

THE EFFECT OF USING WEB BASED VIRTUAL LAB MEDIA ON SCIENCE PROCESS SKILLS IN PLANT TISSUE PRACTICUM

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ABSTRACT

Science process skills are important abilities in biology learning; however, they are still relatively low due to the limitations of conventional practicum implementation. One alternative to overcome this problem is the use of web-based virtual laboratory media. This study aims to determine the effect of using web-based virtual lab media on students' science process skills in plant tissue material. This research employed a quasi-experimental method with a nonequivalent control group design. The research subjects consisted of a control class and an experimental class. The research instruments included a science process skills test, observation sheets of teacher and student activities, and media validation sheets. The data were analyzed using the t-test and N-Gain analysis. The results showed that the science process skills of students in both the experimental and control classes were in the moderate improvement category. However, the mean N-Gain of the experimental class (0.61) was higher than that of the control class (0.31). These findings indicate that the use of web-based virtual lab media has a greater effect on improving students' science process skills compared to conventional learning. Therefore, it can be concluded that web-based virtual lab media positively influences the improvement of students' science process skills compared to conventional learning.

Keywords: Virtual Laboratory; Science Process Skills; Plant Tissue

1. INTRODUCTION

The development of science and technology (IPTEK) in the era of the Industrial Revolution 4.0 requires the education system to produce human resources who are adaptive, competent, and capable of facing global challenges through mastery of technology and 21st-century skills (OECD, 2018). Education plays a strategic role in improving the quality of human resources; therefore, the learning process needs to be developed innovatively in order to produce graduates who are qualified and relevant to the demands of the times (Adha & Wahyuni, 2021).

One of the essential skills that must be developed in science learning is science process skills. These skills include the ability to observe, conduct experiments, interpret data, and communicate findings systematically (Khairunnisa, 2020). Mastery of these skills can encourage students to think critically, actively participate in learning, and solve problems based on scientific procedures (Hartati et al., 2022). Therefore, science process skills are an important aspect that needs to be studied and developed in science learning in schools.

However, the implementation of learning oriented toward science process skills often faces obstacles, particularly the limitations of laboratory facilities and infrastructure. The construction and management of laboratories require substantial costs, careful planning, and strict safety supervision; therefore, not all schools have adequate laboratory facilities (Triatmaja et al., 2021). These limitations can hinder practical activities and result in less optimal development of students' science process skills.

As an alternative solution, the use of web-based virtual laboratories emerges as an educational innovation aligned with the advancement of science and technology. Virtual laboratories allow students to conduct practical simulations safely and flexibly, and they can be accessed anytime without the risk of accidents or equipment damage, while still supporting the development of science process skills through an interactive digital learning environment (Sari & Nugroho, 2020; Wahyuni et al., 2021). This is supported by research conducted by Tatli & Ayas (2013), which states that the use of virtual laboratories can significantly improve students' science process skills through interactive and contextual simulation-based practical activities.

The implementation of web-based virtual laboratories is highly relevant to plant tissue material, which is abstract and difficult to observe directly. Through digital simulations, students can better understand the structure and function of plant tissues such as xylem, phloem, parenchyma, collenchyma, and sclerenchyma. Therefore, a study entitled "The Effect of Using Web-Based Virtual Lab Media to Improve Science Process Skills in Plant Tissue Practicum" needs to be conducted, particularly at SMK Kesehatan Rambah Samo, which has limited biology laboratory facilities, in order to support effective practicum implementation in accordance with the expected learning competencies

2. METHODOLOGY

This study employed a quasi-experimental method. This method involves a control group; however, it cannot fully control external variables that may influence the implementation of the experiment. The research design used in this study was the nonequivalent control group design.

The population of this study consisted of all eleventh-grade students of SMK Kesehatan Rambah Samo in the odd semester of the 2025/2026 academic year. The sampling technique used was purposive sampling. The sample in this study included class XI.1 as the experimental group and class XI.2 as the control group. The control class consisted of 26 students, and the experimental class also consisted of 26 students. Data collection techniques included written tests and observations.

The parameter measured in this study was students' science process skills, which were assessed using written test questions and observation sheets. This study used two types of instruments: test instruments in the form of plant tissue material questions and non-test instruments in the form of observation sheets for both teachers and students.

The data analysis technique used in this study was quantitative analysis. To determine the effect of the use of virtual laboratory media on science process skills, the data were analyzed using the N-Gain formula (Meltzer, 2002). The formula is as follows :

$$N\text{-Gain} = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{maks}} - S_{\text{pre}}}$$

Description :

S_{post} : *posttest score*

S_{pre} : *pretest score*

S_{maks} : Maximum ideal score

Hypothesis testing was conducted using the independent samples t-test for parametric data (if the data were normally distributed) or the Mann–Whitney U test for non-parametric data. The independent samples t-test is a parametric statistical test used to examine hypotheses by comparing the means of two independent samples when the data are in the form of interval or ratio scales. The t-test is applied when the data are normally distributed and the variances are homogeneous. To determine the normality of the data, normality and homogeneity tests were conducted (Sugiyono, 2009).

a. Normality Test

The normality test is conducted to determine the distribution of the data. Data normality can be identified from the distribution pattern, where the data are evenly distributed across values. One of the methods used to test data normality is the Kolmogorov–Smirnov (KS) test. The formula for the Kolmogorov–Smirnov test is based on Steel (2010).

$$KS = F_n(Y_i - 1) - F_o(Y_i)$$

Description:

KS : Calculated KS value

$F_n(Y_i - 1)$: Cumulative percentage frequency before the i-th data point

$F_o(Y_i)$: Frequency of the normal distribution data at the i-th data point

b. Homogeneity Test

The homogeneity test was conducted to determine the uniformity of the research data. In regression analysis, good research data should have homogeneous variance. The method used to test homogeneity in this study was Levene's test.

The formula for Levene's test is as follows (Sugiyono, 2010)

$$L = \frac{(N-k) \sum ni (\bar{v}i - \bar{v}k)^2}{(k-1) \sum (\bar{v}ij - \bar{v}k)^2}$$

$$Vij = |Xij - \bar{X}|$$

Description:

L : Calculated Levene value

X : Residual data value

$\bar{x}$: Mean of residual data

N : Number of samples

K : Number of groups

c. T-test

Sugiyono (2010) states that hypothesis testing can be conducted using the t-test formula as follows:

$$t = \frac{X_1 - X_2}{\sqrt{S_1^2 + S_2^2}}$$

Description:

X_1 : Mean score of the experimental group

X_2 : Mean score of the control group

S_1^2 : Variance of the experimental group

S_2^2 : Variance of the control group

Prior to hypothesis testing, the statistical hypotheses were formulated as follows:

H_0 : There is no effect of using web-based virtual laboratory media on students' science process skills in plant tissue practicum.

H_1 : There is an effect of using web-based virtual laboratory media on students' science process skills in plant tissue practicum.

3. RESULTS

Data Analysis of Pretest and Posttest

Based on the research data conducted in December 2025 in class XI.1 as the experimental class and XI.2 as the control class, the recapitulation of pretest and posttest data is presented in Table 1 below:

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Class Score		N	Learning Outcomes			Mean
			Ideal Score	Minimum Score	Maximum Score	
<i>Pretest</i>	Control	36	100	30.00	55.00	40,96
	Eksperiment	36	100	30.00	60.00	40,76
<i>Posttest</i>	Control	36	100	40.00	80.00	60.00
	Eksperiment	36	100	60.00	90.00	78,90

Based on Table1, it can be seen that the number of samples in the control class is 26 students, and the experimental class also consists of 26 students. Table 1 presents the descriptive statistics of the pretest and posttest scores in both the control and experimental classes.

At the pretest stage, the control class had a mean score of 40.96, with a minimum score of 30.00 and a maximum score of 55.00. Meanwhile, the experimental class had a mean score of 40.76, with a minimum score of 30.00 and a maximum score of 60.00. These results indicate that the initial abilities of both classes were relatively equivalent.

After the treatment, there was an improvement in the posttest scores in both classes. The control class obtained a mean score of 60.00, with a score range of 40.00–80.00. In contrast, the experimental class showed a higher mean score of 78.90, with a score range of 60.00–90.00.

Based on these data, it can be concluded that the improvement in learning outcomes in the experimental class is higher than in the control class. Therefore, the use of a web-based virtual lab media has a more positive effect on students' learning outcomes.

The pretest and posttest data obtained from both the control and experimental classes were then analyzed using statistical tests, including the normality test using the Kolmogorov-Smirnov (KS-21) method and the homogeneity test using Levene's test. These tests serve as prerequisites to determine whether to use parametric or non-parametric comparative hypothesis testing. If the data are normally distributed, a t-test is applied; otherwise, the Mann-Whitney U test is used. The results of the normality test for the pretest and posttest data in both the control and experimental classes are presented in Table 2 below.

Table 2. Results of the Normality Test for Pretest and Posttest

Data Type	Class	Normality Test Results			
		<i>Asymp. Sig (2-tailed)</i>	α	Decision	Description
<i>Pretest</i>	Control	0.104	0.05	Accepted H_0	Normal
	Eksperiment	0.214	0.05	Accepted H_0	Normal
<i>Posttest</i>	Control	0.290	0.05	Accepted H_0	Normal
	Eksperiment	0.154	0.05	Accepted H_0	Normal

Table 2 shows the results of the normality test for the pretest and posttest data in both the control and experimental classes using the Kolmogorov-Smirnov test. Based on the testing criteria, if the value of *Asymp. Sig (2-tailed)* $> \alpha$ (0.05), then H_0 is accepted and the data are considered to be normally distributed.

For the pretest data, the *Asymp. Sig (2-tailed)* value of the control class is $0.104 > 0.05$, thus H_0 is accepted, indicating that the data are derived from a normally distributed population. Furthermore, the experimental class obtained an *Asymp. Sig (2-tailed)* value of $0.214 > 0.05$, so H_0 is also accepted and the data are normally distributed.

For the posttest data, the control class obtained an *Asymp. Sig (2-tailed)* value of $0.290 > 0.05$, indicating that H_0 is accepted and the data are normally distributed. Similarly, the experimental class obtained an *Asymp. Sig (2-tailed)* value of $0.154 > 0.05$, so H_0 is accepted and the data are derived from a normally distributed population.

Therefore, all pretest and posttest data in both classes meet the assumption of normality, allowing further analysis to be

Table 3. Results of the Homogeneity Test for Pretest and Posttest

Data Type	<i>Sig.(2-tailed)</i>	α	Decision	Description
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<i>Pretest</i>	0.634	0.05	Accepted H_0	Homogen
<i>Posttest</i>	0.101	0.05	Accepted H_0	Homogen

Based on Table 3, the results of the homogeneity test show that the value based on the trimmed mean for the pretest is $0.634 > 0.05$ with a significance level (α) of 0.05. Therefore, the decision is to accept H_0 , which means that the pretest data come from a homogeneous variance. Meanwhile, the posttest value is $0.101 > 0.05$ with a significance level (α) of 0.05, so the decision is also to accept H_0 . This indicates that the posttest data come from a homogeneous variance.

Based on the results of the pretest and posttest data analysis, it is known that the data are normally distributed and homogeneous. Therefore, it can be concluded that the t-test can be applied. The results of the t-test for the pretest and posttest data are presented in Table 4 below:

Table 4. Results of the t-test for Pretest and Posttest Data

Data Type	<i>Sig.(2-tailed)</i>	α	Decision	Description
<i>Pretest</i>	0.583	0.05	Accepted H_0	Not significantly different
<i>Posttest</i>	0.001	0.05	Accepted H_0	Significantly different

Based on Table 4 above, the results of the t-test for the pretest show a value of $0.583 > 0.05$; therefore, H_0 is accepted, which means that there is no significant difference in pretest scores between the control class and the experimental class.

Meanwhile, the results of the t-test for the posttest data show a value of $0.001 < 0.05$; therefore, H_0 is rejected, indicating that there is a significant difference in posttest scores between the control class and the experimental class.

N-Gain Data Analysis

Based on the research conducted in November 2022 in class X.8 as the control class and X.7 as the experimental class, the recapitulation of the N-Gain data is presented in Table 5 below:

Table 5. Descriptive Statistics of N-Gain Data in the Control and Experimental Classes

Numb Class er	N	N-Gain			Mean	Category
		Ideal Score	Minimum Score	Maximum Score		

1	Control	36	1.00	0.00	0.90	0.31	Moderate
2	Eksperiment	36	1.00	0.33	0.80	0.61	Moderate

In Table 5, the mean N-Gain score of the control class is 0.31, which falls into the moderate category, while the experimental class has an N-Gain score of 0.61, which is also categorized as moderate.

Table 6. Results of the t-test on N-Gain Data

Data Type	<i>Sig.(2-tailed)</i>	α	Decision	Description
<i>N-Gain</i>	0.001	0.05	Reject H_0	There is a significant difference

Based on the t-test results in Table 6, the Sig. (2-tailed) value under *Equal variances not assumed* in the Independent Samples Test output is $0.001 < 0.05$; therefore, H_0 is rejected, indicating that there is a significant difference in the N-Gain between the control class and the experimental class.

Teacher and Student Activities

The following are the results of the observation of student activities in the control class during Meeting I and Meeting II, as presented in Table 9 below:

Table 7. Recapitulation of Teacher Activities in the Experimental Class and Control Class

Class	Meet I (%)	Meet II (%)	Average Percentage%
Control	100.00	100.00	100.00
Eksperiment	100.00	100.00	100.00

Based on Table 7, it is known that the teacher's activity in the experimental class during Meeting I achieved an average percentage of 100%, and in Meeting II it remained at 100% with an average percentage of 100%. The student activities in both the control class and the experimental class are presented in Table 10 below:

Table 8. Recapitulation of Student Activities in the Control Class

Meet	Activity %	
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	1	2	3	4	5	Average Percentage
I	100%	73%	100%	50%	100%	85%
II	100%	73%	100%	35%	100%	76%

Based on Table 8, it can be seen that the average percentage of student activity in the control class during Meeting I was 85.00%, while in Meeting II the average percentage was 76.00%. This differs from the student activities in the experimental class, which are presented in Table 9 below:

Table 9. Recapitulation of Student Activities in the Experimental Class

Meet	Activity %					Average Percentage
	1	2	3	4	5	
I	100%	100%	70%	54%	100%	85%
II	100%	100%	100%	100%	100%	100%

Based on the observation results in Table 9, it can be seen that the average percentage in Meeting I of the experimental class was 85.00%, while in Meeting II it increased to 100.00%.

4. DISCUSSION

a. Initial Condition of Students' Science Process Skills

Based on the pretest results, the science process skills of students in both the control and experimental classes were relatively equivalent and still categorized as low. This is indicated by the mean pretest scores of 39.62 for the control class and 40.77 for the experimental class. These findings suggest that students had not yet optimally mastered science process skills prior to the learning intervention.

The limitations were particularly evident in the observing indicator, where students experienced difficulties in identifying plant tissue structures, distinguishing xylem and phloem, and describing observations systematically. Other indicators, such as classifying, interpreting data, formulating hypotheses, and communicating results, also showed limited development. This condition is likely influenced by learning practices that are still theoretical in nature, limited hands-on practicum activities, and the lack of instructional media that can effectively visualize microscopic objects.

These findings are consistent with previous studies which state that science process skills tend to be low when learning does not involve experimental and inquiry-based activities (Hartati et al., 2022; Rahayu & Putri, 2024). Statistical analysis further showed that the

pretest data were normally distributed and homogeneous, and the t-test results (Sig. 0.583 > 0.05) indicated no significant difference between the two classes, confirming that both groups had equivalent initial abilities.

b. The Effect of Web-Based Virtual Lab Media

The posttest results showed a higher improvement in science process skills in the experimental class compared to the control class. The control class achieved a mean score of 60.00, while the experimental class reached 78.85. The t-test results (Sig. 0.001 < 0.05) indicated a significant difference between the two groups, demonstrating that the use of web-based virtual lab media has a positive effect on students' science process skills.

This improvement can be attributed to the interactive nature of virtual lab media, which allows students to actively engage in learning through simulated practicum activities. Students can observe, manipulate virtual objects, analyze data, and draw conclusions independently. In addition, virtual labs provide flexibility, allowing students to repeat experiments without limitations in tools and materials.

These results are in line with Zhang and Han (2023), who found that virtual laboratories significantly enhance inquiry skills and science process skills compared to conventional learning.

The most prominent improvement was observed in the observing skill. Students in the experimental class demonstrated better ability in identifying plant tissue structures and describing microscopic observations systematically. This is supported by the features of virtual labs, such as object magnification and detailed visualization. Improved observation skills also contributed to the development of other science process skills, including classification, data interpretation, hypothesis formulation, and communication. This finding is supported by Al-Abdullatif (2024), who reported that virtual labs significantly improve observation, data analysis, and scientific inference skills.

c. Improvement Based on N-Gain Analysis

The N-Gain analysis showed that the experimental class achieved a higher improvement (0.61) compared to the control class (0.31), although both were categorized as moderate. The t-test results for N-Gain (Sig. 0.001 < 0.05) confirmed that the improvement between the two classes was significantly different.

This indicates that the use of web-based virtual lab media not only improves learning outcomes but also enhances the quality of learning experiences. Virtual labs create an interactive digital learning environment that encourages active student engagement in scientific processes. These findings are consistent with Kumar and Mishra (2021) and Prasetyo et al. (2023), who stated that virtual laboratories can improve both learning outcomes and science process skills in a sustainable manner.

d. Challenges in Implementing Virtual Lab Media

Despite its positive impact, the implementation of web-based virtual lab media faces several challenges. The primary issue is unstable internet connectivity, especially when accessed simultaneously by many students. Additionally, differences in device specifications affect students' ability to access and run the virtual lab smoothly.

Time limitations in classroom learning also pose challenges in completing all stages of virtual practicum. These findings are consistent with Kumar and Mishra (2021) and Aljuhani et al. (2022), who reported that the main barriers to virtual lab implementation are related to technological infrastructure and device readiness.

e. Teacher and Student Activities

Observation results showed that teacher activities in both classes reached 100%, indicating that the learning process was implemented according to the lesson plan. Therefore, differences in learning outcomes are primarily influenced by the learning media used rather than teacher performance.

Student activities in the experimental class showed a more significant increase compared to the control class. The interactive and flexible nature of virtual lab media encourages active student participation and promotes student-centered learning.

These findings are supported by Arumningtyas et al. (2022) and Wahyuni et al. (2021), who stated that virtual laboratories can enhance student engagement and improve the overall quality of science learning.

5. CONCLUSION

This study was conducted at SMK Kesehatan Rambah Samo to determine the effect of using web-based virtual laboratory media on students' science process skills in plant tissue practicum. The results showed that the mean pretest score of the control class was 40.76, while the experimental class was 39.61, indicating that the students' initial abilities were relatively equivalent.

After the treatment, the mean posttest score of the control class increased to 61.92, while the experimental class improved to 78.84. The improvement in learning outcomes was further supported by the mean N-Gain values, which were 0.31 (moderate category) for the control class and 0.61 (moderate category) for the experimental class.

The results of the t-test on the N-Gain data showed a significance value of $0.001 < 0.05$, indicating that there was a significant difference in the improvement of science process skills between the two classes. The most prominent indicator of science process skills observed in this study was observing. The improvement in observation skills also contributed to the development of other science process skill indicators, such as classifying, interpreting data, formulating hypotheses, and drawing conclusions.

Therefore, it can be concluded that the use of web-based virtual laboratory media at SMK Kesehatan Rambah Samo has a significant effect on improving students' science process skills in plant tissue practicum compared to conventional learning.

REFERENCES

- Adha, D. F., & Wahyuni, I. (2021). Penerapan Model Inquiry Training Menggunakan Media Laboratorium Virtual (Online Labs) Terhadap Keterampilan Proses Sains Pada Pelajaran Fisika Di SMA. *Jurnal Ikatan Alumni Fisika*, 6(3). <https://doi.org/10.24114/jiaf.v6i3.15246>
- Al-Abdullatif, A. M. (2024). Effect of Virtual Science Laboratories On Student Achievement And Science Process Skills: A Meta-Analysis. *Journal of Science Education and Technology*, 33(1), 1–18.
- Aljuhani, K., Sonbul, M., Alhabiti, M., & Meccawy, M. (2022). Creating a Virtual Science Lab (VSL): The Adoption of Virtual Labs in Science Education. *Education and Information Technologies*, 27(1), 121–140.
- Arumningtyas, D., & Wahyuni, S. (2022).** The effectiveness of virtual laboratory on students' learning activities and science learning outcomes. *Jurnal Pendidikan Sains*, 10(2), 123–130.
- Hartati, H., Azmin, N., Nasir, M., & Andang, A. (2022). Keterampilan Proses Sains Siswa melalui Model Pembelajaran Problem Based Learning (PBL) pada Materi Biologi. *JIIIP - Jurnal Ilmiah Ilmu Pendidikan*, 5(12). <https://doi.org/10.54371/jiip.v5i12.1190>
- Khairunnisa. (2020). Analisis keterampilan proses sains peserta didik dalam pembelajaran biologi. *Jurnal Pendidikan Biologi*, 8(2), 123–130.
- Kumar, V., & Mishra, P. (2021). Virtual Laboratory Interventions in Science Education: Challenges and Learner Outcomes. *Education and Information Technologies*, 26(5), 5637–5661.
- Prasetyo, Z. K., Wijaya, A., & Sulaiman, S. (2023). Implementasi Media Virtual Lab Pada Pembelajaran Biologi Untuk Meningkatkan Keterampilan Proses Sains Siswa. *Jurnal Pendidikan dan Pembelajaran*, 50(2), 145–156.
- Sari, P. M., & Nugroho, A. A. (2020). Pemanfaatan Laboratorium Virtual Dalam Meningkatkan Keterampilan Proses Sains Siswa. *Jurnal Pendidikan IPA Indonesia*, 9(2), 210–218.
- Steel, R. G. D., & Torrie, J. H. (2010). *Prinsip dan prosedur statistika: Pendekatan biometrik* (Edisi ke- 3). PT Gramedia Pustaka Utama.
- Sugiyono. (2009). *Metode penelitian kuantitatif, kualitatif, dan R&D* (Cetakan ke-8). Alfabeta.
- Sugiyono. (2010). *Metode Penelitian Pendidikan Pendekatan Kuantitatif, kualitatif, dan R&D*.

Bandung:
Alfabeta.

Tatli, Z., & Ayas, A. (2013). Effect of a Virtual Chemistry Laboratory On Students' Achievement. *Educational*

Technology & Society, 16(1), 159–170

Triatmaja, A. K., Muchlas, M., & Wardana, Y. (2021). Virtual Laboratorium Teknik Digital Berbasis Mobile

Virtual Reality. *Jurnal Edukasi Elektro*, 5(1). <https://doi.org/10.21831/jee.v5i1.38705>

Wahyuni, S., Fikri, A., & Hadi, W. (2021). Implementation of Virtual Laboratory to Support 21st-Century

Science Learning. *Journal of Science Learning*, 4(2), 85–92.