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ORIGINAL RESEARCH

Implementation of Virtual Laboratory with Problem-Based Learning on Students' Written Communication Skills

Ainun Mardiyah, Muhammad Arsyad, Ahmad Dahlan

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Abstrack
This This study is a pre-experimental study that aims to describe students' communication skills before and after the implementation of virtual laboratories with problem-based learning, as well as analyze the improvement of students' communication skills in high school after participating in learning using virtual laboratories with problem-based learning. The design in this study is a One Group Pretest-Posttest design, with a population and sample of 30 students selected using saturated sampling techniques. The instrument used to collect data is an essay test consisting of 15 questions developed according to the indicators of students' communication skills, namely interpreting graphs, interpreting tables, interpreting images, changing the form of presentation, drawing conclusions, providing reasons, and explaining the results of observations. The data obtained in this study are quantitative data analyzed using descriptive statistics and inferential statistics. Based on the research data, it was found that high school students' communication skills are in the moderate category with an average N-Gain value of 0.68. Meanwhile, the results of the significance test using the Wilcoxon Signed Rank test showed a p-value of 0.001, which is smaller than 0.05. This indicates that the implementation of virtual laboratories with problem-based learning can improve students' communication skills.

Keywords: Virtual Laboratory · Problem Based Learning · Communication Skills

INTRODUCTION

The 21st century is known as the knowledge era, marked by the rapid development of technology and information across various aspects of life. Technological developments in this century require students to be able to integrate information technology into education, as it has become a necessity. The use of technology in the learning process can provide a more varied and engaging learning experience for students. This century has experienced significant changes in various fields, with high demands for producing quality human resources leading to changes in the structure of human life. Therefore, humans in this century are required to be able to integrate technology into learning and possess innovative skills and strong characteristics (Drake & Reid, 2020).

21st-century innovative skills that students must possess include the 4Cs: (1) critical thinking and problem-solving, (2) communication, (3) collaboration, and (4) creativity and innovation. One of them, communication skills, plays a crucial role in successful learning because effective communication supports the achievement of learning objectives (González-

✉ Ainun Mardiyah ainunsoniq28@gmai.com
Muhammad Arsyad m_arsyad288@unm.ac.id
Ahmad Dahlan ahmaddahlan@unm.ac.id

Universitas Negeri Makassar. Makassar, Indonesia.

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pérez & Ramírez-montoya, 2022; Thornhill-Miller dkk., 2023). Communication is an integral part of the learning process (Ginting et al., 2024).

Learning objectives will be achieved effectively not only when teachers are able to deliver the material, but also when students possess good communication skills. Students' ability to ask questions, explain ideas, discuss, and present their thoughts is a key element in the learning process. These skills are crucial in conveying the scientific process, both directly and indirectly, both individually and in groups. Therefore, effective communication supports student learning outcomes.(Siswanti & Indrajit, 2023; Sukarna, 2021).

According to Martiningtiyas et al. (2023) a communication process is considered effective if it meets the 7Cs: completeness, conciseness, consideration, concreteness, clarity, courtesy, and correctness.s Meanwhile, according to Putri & Arsil (2020) several factors influence communication skills in the learning process, including self-confidence, understanding of the material, opportunities, and language use.

According to Azis & Hasan (2024), communication skills indicators are divided into oral communication, namely the ability to convey and listen to opinions, ask questions of teachers or other students, convey reports or discussion results systematically and clearly, and answer questions from teachers or students. Meanwhile, written communication skills include the ability to use graphs, tables, interpret images, and interpret ideas in appropriate written form. In addition, skills in graphs, tables, reading images, explaining observation results and skills in changing presentation forms are indicators of achieving communication skills (Rustaman & Nuryani, 2005).

According to Yanti et al. (2015), the indicators of communication skills are as follows: (1) presenting statements orally, in writing, in tables, or in pictures (2) proposing conjectures, (3) carrying out mathematical manipulations (4) drawing conclusions, compiling evidence, providing reasons or proof of the truth of the solution, (5) drawing conclusions from statements, (6) checking the validity of an argument, (7) finding patterns or properties of mathematical phenomena to make generalizations.

In addition to communication skills, the use of technology in learning is also important because it supports the way students interact, collaborate, and convey ideas in a more varied form and in accordance with the demands of the 21st century. One relevant technology today is the virtual laboratory. Virtual laboratories allow students to conduct digital experimental simulations, thus overcoming the limitations of physical laboratory facilities. Their use is more flexible, efficient, and safe in supporting the practicum process (Sutarno et al., 2023; Zhang & Liu, 2023). In addition, virtual laboratories also increase active learning and engagement compared to physical laboratory facilities (Kebande, 2024).

A virtual laboratory is a computer-based interactive medium that provides simulations of science experiments and functions to support the classroom learning process (Hikmah dkk., 2017). Virtual laboratories facilitate students in conducting practical work and understanding physics concepts, thereby improving their understanding and thinking skills (Fatimah dkk., 2020). Virtual laboratories enable students to learn through a case study approach, interact with laboratory equipment, conduct and analyze experiments, and evaluate the processes carried out (Wibawanto, 2020).

For the practicum process to run optimally using a virtual laboratory, a learning model that encourages student activity and engagement is required. One model that aligns with 21st-

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century characteristics is problem-based learning. This model presents contextual problems to be discussed and solved in groups, thus training students in expressing opinions, collaborating, and developing communication skills (Noris dkk., 2022; Widodo, 2021).

According to Fatimah et al. (2020), there are several advantages to using a virtual laboratory, including: (1) enabling students to produce new experimental work more efficiently in terms of time and cost; (2) providing opportunities for students to visualize concepts at the macroscopic, submicroscopic, and symbolic levels; (3) presenting a dynamic representation of the world of submicroscopic particles; (4) supporting a deeper understanding of chemical material; and (5) serving as an effective motivational tool.

In this study, the virtual laboratories used were PhET and Olabs simulations. PhEt was created based on simulations in science (Physics, Chemistry, Biology, and Mathematics) developed using advanced computer technology. These simulations are designed to be as engaging as possible, using moving animations, interactive features, and game-like gameplay, so students can learn through exploration (Badriyah dkk., 2023). Furthermore, the PhEt simulations can be accessed online and offline, with shapes and colors designed to enhance the appearance of the PhEt simulations, as they directly match the base color of the materials and the actual shape of the equipment used in a real laboratory (Narulita dkk., 2024).

The Olabs simulation, meanwhile, is an interactive multimedia application that provides all the laboratory tools and materials, designed with software to make it easier for users to experience the experience of conducting practical work in a real laboratory (Rihi & Bano, 2022). Olabs is accessible for free via laptops and mobile phones (Bungkuran dkk., 2021).

Furthermore, the learning process using virtual laboratories requires an appropriate learning model to support classroom activities. A model considered appropriate is problem-based learning, as it involves steps that enable students to actively collaborate. In this model, students are first guided by a problem, then organized to plan learning activities. The teacher plays a role in guiding the learning experience, both individually and in groups, until students are able to develop and present their work. In the final stage, students are invited to analyze and evaluate the problem-solving process (Rusman, 2010).

Based on observations and interviews with a physics teacher at a high school, it was discovered that out of three eleventh-grade classes, only one focused on physics. Students' communication skills, particularly written communication skills, were found to be lacking. Students often struggled to interpret data, explain observations, and formulate conclusions after conducting experiments. If this situation persists, students will continue to struggle to understand and communicate their learning outcomes scientifically.

Furthermore, observations indicate that physical laboratory facilities in schools are still limited, leading physics teachers to sometimes use virtual laboratories in their lessons. However, the model used when utilizing virtual laboratories remains less engaging because it lacks structured and motivating learning steps. As a result, students tend to feel bored and lack focus during the learning process.

Widyaningsih et al. (2024), examined the application of a problem-based learning model assisted by PhET simulations to improve student learning outcomes and activities in physics. The results of this study indicate that the use of PhET simulations can broaden students' understanding of physics concepts. However, this study still emphasizes improving cognitive aspects, while students' communication skills have not been the main focus. In fact, in problem-

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based learning there are steps that encourage interaction, discussion, and collaboration between students, which should be able to train their communication skills. This is where the gap that forms the basis of this study emerged, namely how the integration of virtual laboratories with problem-based learning models not only functions to deepen conceptual understanding, but also theoretically and practically can develop students' communication skills through discussions of experimental results, argumentation, and presentation of findings.

This study examines three main questions related to the application of virtual laboratories with a problem-based learning approach to students' communication skills. These questions include an overview of students' communication skills before and after the application of virtual laboratory learning with a problem-based learning approach. In addition, the application of virtual laboratory learning with a problem-based learning approach has resulted in a significant improvement in students communication skills.

The main objective of this study was to describe the communication skills of students before and after the implementation of problem-based learning in the laboratory. In addition, it aimed to analyse the improvement in students' communication skills before and after the implementation of virtual laboratories with problem-based learning, particularly in the subject of fluids.

METHOD

Research Design

The research method used in this study was a quantitative method with a pre-experimental design using a one-group pretest-posttest design. In this design, a pretest was conducted before the treatment was given, so that the impact of the treatment could be determined more accurately, as there was information on the situation before and after the treatment that could be compared (Sugiyono, 2013). The population and sample consisted of all 30 grade XI students, selected using saturated sampling techniques.

Data Collection

In this study, the author used a virtual laboratory with problem-based learning, where virtual laboratory with problem-based learning is defined as learning that is expected to make students active in the learning process. The virtual laboratory in this study was used as a medium in the learning process and then combined with problem-based learning steps, where each step in problem-based learning can train students to work together in conducting experiments using a virtual laboratory.

There were several stages carried out during the research process, including:

a. Preparation stage, where researchers conduct observations as preliminary research data and then compile research proposals. In addition, at this stage, researchers compile learning modules, research instruments, and validate research instruments.
b. The research implementation stage began with data collection in the form of a pretest. Next, virtual laboratory learning with problem-based learning was provided to the research sample. After that, data collection in the form of a posttest was carried out. The research implementation process is described in Table 1 below.

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Table 1 Research Implementation

No.	Day/Date	Activities
1.	January 17, 2025	Conduct a pretest (initial test).
2.	January 23, 2025	Meeting 1, discussing hydrostatic pressure and completing Worksheet 1 on Hydrostatic Pressure.
3.	January 24, 2025	Meeting 2, discussing Archimedes' principle and completing Worksheet 2 on Archimedes' principle.
4.	January 30, 2025	Session 3, discussing viscosity (Stokes' law) and completing Worksheet 3 Viscosity (Stokes' Law).
5.	January 31, 2025	Meeting 4, discussing continuity law material and completing LKPD 4 Continuity Law.
6.	February 6, 2025	Meeting 5, discussing Bernoulli's law and completing Worksheet 5 on Torricelli's Theorem.
7.	February 7, 2025	Conducting a post-test (final test)

Based on Table 1, the implementation of the research began on January 17, 2025 with a pretest activity to determine students' initial communication skills. Next, on January 23, 2025, the first meeting was held to discuss the material on hydrostatic pressure through Worksheet 1. The second meeting was held on January 24, 2025, discussing Archimedes' principle and completing Worksheet 2. On January 30, 2025, the third session was held on viscosity (Stokes' law) accompanied by work on Worksheet 3. The fourth meeting took place on January 31, 2025, focusing on the law of continuity through Worksheet 4. Then, the fifth meeting was held on February 6, 2025, discussing Bernoulli's law and Torricelli's Theorem through Worksheet 5. Finally, the research was closed with a post-test on February 7, 2025, to determine the improvement in students' communication skills after the learning.

c. The final stage involves researchers collecting all the results of the students' communication skills tests. The collected data is then processed, analysed, and interpreted before being elaborated in the form of a discussion and reported in the form of a thesis draft.

A summary of the research procedure can be seen in Figure 1.

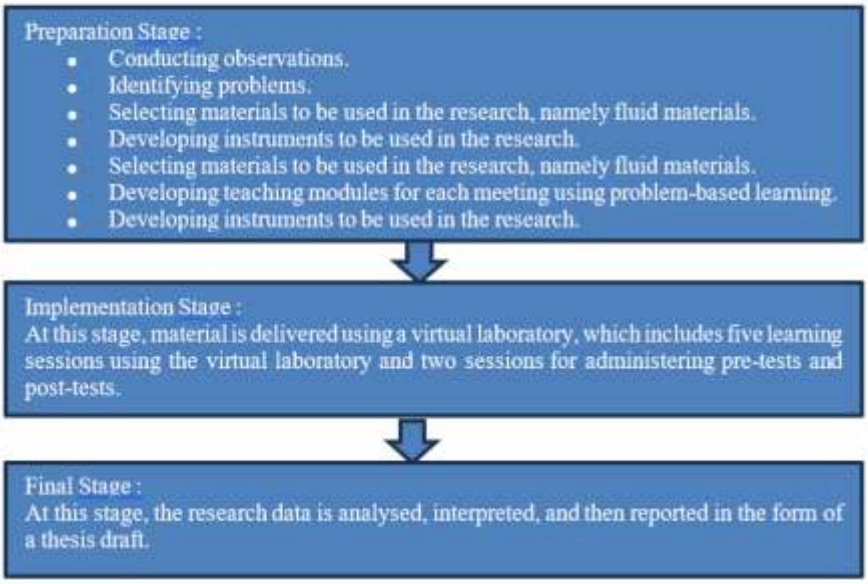

Figure 1 Research Procedures

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The data collection technique used in this study was a test. Tests were used in this study to measure the written communication skills of students before and after treatment. Communication skill scores in this study were collected through pre-tests and post-tests, which aimed to measure students' communication skills before and after learning using a virtual laboratory with problem-based learning.

Validity and Reability

The instrument used in this study is a test instrument for students' communication skills, specifically to measure students' written communication skills, which consists of 15 questions developed based on written communication skills indicators, namely interpreting graphs, interpreting images, interpreting tables, changing presentation forms, drawing conclusions, providing reasons, and explaining observation results.

Based on the results of the Gregory test criteria, the $V_c = 0{,}87$ was obtained. The instrument was declared suitable for use if V ≥ 0,75 or ≥ 75%. Determination of item validity was carried out by comparing the calculated r and the table r. The item was declared valid if the calculated $r_{value} > r_{tabel}$ and if the calculated $r_{value} < r_{tabel}$ table then the item was declared dropped. The empirical test results showed r_{table}= 0,3338. The calculation of the reliability test in this study using the Croanbach Alpha test obtained a reliability value of 0,691, the instrument was included in the high reliability category.

Meanwhile, to assess the feasibility of the instrument in terms of language, substance, and technical aspects before being used on the research sample, an expert validity test was conducted. Based on the results of the expert validity test, the Gregory criteria were obtained, $V_c = 0{,}87$with the conclusion that the instrument was declared suitable for use if V ≥ 0.75 or ≥ 75%.

Data Analysis

The data analysis technique used descriptive analysis and inferential analysis. Descriptive analysis was conducted to describe students' written communication skills, including determining the average score, variance, standard deviation, and Normalized Gain (N-Gain) test. Meanwhile, inferential analysis was used to analyze the improvement of students' written communication skills after being given treatment with a virtual laboratory. In the inferential analysis, a normality test was carried out which showed a significance value for the pretest of 0.294, which was greater than the significance level of 0.05. In the posttest, the significance value was 0.017, which was smaller than the significance level of 0.05. Thus, it can be concluded that the pretest data were normally distributed and the posttest were not normally distributed. Because the data were not normal, a non-parametric statistical test was carried out using the Wilcoxon Signed Rank Test.

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RESULT AND DISCUSSION

Results

Descriptive Analysis

Description of Student Pretest Scores

The following is a description of the pre-test scores for students' written communication skills, which can be seen in Table 2. This table provides initial data on students' written communication skills before the learning process, so that it can be used as a reference for assessing the development and effectiveness of the learning process.

Table 2 Analysis of Students' Written Communication Skills Pretest Scores

Statistics	Statistical Values
Sample size (n)	30
Maximum ideal score	46
Minimum ideal score	0
Maximum empirical score	19
Minimum empirical score	7
Score range	12
Average score	12,37
Variance	9,69
Standard deviation	3,11

Based on table 2 above, it can be seen that the students' written communication skills before being given treatment using a virtual laboratory were in the low category, as evidenced by the maximum and minimum empirical scores obtained by the students. The categorization of the level of students' written communication skills based on the pretest results can be seen in Table 3 as follows.

Table 3 Frequency Distribution of Pretest Score Classification of Students' Written Communication Skills

Score Interval	Category	Frequency	Percentage (%)
19 - 21	Very High	2	6,67
16 - 18	High	3	10
13 - 15	Medium	10	33,33
10 - 12	Low	10	33,33
7 - 9	Very Low	5	16,67
Total		30	100

Table 3 above shows that most students had low written communication skills before the implementation of the virtual laboratory with problem-based learning. If presented in diagram form, the percentage of students' written communication skills scores before being given treatment based on data processed using the Microsoft Excel 2010 program is presented in Figure 2 as follows.

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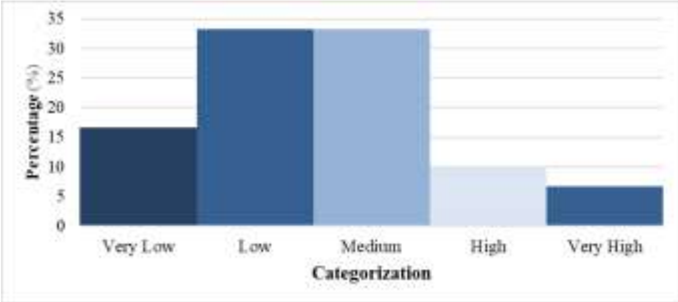

Figure 2 Percentage of Students' Pretest Scores

Description of Student Posttest Scores

The following is an overview of the posttest scores for students' communication skills, presented in Table 4.

Table 4 Analysis of Post-test Scores of Students' Written Communication Skills

Statistics	Statistics Value
Sample size (n)	30
Maximum ideal score	46
Minimum ideal score	0
Maximum empirical score	43
Minimum empirical score	25
Score range	18
Average score	35,17
Variance	15,18
Standard deviation	3,90

Categorization of students' communication skill levels based on posttest results can be seen in Table 5 as follows.

Table 5. Frequency Distribution of Posttest Scores for Written Communication Skills

Score Interval	Category	Frequency	Percentage (%)
41 - 44	Very High	2	6,67
37 - 40	High	12	43,3
33 - 36	Medium	9	30
29 - 32	Low	5	16,67
25 - 28	Very Low	2	6,67
Total		30	100

In Table 5 above, it can be seen that in general, students' written communication skills are in the high category. Meanwhile, in Table 4, it can be seen that the maximum and minimum empirical scores of students are almost close to the ideal maximum score. Therefore, it can be said that there is a difference in students' communication skills scores before and after being given treatment using a virtual laboratory with problem-based learning. If depicted in a diagram, the percentage of students' written communication skills scores after being given treatment based on data processed using the Microsoft Excel 2010 program is presented in Figure 3 as follows.

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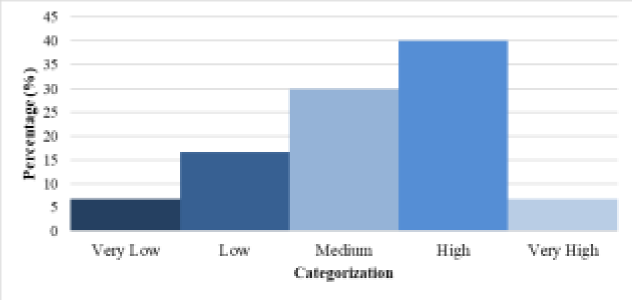

Figure 3 Percentage of Posttest scores

Results of the Normalized Gain (N-Gain) Test of Students' Communication Skills

To determine the extent of improvement from pretest to posttest, an N-Gain (Normalized Gain) test was conducted. The N-Gain test results showed a score of 0.68. Referring to the N-Gain categorization table, it can be concluded that the N-Gain score is moderate. This indicates that, on average, students' communication skills improved significantly after being treated with the application of a virtual laboratory with problem-based learning.

Table 6 N-Gain Categorization between Pretest and Posttest of 11th Grade High School Students

Rentang Skor	Kategori	Frekuensi	Persentase (%)
$g > 0,7$	Tinggi	16	53,33
$0,3 \leq g \leq 0,7$	Sedang	14	46,67
$g < 0,3$	Rendah	0	0

Table 6 shows that the increase in communication skills of students in the low category was 0 with a percentage of 0%, in the medium category there were 14 students with a percentage of 46.47%, and in the high category there were 16 students with a percentage of 53.33%. The results obtained showed an increase with the majority being in the high category followed by the medium category as can be seen in Figure 5 as follows.

Figure 5 N-Gain Diagram of Communication Skills of Grade XI High School Students

Inferential Analysis

Based on the normality test using the Shapiro Wilk method, the pretest scores were normally distributed and the posttest scores were not normally distributed, so the hypothesis testing was carried out using the Wilcoxon signed rank test. With the hypothesis testing criteria based on the p-value (sig) of the Wilcoxon signed rank test. If the p-value <0.05 then H_0 is rejected and H_1 is accepted, which means there is an increase in the application of virtual laboratories with problem-based learning on students' communication skills. Meanwhile, if the p-value $\geq$ 0.05 then H_0 is accepted and H_1 is rejected, which means there is no increase in the application of

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virtual laboratories with problem-based learning on students' communication skills. The results of data analysis using the Wilcoxon signed rank test show that the significance value (Asymp. Sig. 2-tailed) is 0.001 which means less than 0.05. Therefore, it can be concluded that there is a statistically significant increase between the pretest and posttest scores, so that the treatment given has an effect on students' communication skills.

Discussion

In research using a virtual laboratory with problem-based learning, a laptop is used as a supporting tool in conducting practical work using a virtual laboratory. In its application using problem-based learning, students are first given a video or given a trigger question, after which students are given the opportunity to express their opinions regarding the trigger question. After that, the teacher directs students to sit in groups, to conduct experiments and after conducting the experiments, students will complete the Student Worksheet (LKPD). In this Student Worksheet, there is a process in training students' written communication skills. Starting from directing students to interpret experimental data in the form of graphs, images, and tables. While at the end of the learning, students are given the opportunity to conclude the results of the experiments that have been carried out. So that in the learning process using a virtual laboratory hones students' written communication skills.

This was evident in the delivery of the material at each meeting. In the first meeting, students had not yet begun to show courage in answering provocative questions posed by the teacher, and some students did not even read the teaching materials distributed. Some students were also less active in asking or answering questions from other groups during the discussion process, so that at the end of the lesson, only a few students were able to summarize the learning well.

In the second meeting, several students showed significant courage by actively answering provocative questions from the teacher, having in-depth discussions with their group mates while working on the Student Worksheet (LKPD), and enthusiastically asking and responding to the opinions of their classmates, so that learning became more interactive and participatory.

In the third meeting, students demonstrated greater courage in answering provocative questions. This was evident in class activities, where every student actively raised their hand to answer when the teacher asked a provocative question. Furthermore, during the discussion and question-and-answer sessions, students enthusiastically responded and offered suggestions to other groups.

Finally, in the fourth and fifth meetings, students were very active in the learning process. To encourage this engagement, the teacher emphasized the importance of active participation in asking questions and expressing opinions. In addition, students were given the opportunity to work on problems on the board to strengthen their understanding of the material they had learned. Overall, students showed enthusiasm and motivated each other to express their opinions, as well as provide criticism and suggestions regarding the results of the discussions and experiments. This phenomenon of increased student courage in asking and answering questions is in line with the theory of Problem-Based Learning, which emphasizes group discussions, investigations, and presentations of results as a means of practicing communication skills (Resty Ayu Herdini dkk., 2019).

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Secara keseluruhan, siswa menunjukkan antusiasme dan saling memotivasi untuk menyampaikan pendapat, serta memberikan kritik dan saran terkait hasil diskusi dan eksperimen. Perkembangan ini juga tercermin dalam hasil pretes dan postes, sebagaimana ditunjukkan oleh indikator keterampilan komunikasi berikut.

Interpreting Graphs

During the pretest, some students provided answers using simple sentences and did not demonstrate a complete understanding of the graphs presented. Some students simply explained the shape of the line without linking it to relevant concepts, and some students failed to interpret the data presented in the graphs. However, after the learning process, during the posttest, most students were able to interpret the graphs better. They were able to explain the meaning of the graphs in more depth and used terms or concepts relevant to the material, such as the relationship between pressure and depth, which were consistent with the concept.

Interpreting Images

During the pretest, most students still responded with simple descriptive sentences, for example, simply stating what was seen in the image without explaining its meaning or relationship to the concept being studied. This indicates that their ability to interpret images was still limited. However, after participating in the learning process, during the posttest, most students were able to interpret images better. They were not only able to describe the images but also able to explain their content, meaning, and relationship to existing theories.

Interpreting Tables

During the pretest, most students still gave answers limited to reading the table's contents directly, without connecting the data in the table to broader information or conclusions. Students tended to give simple answers and did not yet demonstrate analytical skills. However, during the posttest, after the learning process began, most students were able to interpret the table better. They were able to read the data carefully, draw conclusions, compare information across columns or rows, and connect the data in the table to concepts or material they had learned.

Changing Presentation Formats

During the pre-test, some students were unable to accurately convert information from one format to another. They still struggled to understand data structures and reorganize them into tables or graphs. After the learning process, post-test results showed improvement. Students were able to process information and re-present it in the required format with greater coherence and accuracy.

Drawing Conclusions

During the pretest, most students were unable to draw accurate conclusions. They tended to simply repeat information without formulating a final statement that reflected a comprehensive understanding. However, after learning, on the posttest, students showed improvement in their ability to draw conclusions. They were able to identify important information, connect it to existing theories, and formulate logical and contextualized conclusions.

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Providing Reasoning

During the pretest, most students were unable to provide reasons to support their answers. They tended to answer directly without logical explanation or without linking them to existing theories. After learning, in the posttest, students' reasoning skills improved. Students began to present relevant arguments based on the facts or concepts they had learned.

Explaining Observation Results

Pretes menunjukkan bahwa siswa kesulitan menjelaskan hasil pengamatan mereka secara efektif. Mereka seringkali hanya menjelaskan hasil tanpa memberikan penjelasan yang mendalam. Setelah pembelajaran dan postes, siswa mulai mengembangkan penjelasan yang lebih jelas, lebih logis, dan lebih terstruktur, serta menghubungkan pengamatan mereka dengan teori atau konsep yang telah dipelajari sebelumnya.

Figure 3 shows significant improvements in students' pre- and post-test results. Based on this, it can be concluded that learning using virtual laboratories can improve students' communication skills, although not yet to a high level.

Furthermore, several student responses indicated that learning using virtual laboratories was quite enjoyable because it allowed students to work collaboratively in groups to understand the material. Using virtual laboratories, they were able to visualize physics concepts more clearly, engagingly, and easily understood.

This is in line with research conducted by Anisa Furtakhul Janah et al. (2023) using a virtual laboratory (PhET simulation) with the TaRL strategy. They found that students' communication skills scores in cycle I were 75.23%, categorized as good, and in cycle II, 83.8%, categorized as very good. This indicates that learning using a virtual laboratory can improve students' communication skills, particularly written communication skills.

Research using a virtual laboratory was conducted by Purwanti et al. (2025) by measuring students' science process skills using PhET and Olabs simulations on temperature and heat materials. Data analysis was obtained using a t-test after fulfilling the assumptions of normality and homogeneity. Based on the results of the analysis using SPSS 26, a t-test significance value of $0.000 < 0,05$ (α) was obtained, which indicates that the implementation of a virtual science laboratory is effective in improving students' KPS on temperature and heat materials.

Overall, students achieved learning completion during the learning activities. This was because students were enthusiastic and motivated, making them more active in the learning activities. The features presented in the virtual laboratory were quite interesting and able to improve student understanding, so that they not only improved understanding but also were able to attract students' interest in learning. In addition to media, classroom learning methods also supported the learning process where the stages or steps of problem-based learning, namely problem orientation, organizing students to learn, guiding individual/group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process, could be provided to students to assist them during the learning process. Another factor that helped students achieve learning completion was the teacher's success in managing learning by using a learning model that was effective and interesting for students.

CONLUSION

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Based on the results and discussion of the implementation of virtual laboratories with problem-based learning, it can be concluded that students' communication skills before the implementation of virtual laboratories with problem-based learning were in the low and medium categories with a percentage of 33.33%. This indicates that students' initial communication skills were still limited. Students' communication skills after the implementation of virtual laboratories with problem-based learning increased to the high category with a percentage of 43.3%. There was a significant increase in students' communication skills before and after the implementation of virtual laboratories with problem-based learning. This is evidenced by the N-Gain value of 0.68 which is in the medium category, as well as the results of the Wilcoxon signed rank test with a p value = 0.001 ($p < 0.05$), which means the increase is statistically significant.

REFERENCES

Anisa Furtakhul Janah, Dwi Yulianti, & Hadi Purnomo. (2023). Penerapan Model Problem Based Learning dengan Strategi TaRL untuk Meningkatkan Keterampilan Berkomunikasi Peserta Didik. *Jurnal Penelitian Pendidikan Fisika*, *3*, 158–164.

Azis, A. A., & Hasan, N. R. (2024). Implementasi Model Problem Based Learning untuk Meningkatkan Keterampilan Komunikasi Peserta Didik Kelas VII di SMP Negeri 13 Makassar. *Jurnal Pemikiran Dan Pengembangan Pembelajaran*, *6*(2), 688–695.

Badriyah, B., Setiyo, R. D., El Firdausi, Z., Nuqia, K., Mahardika, I. K., & Baktiarso, S. (2023). Manfaat PhEt Simulasi Dalam Menopang Sarana dan Prasarana Laboratorium Fisika Untuk Meningkatkan Minat Belajar Siswa. *Jurnal Ilmiah Wahana Pendidikan*, *9*(2), 84–90.

Bungkuran, A., aunaumang, H., & Komansilan, A. (2021). Pengembangan Bahan Ajar Berbantuan Amrita Olabs Pada Materi Gelombang Bunyi. *Charm Sains: Jurnal Pendidikan Fisika*, *2*(3), 149–155.

Drake, S. M., & Reid, J. L. (2020). 21st Century Competencies in Light of the History of Integrated Curriculum. Dalam *Frontiers in Education* (Vol. 5). Frontiers Media S.A. https://doi.org/10.3389/feduc.2020.00122

Fatimah, Z., Rizaldi, D. R., Jufri, A. W., & Jamaluddin, J. (2020). Model inkuiri terbimbing berbantuan laboratorium virtual untuk meningkatkan keterampilan proses sains. *Jurnal Pendidikan, Sains, Geologi, dan Geofisika (GeoScienceEd Journal)*, *1*(2).

Ginting, F. A., Naluri, T., & Widiyatmoko, A. (2024). Penerapan Model Pembelajaran Discovery Learning dengan Pendekatan TaRL untuk Meningkatkan Keterampilan Komunikasi Peserta Didik Kelas VIII SMP Negeri 15 Semarang. *Prosiding Seminar Nasional Pendidikan dan Penelitian Tindakan Kelas*, 573–580.

González-pérez, L. I., & Ramírez-montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. Dalam *Sustainability (Switzerland)* (Vol. 14, Nomor 3). MDPI. https://doi.org/10.3390/su14031493

Hendrik Siswono, Wartono, & dan Supriyono Koes H. (2014). Pf-02:Pengaruh Problem Based Learning Berbantuan Virtual Laboratory Terhadap Ketrampilan Proses Sains Dan Penguasaan Konsep Siswa Di Sma. Prosiding Seminar Nasional Fisika, 3, 22–26.

Hikmah, N., Saridewi, N., & Agung, S. (2017). Penerapan laboratorium virtual untuk meningkatkan pemahaman konsep siswa. *EduChemia (Jurnal Kimia dan Pendidikan)*, *2*(2), 186–195.

Kebande, V. R. (2024). The Impact of Virtual Laboratories on Active Learning and Engagement in Cybersecurity Distance Education. *arXiv preprint arXiv:2404.04952*. http://arxiv.org/abs/2404.04952

Martiningtiyas, C. R., Hermawan, A., Chaniago, N., Baliartati, B. O., & Lestari, N. (2023). Pentingnya kemampuan komunikasi dalam berwirausaha. *Rural Development For Economic Resilience (Rudence)*, *2*(2), 79–84.

https://doi.org/10.17509/wapfi.v10i2.89146

Narulita, L., Rizqi, N. F., Wati, R., Amelia, S. D., & Alpian, Y. (2024). Penggunaan Media Simulasi PhEt terhadap Hasil Belajar IPA Siswa di SD pada Materi Rangkaian Listrik. *El-Mujtama: Jurnal Pengabdian Masyarakat*, *4*(3), 496–507.

Noris, M., Saputro, S., & Muzazzinah, M. (2022). The Virtual Laboratory Based on Problem Based Learning to Improve Students' Critical Thinking Skills. *European Journal of Mathematics and Science Education*, *volume-3-2022*(volume-3-issue-1-june-2022), 35–47. https://doi.org/10.12973/ejmse.3.1.35

Purwanti, Darwis, R., & Natsir, N. (2025). Efektivitas Laboratorium Virtual IPA dalam Meningkatkan Keterampilan Proses Sains Peserta Didik Kelas VII pada Materi Suhu dan Kalor. *Jurnal Pendidikan MIPA*, *25*(1), 322–330.

Putri, A. J., & Arsil, A. (2020). Analisis pencapaian keterampilan komunikasi pada proses pembelajaran. *JRPD (Jurnal Riset Pendidikan Dasar)*, *3*(2), 154–161.

Resty Ayu Herdini, Hardi Suyitno, & Putut Marwoto. (2019). Mathematical Communication Skills Reviewed from Self-Efficacy by Using Problem Based Learning (PBL) Model Assisted with Manipulative Teaching Aids. *Journal of Primary Education*, *8*, 75–83.

Rihi, S. P. P., & Bano, V. O. (2022). Pengaruh Laboratorium Virtual Terhadap Hasil Belajar Siswa Kelas XI Pada Materi Sistem Pencernaan Makanan. *Quagga: Jurnal Pendidikan dan Biologi*, *14*(2), 183–188.

Rusman. (2010). *Model-Model Pembelajaran*. PT Rajagrafindo Persada.

Rustaman, & Nuryani. (2005). *Strategi Pembelajaran Mengajar Biologi*. Universitas Negeri Malang.

Siswanti, A., & Indrajit, R. (2023). *Problem Based Learning*. Penerbit Andi.

Sugiyono. (2013). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Alfabeta.

Sukarna, T. F. (2021). The Effect of Student's Interpersonal Communication Skills On Student's Learning Outcomes In Mechanical Engineering Subjects. *Journal of Architectural Research and Education*, *3*(2), 115–127. https://doi.org/10.17509/jare.v3i2.37402

Sutarno, S., Putri, D. H., Malik, A., Gunawan, G., & Purwanto, A. (2023). Student's Written Communication Skills in Learning Physics Using Virtual Lab-Based Video Tutorials. *Proceedings of the Mathematics and Science Education International Seminar 2021 (MASEIS 2021), Advances in Social Science, Education and Humanities Research*, 307–315. https://doi.org/10.2991/978-2-38476-012-1_38

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. Dalam *Journal of Intelligence* (Vol. 11, Nomor 3). MDPI. https://doi.org/10.3390/jintelligence11030054

Wibawanto, W. (2020). *Laboratorium Virtual: Konsep dan Pengembangan Simulasi Fisika*. Penerbit LPPM Unnes.

Widodo, E. (2021). The Effect of Virtual Laboratory Application of Problem-Based Learning Model to Improve Science Literacy and Problem-Solving Skills. *Journal of Physics: Conference Series*, *1747*(1), 633–640. https://doi.org/10.1088/1742-6596/1747/1/012017

Widyaningsih, S. W., Rumansara, T. H., & Yenusi, K. A. (2024). Penerapan Model Pembelajaran Berbasis Masalah Berbantuan Simulasi PhET Untuk Meningkatkan Hasil Belajar dan Aktivitas Fisika di SMAS Advent Manokwari. *Optika: Jurnal Pendidikan Fisika*, *8*(1), 1–10.

Yanti, E., Haryani, S., & Supardi, K. (2015). Pengembangan Bahan Ajar Koloid Bermuatan Karakter Berbasis Discovery-Inquiry Untuk Meningkatkan Keterampilan Berkomunikasi Siswa SMA. *Journal of Innovative Science Education*, *4*(1), 1–9.

https://doi.org/10.17509/wapfi.v10i2.89146