacy Post-Test Score

Range	Frequency	Relative Frequency (%)
75-81	5	17.24
68-74	14	48.28
61-67	7	24.14
54-60	2	6.90
47-53	0	0
40-46	1	3.45
Total	29	100.00

The post-test frequency distribution for Class B shows that nearly half of the students (48.28%) scored in the 68-74 range, making it the most common performance level. A significant portion (24.14%) scored between 61-67, while 17.24% reached the highest range of 75-81, indicating strong performance by several students. Only one student (3.45%) scored in the lowest range (40-46), and none scored below 40. These results suggest a clear shift toward higher achievement levels, with most students performing above 60 and very few at the lower end, reflecting the success of the instructional intervention.

The average n-gain values for both Groups A and B fall into the medium category, indicating a moderate improvement in science literacy skills among pre-service science teachers before and after the treatment, as shown in TABLE 15.

TABLE 15. N-Gain Result

Class	Average n-gain	% Average N-gain	Category
A	0.48	48	Medium
B	0.46	46	Medium

Results of Inferential Statistical Analysis

Normality Test

Using IBM SPSS 25, a normality test was conducted using the Kolmogorov Smirnov test. The recapitulation of the normality test data of the science literacy skills learning outcomes score is presented in TABLE 16 and TABLE 17.

TABLE 16. Normality Test of Science Literacy Skills Pre-Test Score

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
A	.112	29	.200*	.988	29	.978
B	.121	29	.200*	.976	29	.725

TABLE 17. Normality Test of Science Literacy Skills Post-Test Score

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
A	.121	29	.200*	.976	29	.725
B	.124	29	.201	.986	29	.830

Based on TABLE 16 and TABLE 17, it is known that the significance value for the pre-test and post-test score data for both normality tests is greater than $\alpha = 0.05$ (Sign. > 0.05). So the data can be declared normally distributed.

Homogeneity Test

Using IBM SPSS 25, a homogeneity test was conducted using the Levene test. A recapitulation of the data homogeneity test is presented in TABLE 18.

TABLE 18. Data Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
.042	1	56	.838

TABLE 18 shows that the significance value obtained in the homogeneity test is greater than $\alpha = 0.05$ (Sign. > 0.05). So the data can be declared homogeneously distributed.

Paired Sample t – Test

The Paired Sample T-Test test was conducted using IBM SPSS 25. The recapitulation of the paired sample t-test results is presented in TABLE 19 and TABLE 20.

TABLE 19. Paired Sample Test Results Class A

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest Postest	-25.41379	1.47642	.27416	-25.97539	-24.85219	-92.696	28	.000

TABLE 20. Paired Sample Test Results Class B

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest Postest	-25.55172	1.63851	.30426	-26.17498	-24.92847	-83.979	28	.000

Based on TABLE 19 and TABLE 20, it is known that the significance value obtained is smaller than the value of $\alpha = 0.05$ (Sign. <0.05). So it can be stated that there is a difference in the increase in the average score of the pretest-posttest of science literacy of group A and B.

Independent Sample T-Test

The Paired Sample T-Test test was conducted using IBM SPSS 25. The recapitulation of the paired sample t-test results is presented in TABLE 21.

TABLE 21. Independent Sample T-Test Results

Science Literacy	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.042	.838	.867	56	.390	2.03448	2.34736	-2.66785	6.73681
Equal variances not assumed			.867	55.64	.90	2.03448	2.34736	-2.66852	6.73749

The independent sample t-test results show that there is no significant difference in science literacy between the two groups. Levene's test indicates that the variances are equal (p = 0.838), so we use the row assuming equal variances. The t-test result (t = 0.867, p = 0.390) shows that the difference in average scores is not statistically significant. Although one group scored about 2.03 points higher, this difference could have happened by chance, as the 95% confidence interval (-2.67 to 6.74) includes zero. Therefore, TABLE 21 concludes that both groups have similar levels of science literacy.

Effect Size Analysis

Effect size analysis is necessary to determine the extent of a treatment's influence, thereby making research results more meaningful and facilitating comparisons between studies. The results of the effect size analysis are presented in TABLE 22.

TABLE 22. Results of Effect Size Analysis of Students' Science Literacy Skills

Class	Effect Size	Category
A	1.0	Strong
B	0.4	Medium

TABLE 22 shows that the effect size of science literacy skills in Group A is in the high category, and in Group B, it is moderate. This means that the effect of learning provided in both groups is significant in improving the science literacy skills of natural science pre-service teachers

Discussion

This study was conducted in two classes, designated as Group A and Group B, each of which received a pre-test and a post-test to assess the science literacy skills of prospective natural science pre-service teachers. The treatment involves the application of a scientific approach based on a virtual laboratory, focusing on learning waves and optics. Learning activities with a scientific approach consist of five stages, namely observing, asking questions, exploring/experimenting, associating, and communicating.

Learning with a scientific approach takes place in three main activities. The first activity is an introductory activity, where the lecturer creates an effective and engaging learning atmosphere for students. In this activity, the lecturer introduces the problems that prospective natural science pre-service teachers must observe when learning takes place. The second activity is the core activity, where students begin to observe the problem, discuss and ask each other about the existing problems, collect data through exploration or experimentation, process and present the information obtained, and then analyze and reason to conclude a solution to the problem. The third activity is the closing activity, in which the lecturer summarizes the learning outcomes. In this study, learning activities were supported by a virtual laboratory developed using PheT simulation and Microsoft Excel.

Based on the pre-test data for groups A and B, the average score of science literacy skills for prospective natural science pre-service teachers remains relatively low, at 45.89 and 42.59, respectively. After being treated, specifically through the application of learning with a scientific approach using virtual labs and simulations developed by PheT Simulation and Microsoft Excel, there was a 48% increase in science literacy skills for class A and a 46% increase for class B, categorized as moderate improvement. Based on the post-test results, the average scores of science literacy skills of groups A and B were 71.31 and 68.24. This finding aligns with the results of the paired sample T-test.

Based on the results of the paired sample t-test, the significance value for the pretest-posttest comparison between groups A and B is 0.00. The significance value obtained is smaller than 0.05. There is a difference in the average increase in the score of science literacy skills of prospective natural science pre-service teachers. These results indicate a change in the science literacy skills of prospective natural science pre-service teachers before and after being treated. Some research results were reported (Handayani., Adisyahputra & Indrayanti, 2018; Hernawati, Amin, Muhdhar & Indriwati, 2019; Hestiana & Dadan, 2020; Hewi & Shaleh, 2020; Hikmayanti, Saehana & Muslimin, 2017) which stated that the application of a virtual laboratory-based scientific approach can improve learning outcomes and science literacy skills of prospective natural science pre-service teachers.

Based on the results of the n-gain test, the average n-gain for groups A and B is 0.48 and 0.46, respectively, and falls within the medium category. There is no difference in n-gain values in groups A and B. This is in line with the results of the independent sample t-test, which indicate that there is no difference in the level of science literacy between groups A and B. So, it can be concluded that learning waves and optics with a scientific approach based on virtual laboratories is equally effective for improving the science literacy skills of prospective natural science pre-service teachers in groups A and B.

The scientific approach based on virtual laboratories is concluded to improve the science literacy skills of prospective natural science pre-service teachers. Research results have found that science literacy skills can be applied through scientific learning (Amelia et al., 2019; Good et al., 2018; Lestari et al., 2022; Lubis & Listyarini, 2021; Putri et al., 2020). The magnitude of the effect of learning a scientific approach based on a virtual laboratory on science literacy skills in group A and B can be seen from the results of the effect size analysis test. Based on the results of the effect size analysis test, the effect size value for group A is 1.0 and is in the strong category. While the effect size value for group B is 0.4 and is in the medium category. This means that the effect of learning a scientific approach given to both group has a significant effect on improving the science literacy skills of prospective natural science pre-service teachers. The study's results confirmed findings from research conducted by M. Amelia et al. (2023), Luthfiana et al. (2023), Luzyawati et al. (2025), Ma (2022), and Sutiani et al. (2021). Theories of learning and teaching that can be used to explain the findings of the influence of the scientific approach based on virtual laboratories include i.e. Piaget's learning theory, related to self-discovery learning of lesson concepts; Vygostki's learning theory related to group learning carried out during practicums and discovery learning theory(Sakdiah et al., 2024; Sanjayanti et al., 2022; Santoso et al., 2023; Saraswati et al., 2021; Sari et al., 2018).

CONCLUSION

1. There is an increase in the science literacy skills of prospective natural science pre-service teachers after learning the scientific approach based on virtual laboratories.Group A experienced an increase in the average score of science literacy skills by 48% and group B experienced an increase of 46%.
2. There is a difference in the average score of science literacy skills of prospective natural science pre-service teachers before and after participating in learning with a scientific approach based on virtual laboratories. Group A and B before being given scientific learning have an average score ofscientific literacy skills of 45.89 and 42.59. After being given a virtual laboratory-based scientific approach learning, the average score of science literacy skills of group A and groupB became 71.31 and 68.24.
3. There is no difference in the average n-gain score of prospective natural science pre-service teachers in participating in learning with a virtual laboratory-based scientific approach for group A and group B.
4. The effect size of the application of the scientific approach based on virtual laboratories on the science literacy skills of prospective natural science pre-service teachers in group A is 1.0 and is in the high category, while in group B it is 0.4 and is in the medium category

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APPENDIX

Science Literacy Skills

1. Observe the following picture!


(Source: Bola.com)

The picture above shows the situation after the rain, Rani tried to get out of her house, and she saw a rainbow appear. The rainbow has various colors, there are red, orange, yellow, green, blue, indigo, and purple. This event can occur because when sunlight passes through a water drop, the sunlight will be bent so that it will make the colors separate from other colors. Each color of the rainbow will be deflected at a different angle so that it will give the rainbow beautiful colors.The event is an example of the properties of light can...
   A. propagates straight
   B. refracted
   C. reflected
   D. reflected and refracted

2. As Rani was cleaning out her shed, she found some items that could still be used. Here are some of the items that Rani found in her warehouse.
   A. Microscope, a tool used to view very small objects or objects that are difficult to see with the naked eye.
   B. Lup, which is a tool used to enlarge the shadow of objects
   C. Camera, which is a tool used to create or capture an image of the object.
   D. TV, which is a tool used as information media, education media and entertainment media

3. Observe the following picture!


(Source: fisikabc.com)

When we drive, we can see other drivers who are behind us by using the rearview mirror as in the picture above. We can see distant drivers in the rearview mirror so that we can drive safely and estimate the speed of vehicles on the road.In addition, when we look in the rearview mirror, our faces appear larger than they really are.Based on the explanation above, what type of mirror is used in rearview mirrors?
   A. Convex
   B. Concave
   C. Flat
   D. Convex and concave

Take a look at the following article to answer question number 4

Light is an electromagnetic wave that can propagate without a medium as a place of propagation. Light can also propagate in a medium, but its speed is not the same as the speed of light in a vacuum. The concept of refraction and reflection of light can be explained following the behavior of light beams propagating in a medium. If light comes from a medium when another medium whose density (density) it will be deflected or refracted. An example of refraction is a pencil inserted into water and will look broken when viewed through the outer surface of the glass (Prihati, 2016).

4. Based on the article, the correct explanation of light is...
   A. Light reflection occurs due to differences in medium density
   B. Electromagnetic waves are said to be the source of all light
   C. Light can travel with or without a medium
   D. Including electromagnetic waves that cannot propagate without a medium

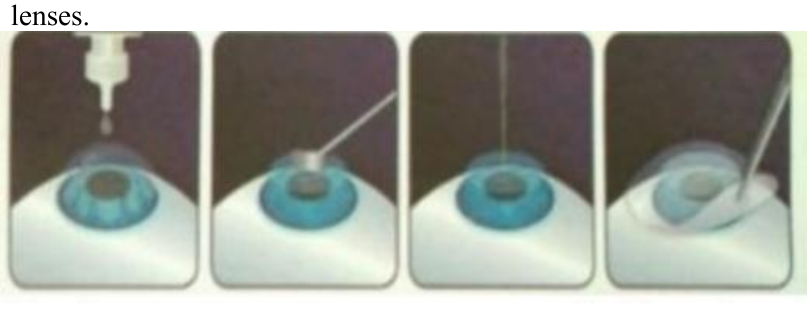
Take a look at the following article to answer question number 5

The recent hot weather has made people reluctant to linger outdoors. Excessive sun exposure can cause a number of health problems. Such as sunburn and skin cancer. Most people choose to take shelter or immediately enter a cool room. Home is one of the favorite places to take shelter from the sun. However, it can be uncomfortable if your home feels hot even when you're not sweating. Even if you turn on the air conditioner, it usually doesn't do much.

Indonesia is a tropical country with high temperatures and humidity throughout the year. Exposure to sunlight and high-intensity rain are factors that can interfere with the comfort level of its inhabitants. Therefore, the selection of materials becomes very important to make dwellings such as houses feel comfortable. One of the things that trigger heat in the house is the wrong choice of paint color.

5. The paint color that a builder should choose so that the house is not too hot during the day is...
   A. Black, because it absorbs light
   B. Gray, because it reflects light
   C. White, because it reflects light
   D. Red, because it absorbs light

6. LASIK surgery or Laser-Assisted In-Situ Keratomileusis is a medical procedure aimed at treating several vision disorders, including nearsightedness (Myopia), farsightedness (Hyperopia), and astigmatism. This surgery is performed using a laser beam on the eye that focuses the light entering the eye so that vision becomes better and patients can be free from wearing glasses or contact lenses.



(Source: TribunJogja.com)

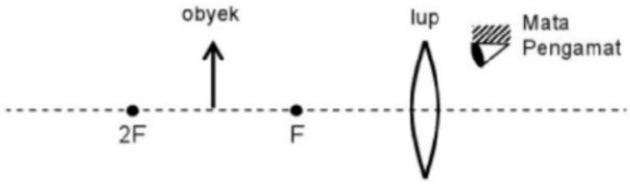
The part of the eye that is the object of LASIK surgery is...
   A. Pupil
   B. Cornea of the eye
   C. Iris
   D. Retina

7. A watch repairman uses a magnifying glass (lup) to be able to see the small objects he will be observing.

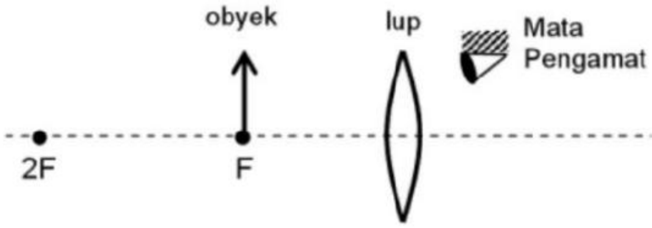

(Source: kronostoria.blongspot.com)

If he observes the object using magnifying glasses (lup) with a maximum accommodating eye, then the correct position of the object is...

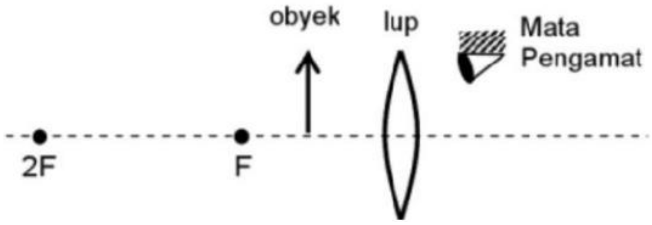
A.



B.



C.



D.

8. Below is the data from the experiment on light reflection on a flat mirror.

Angle of incidence (i)	Reflection angle (r)
10°	10°
20°	20°
30°	30°

From the table above, it can be seen that the angle of reflection will be equal to the angle of incidence. What will happen if the angle of incidence is 90°, the light will...
A. reflected 90°
B. reflected smaller than 90°
C. reflected is greater than 90°
D. not reflected

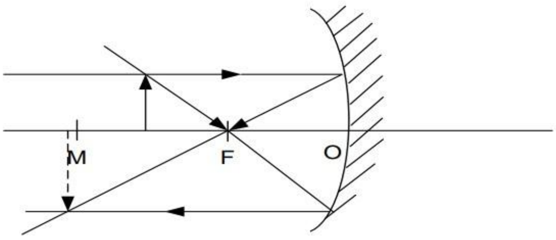
9. Nayla was curious about the tempeh that her mother always fried and served at breakfast. Nayla noticed that there was a white part of the tempeh on the outside. Her mother said that the white part was a type of mushroom that could be clearly observed using a special tool.

   Take a look at the following experiment steps
   1) Cut the tempeh sample into very thin pieces for easier observation.
   2) Place a magnifying glass over a thin piece of tempeh sample
   3) Place a thin piece of tempeh sample on the microscope object
   4) Place the telescope over a thin piece of tempeh sample
   5) Observe the microscopic structure of tempeh and record your observations.

   The sequence of work steps that Nayla should do to observe the mold on the tempeh is...
   A. 1-2-5
   B. 1-3-5
   C. 1-4-5
   D. 1-2-3

10. A grandmother accompanied by her grandson visited an optician to order glasses. The granddaughter said that the grandmother was experiencing vision problems that made it difficult for her to do her usual activities. She could only see clearly at a distance of 2 m at most. Then the lens power of the glasses that the grandmother should use is...
    A. - 0.5 Diopters
    B. + 0.5 Diopters
    C. - 2 Diopters
    D. + 2 Diopters

11. The process of forming shadows on a concave mirror uses the help of special rays from a concave mirror. The shadow is located at the point of intersection of the two reflected rays of the special rays. For example, suppose an object is placed between the center of curvature (M) and the focus point of the mirror (f) as shown in the following figure:

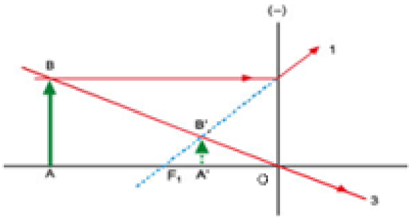


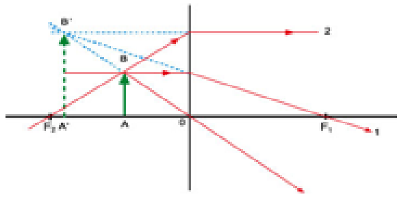
Source: (Marthen, 2002)

   Given the distance of the focal point of a concave mirror is 2 cm, the distance of the object is 3 cm and the height of the object is 1 cm, the magnification of the image on the mirror is ...
   A. 2
   B. 3
   C. 4
   D. 5

12. Two days ago, Riko had an accident after crashing into the road divider beside the intersection near the market. This happened due to the absence of street lights and the motorcycle's lights were broken and unusable, so the eyes could not see the road clearly. Why can't the road divider be seen by the eye when there is not enough light?
    A. Because there is no beam of light, which can be reflected into the eye
    B. Because the road divider is too big
    C. Because of the refraction of light into the eye
    D. Due to the reflection of light into the eye

13. Concave lenses have almost the same formation properties as convex lenses in space I, convex lenses have virtual and upright properties as well as concave lenses but there is a difference between the two.





Source : (eandroidfisika.wordpress.com)

What is the difference between the two lenses?

A. The shadow on a concave lens is minimized while that on a convex lens is enlarged
B. The shadow on a concave lens is enlarged while that on a convex lens is reduced
C. The shadow on a concave lens is greatly enlarged while that on a convex lens is slightly enlarged
D. The shadow on a concave lens is very slightly reduced while on a convex lens it is greatly enlarged

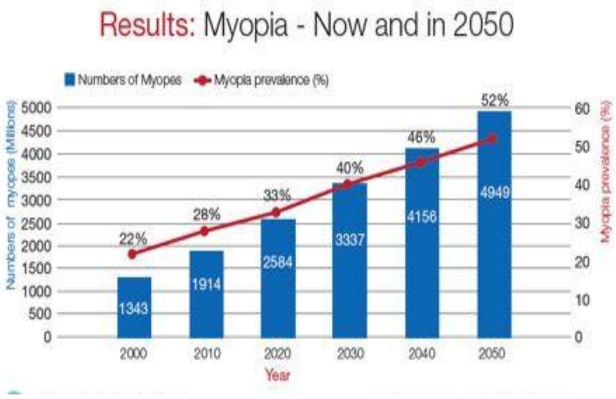
14. A grandmother accompanied by her grandson visited an optician to order glasses. The granddaughter said that the grandmother was experiencing vision problems that made it difficult for her to do her usual activities. She could only see clearly at a distance of 2m at most. Based on this event, what visual impairment does grandma suffer from?

A. Myopia
B. Hyperopia
C. Color blindness
D. Presbyopia

Take a look at the following article to answer questions 15-16

Myopia is one of the most common ocular disorders in childhood and can be prevented before it occurs. Myopia is a threat to vision impairment in children, due to lack of time to do outdoor activities and increased time to face digital screens as children seek social media entertainment through smartphones which is not good for eye health. There is an increasing prevalence of myopia in many countries around the world. According to UNESCO, more than 160 countries have implemented learning from home in an effort to limit the spread of Covid-19 which covers about 87% of the student population worldwide.

Before the Covid-19 pandemic, myopia had actually received widespread attention globally. In the World Health Organization (WHO) report, it is predicted that 40% or 3.337 billion people worldwide will suffer from myopia. By 2050, it is predicted to increase sharply to 52% or 4.949 billion people.



Source : (World Health Organization, 2017)

Considering the influence of the current covid-19 pandemic, especially for school-age children who will enter adolescence in 2030 and adulthood in 2050, it is not impossible that myopia sufferers exceed the WHO prediction (Simarmata, 2021).

15. The correct statement based on the graph above is...
    A. In 2017, WHO predicts that the Covid-19 pandemic will increase the percentage of myopia sufferers in all countries in the world.
    B. Looking at data from the WHO report on the predicted percentage increase in myopia patients worldwide, researchers consider that the increase in 2020 could exceed 33%.
    C. The number of people with myopia worldwide in n2020 almost doubled compared to 2010.
    D. By 2020, WHO predicts an increase in myopia with a percentage of 33% by less than 2,500,000 population in the world.

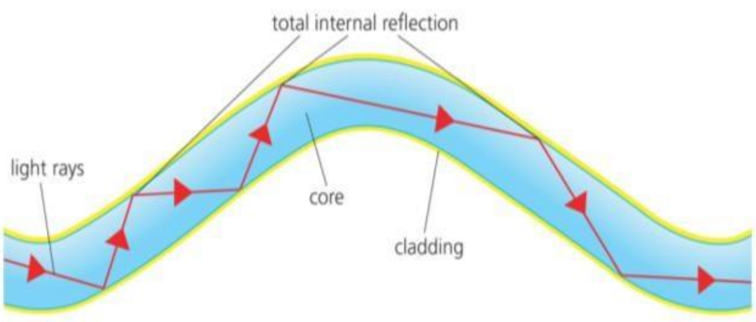
16. A learner suffers from nearsightedness or myopia. After seeing a doctor, he is required to wear -3.00 Diopters glasses with lenses that can place the image exactly on the retina. Based on the doctor's instructions, the lens of the glasses that the learner should use is ...
    A. Convex
    B. Concave
    C. Convex-concave
    D. Convex-convex

17. A motorcyclist wants to see the vehicle behind him.

Source: (Pratiwi, 2008)

The type of mirror that should be installed on the rearview mirror of the motorcycle is...
    A. Concave mirror because it casts an upright and minimized shadow
    B. Convex mirror because it casts an upright and minimized shadow
    C. A concave mirror because it casts an upright and magnified shadow
    D. Convex mirror because it casts an upright and magnified shadow

Take a look at the following article to answer question number 18
Fiber optic cable technology is the main medium of communication technology and information technology. In fiber optic technology, light is treated not only as a wave but as a particle as well.



Source : (netsolution.co.id)

The concept of *total internal reflection* is the basic concept of light signal propagation in fiber optic cables. The angle of incidence of the light signal is made so as to produce total internal reflection as a result of which the light signal is continuously reflected perfectly along the fiber optic cable until it finally reaches the other end of the cable. This *total internal reflection* ensures that the light signal travels following the curved physical shape of the cable until the signal finally reaches the other end of the fiber optic cable.

18. Based on the article, the concept of *total internal reflection* in light reflection described in the article is a type of reflection...
    A. Baur
    B. Regular
    C. Perfect
    D. 90° angle reflection

Take a look at the following article to answer question number 19

The diversity of butterfly species in Indonesia ranks second only to Brazil and it is estimated that as many as 1200 butterfly species in the world are found in Indonesia (Cortbert and Pendleburry 1956 in PHKA Journal 2005). One of the areas that is a butterfly habitat in Indonesia is BantimurungBulusaraung National Park (Babul National Park). According to Wallace (1856), at least 257 species of butterflies were recorded in this area, earning it the nickname The Kingdom of Butterfly.Putra is a child born into a family of *wildlife photography* hobbyists. His father and brother are senior photographers, while he is still an amateur.

Source : (DocPlayer.info)

One day, Putra and his family went on vacation to BantimurungBulusaraung National Park. Then, he found a rare transparent-winged butterfly with the scientific name *Charaxesaffinis*. He wanted to take a picture of the butterfly to add to his collection, but he was afraid that the butterfly would be killed when he photographed it.

19. If you were Putra's brother, what advice would you give to Putra so that the butterfly doesn't fly away while being photographed, but the photo is still sharp?
    A. I would suggest photographing the butterfly from a distance
    B. I would suggest shooting using a standard lens
    C. I would suggest changing the position of the lens relative to the butterfly according to the distance of the butterfly to be photographed.
    D. I would suggest shooting using a kit lens

20. Tania is planning an observation that she will do together with her friends. They want to know the distance of her shadow on a convex mirror. Tania plans to stand in front of a convex mirror as far as 20 cm. while the distance of Tania's focal point on the mirror is 10 cm. What is the distance of the shadow that will occur on the convex mirror?
    A. 6.7 cm
    B. – 6.7 cm
    C. 7.8 cm
    D. – 7.8 cm