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Development of Virtual Laboratories to Improve Science Literacy and Learning Motivation Among Phase F Students

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ABSTRACT: Students have difficulty understanding biology material, especially material on the reproductive system. This is due to the complex nature of the material, uninnovative learning media, inadequate practical facilities, and conventional learning models. This results in low science literacy and motivation to learn among students. This study aims to develop a valid, practical, and effective virtual laboratory medium on reproductive system material to improve science literacy and learning motivation among phase F students. This study uses a 4D development model consisting of four stages, namely *define, design, develop*, and *disseminate*. The subjects in this study consisted of 37 students for the small-scale trial and 62 students for the large-scale trial. Data collection instruments were tested for validity, practicality, and effectiveness. The results of the study show that (1) a score of 100 (highly valid) was obtained in the validity test by media experts, and 96.18 (highly valid) in the validity test by subject matter experts. (2) In the practicality test, which included a teacher response test, a score of 97.2 (very practical) was obtained, and in the student response test, a score of 97.065 (very practical) was obtained. (3) In the science literacy effectiveness test, an N-gain score of 0.710 (quite effective) was obtained, and in the learning motivation test, an N-gain score of 0.636 (quite effective) was obtained.

KEYWORDS: biology, learning motivation, problem based learning, science literacy, virtual laboratories

I. INTRODUCTION

In terms of material, biology is not only related to scientific facts, but also to concepts of objects that cannot be seen directly by the eye (abstract). These concepts form the basis for students' understanding of biology. Students often have difficulty understanding biology material because it is complex. The biology material in class XI consists of several topics, namely the reproductive system, digestive system, respiratory system, and immune system. (Imam et al., 2024). Based on the questionnaire results, 67.6% of students stated that the reproductive system material was difficult to understand. This is in line with the opinion of Sari & Yogica (2021), who stated that students had difficulty understanding material about the reproductive system because everything that occurs in the reproductive tract, both female and male reproductive organs, cannot be observed directly. According to Qoiriyah and Setyawati (2022), 58.8% of students experienced difficulties in the sub-chapters on gametogenesis, fertilization, and pregnancy, 17.6% in the sub-chapter on abnormalities in the reproductive system, 11.8% in the sub-chapter on breastfeeding and contraception, and 5.9% in the sub-chapter on reproductive organs and reproductive technology.

In addition, another problem often encountered in biology education is the limited laboratory facilities, such as the equipment used for practical work, and practical activities that cannot be repeated independently at home. (Wulandari et al., 2020). Based on observations at MAN Kotim school, the use of tools and materials for practical work is still somewhat limited. As a result, only a few subjects can be covered in practical work. This makes it difficult for students to understand abstract subjects. Then, there are several concepts that cannot be practiced because these processes occur inside the human body and are difficult to observe. This problem will certainly affect the learning process in the classroom. The learning process can be hampered and students will certainly lack the development of science literacy skills and motivation to learn due to the complex and contextual nature of the subject matter. (Rahman et al., 2024).

Science literacy is important for students because it helps them gain an understanding of scientific principles and connect them to everyday activities. Zannah et al. (2022) mentioned that the science literacy ability in a district in Central Kalimantan scored 32.8. This is in line with several studies conducted by previous researchers on science literacy in schools in the city of Palangkaraya, which indicated that the level of science literacy was relatively low (Wulandari et al., 2023; Septiya et al., 2023). Based on

preliminary research data conducted on 11th grade students at MAN Kotim, it was found that the average science literacy score of students was 45.09, which is considered very low. Low science literacy will certainly affect student motivation. This is because science literacy and learning motivation are closely related and influence each other (Wahyuni et al., 2018). If students have high learning motivation, it will encourage them to be more active in seeking information, thereby developing their science literacy skills. In addition, good science literacy among students will enable them to analyze problems and seek information to find solutions to those problems (Rahmadani *et al*., 2022). The success of students in finding solutions to these problems will certainly increase their motivation (Juliastari *et al*., 2024).

Based on the literature review that has been conducted, the reasons for low learning motivation can be attributed to a lack of interest in the material, the continued use of conventional learning models, and uninteresting learning media (Ilyas & Liu, 2020). This causes students to not be actively involved in learning activities in the classroom. As stated in the research conducted by Alfiah et al. (2021), one of the factors causing low learning motivation among students is the application of conventional learning methods or models.

Based on these issues, it is necessary to develop virtual laboratory learning media implemented with a problem-based learning model as a solution to the problems in biology learning at the school. Virtual laboratories have the advantages of easy access anytime, anywhere, the ability to visualize abstract concepts, and the ability to facilitate students in practical activities (Sari et al., 2022). According to Maksum & Saragih (2020), the use of virtual laboratories in learning can minimize accidents, work errors during practical work, and avoid contamination. In addition, virtual laboratories also have other advantages, namely that they are equipped with materials, learning videos, and practice questions based on science literacy indicators so that they can improve students' science literacy skills (Aripin & Suryaningsih, 2020).

The virtual laboratory media developed in this study was implemented using a problem-based learning model. The development of PBL-based virtual laboratory media aims to enable students to better understand theory and practice and improve their skills (Sofi'ah et al., 2017). According to research by Haryanti et al. (2023), the application of virtual laboratories using PBL can stimulate students to think critically in solving given problems. Thus, through this thinking process, students can improve their science literacy. This is also in line with the research by Puyada & Putra (2018), which states that combining PBL with virtual laboratory learning media can make the learning process more focused on students, thereby improving their thinking skills. The PBL learning model is considered more effective in improving students' science literacy because PBL can train and encourage them to actively participate in classroom learning activities. Thus, students' learning abilities and motivation can increase (Megarahayu et al., 2023).

Referring to this background, researchers were encouraged to conduct a study entitled "Development of a virtual laboratory to improve science literacy and learning motivation among phase F students." This study aimed to determine the validity, practicality, and effectiveness of the virtual laboratory media. It is hoped that this will lead to the development of valid, practical, and effective virtual laboratory media to improve science literacy and learning motivation among phase F students.

II. RESEARCH METHODS

This research is a type of Research and Development (RND). According to Sugiyono (2024), RND is a method applied to create a product based on the results of needs analysis and evaluate its feasibility. The development model applied in this study is the 4D model by S. Thiagarajan and Semmel (1994), which consists of four steps: Define, Design, Development, and Disseminate (Nasution & Anas, 2025). The following are the steps of the 4D development model, which can be seen in Figure 1.

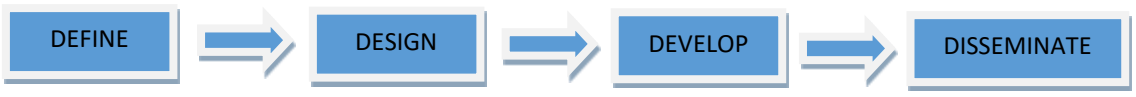

Figure 1. Steps in the 4D Development Model

This study involved two main subjects, namely: 1) three validators consisting of two lecturers and one high school biology teacher, who assessed the virtual laboratory media and other research instruments; 2) students of classes XI A and XI C at Man Kotim, who acted as users of the virtual laboratory media and provided assessments when using the virtual laboratory media in biology learning.

In this study, the validity, practicality, and effectiveness of virtual laboratory media were evaluated using data collection techniques in the form of test and non-test instruments. The data obtained will be analyzed using the following formula:

$$M = \frac{\Sigma X}{N}$$

The validation results obtained can be adjusted to the assessment criteria shown in Table 1 below

Table 1. Criteria and Categories for Learning Media Validation Results

Value	Category
81-100	Very Valid
61-80	Valid
41-60	Moderately valid
21-40	Less valid
0-20	Not valid

Source: Jumiarni (2024)

Practicality data was analyzed based on research data obtained through student response questionnaires and teacher response questionnaires regarding the use of virtual laboratory media. The practicality assessment criteria can be seen in Table 2.

Table 2. Criteria and Categories for the Practicality of Learning Media

Value	Category
85-100	Very practical
70-84	Practical
55-69	Moderately practical
40-54	Less practical
0-39	Not practical

Source: Jumiarni (2024)

The analysis of the effectiveness of virtual laboratory media was conducted based on science literacy and learning motivation data. Science literacy data analysis was conducted using test instruments in the form of pre-test and post-test sheets created based on science literacy indicators. The scores obtained from the pre-test and post-test results were then categorized in Table 3.

Table 3. Science Literacy Assessment Criteria

Value	Category
67-100	High
33-66	Moderately
<33	Low

The analysis of learning motivation data was conducted using a non-test instrument in the form of a learning motivation questionnaire based on learning motivation indicators. The percentages obtained from the learning motivation questionnaire results were then categorized in Table 4.

Table 4. Criteria for Assessing Learning Motivation

Value	Category
81%-100%	Very high
61%-80%	High
41%-60%	Moderately
21%-40%	Low
0%-20%	Very Low

Science literacy scores and learning motivation were compared using N-gain calculations in order to identify improvements in students' science literacy and learning motivation after classroom learning activities. Improvements in students' science literacy and learning motivation obtained from N-gain were calculated using the formula according to Hake Meltzer.

$$G = \frac{Skor\ Posttest - Skor\ Pretest}{Skor\ Maks - Skor\ Pretest}$$

N-gain calculations are performed for each student's score. The N-gain scores are then averaged and interpreted based on Table 5.

Table 5. Criteria for Obtaining N-gain

Value	Category
G>0,7	High
0,3<G≤0,7	Moderately
G≤0,3	Low

The effectiveness of virtual laboratories in improving students' science literacy and learning motivation can be determined through the N-gain score percent effectiveness interpretation category in Table 6.

Table 6. Criteria for Interpreting N-gain Effectiveness

Value	Category
<40	Not effective
40-55	Less effective
56-75	Moderately effective
>76	Effective

III. RESULT AND DISCUSSION

A. Validity

The validation test was conducted to determine the feasibility of the developed media. The developed product was validated by media and material experts from Yogyakarta State University. The overall validation results from the expert validators can be seen in Table 7.

Table 7. Validation Results from Expert Validators

No	Validator	Validation Score	Average Score	Category
1	Media Expert	19,33	100	Very Valid
2	Subject Matter Expert	21,66	96,18	Very Valid
Average		20,49	98,09	**Very Valid**

Based on the media validity test, the result was 100 with a category of very valid, and the material validity test resulted in 96.18 with a category of very valid. Thus, overall, the virtual laboratory media validity test on reproductive system material obtained an average of 98.09 with a category of very valid. This shows that the virtual laboratory media is of high quality and has a clear material concept that is in line with the needs of students and teachers. This opinion is in line with the research conducted by Maenah et al. (2024), which states that the material presented in learning media must have a clear material flow in order to achieve learning objectives. The use of virtual laboratory media implemented with the PBL learning model, which addresses issues related to reproductive organ health, can also increase students' learning motivation and science literacy (Pujiyanti et al., (2020); Rahman et al., (2024)).

B. Practicality

The practicality test was conducted to determine the practicality of the virtual laboratory media as assessed by students and biology teachers. The practicality test was conducted by one biology teacher and 37 students. The overall responses from teachers and students are shown in Table 8.

Table 8. Responses from Teachers and Students

No	Validator	Validation Score	Average Score	Category
1	Teacher	19,33	97,2	Very practical
2	Students	10,33	97,06	Very practical
Average		14,83	97,13	**Very practical**

Based on the practicality test conducted by teachers, the result was 97.2 with a category of very practical, and the practicality test conducted by students yielded a result of 97.06 with a category of very practical. Thus, overall, the practicality test of the virtual laboratory media on the reproductive system material obtained an average of 97.13 with a category of very practical. Virtual laboratory media are considered practical if the responses from teachers and students are in the practical or very practical category. This is in line with research conducted by Margita (2023), which states that interactive learning media are considered practical if they receive positive responses from teachers and students.

C. Effectiveness

The effectiveness test was conducted with the aim of determining whether the virtual laboratory learning media implemented with the PBL model was effective in improving students' science literacy and learning motivation. This test was participated in by 62 students from classes XI A and XI C at Man Kotim. The instrument used to measure science literacy was a non-objective test consisting of 10 essay questions. This instrument was compiled based on science literacy indicators, namely explaining scientific phenomena, interpreting scientific data and evidence, and designing and evaluating scientific investigations. The scores obtained were then analyzed using the N-gain test. The N-gain test was conducted to identify improvements in students' science literacy before and after biology learning. The results of the N-gain test for science literacy can be seen in Table 9.

Table 9. Science Literacy N-gain Results

Class	Pre Test	Post Test	N-gain Score	N-gain Score Persen	Category
Experiment	31,35	80,29	0,710	71%	Moderately effective
Control	24,45	61,77	0,490	49%	Less effective

Referring to Table 9, there was an increase in students' science literacy based on the pre-test and post-test results. Before the implementation of the virtual laboratory media, the pre-test score was 31.35. Meanwhile, after the implementation of the virtual laboratory media, the post-test score was 80.29, indicating an increase in students' science literacy. The N-gain score of the experimental group was 0.710, which is in the high category, and the N-gain score percentage was 71.0%, which is in the fairly effective category. Based on the N-gain test results, it can be concluded that virtual laboratory media is quite effective in improving students' science literacy.

Virtual laboratory media can improve science literacy because this media helps students visualize and explore material concepts. The reproductive system is an abstract concept because the processes occur inside the body and are difficult to observe. This makes it difficult for students to understand the material. With virtual laboratory media, students can visualize the concepts (Alnaser & Forawi, 2024).

Virtual laboratory media is implemented using the PBL learning model, which raises issues related to reproductive health. The PBL learning model is a problem-based learning model in which students are asked to solve problems using analytical skills (Marliah & Kumar, 2025). This will certainly encourage students to think about finding solutions to these problems. Thus, it can improve students' science literacy skills (Pratiwi, 2019).

Student learning motivation was measured using a learning motivation questionnaire. This questionnaire was compiled based on learning motivation indicators, namely the desire and will to succeed, the drive and need to learn, hopes and dreams for the future, interesting learning activities, and a conducive learning environment. The learning motivation questionnaire was administered before and after learning using virtual laboratory media. The average learning motivation scores for the experimental and control classes are presented in Table 10.

Table 10. Results of N-gain Learning Motivation

Class	Before	After	N-gain Score	N-gain Persen	Score	Category
Experiment	39,90	78,12	0,6368	63,68%		Moderately effective
Control	37,64	40,93	0,0544	5,44%		Less effective

Referring to Table 10, there was an increase in student learning motivation based on the results of the learning motivation questionnaire. Before the application of the virtual laboratory media, the score was 39.90. Meanwhile, after the application of the virtual laboratory media, the result was 78.12, which shows that there was an increase in student learning motivation. The N-Gain

score percentage for the experimental class was in the sufficiently effective category with a result of 63.68%. Based on the N-gain test results, it can be concluded that virtual laboratory media is quite effective in increasing student motivation to learn.

Virtual laboratory media can increase student motivation because this media is designed with interactive elements such as animations, quizzes, and direct feedback. This certainly creates interaction between users and the content or material being delivered (Parwati, 2023). This interactivity transforms students who were initially passive recipients into active participants in the learning process (Ambusaidi, 2018). The experience gained from using this learning medium will make students interested and increase their motivation to learn (Hermana, 2022).

Virtual laboratory media is implemented using the PBL learning model, which raises issues related to reproductive health. PBL is a problem-based approach that must be solved by students. Students are asked to analyze and find solutions to these problems. This will certainly encourage students to actively think, communicate, search for and analyze material before reaching a conclusion (Munawaroh, 2022). Ultimately, students will feel challenged to learn about the experimental process, which will make them curious and interested in understanding and mastering the material. This will certainly increase students' motivation to learn.

IV. CONCLUSIONS

Based on the results of the study, it can be concluded that:

A. The results of validity testing by media experts and subject matter experts indicate that the virtual laboratory learning media on reproductive system material is highly valid.
B. The results of practicality tests conducted by teachers and students show that virtual laboratory learning media for reproductive system material is considered very practical.
C. The results of the effectiveness test of the use of virtual laboratory learning media implemented with a problem-based learning model on reproductive system material were found to be quite effective in improving science literacy and learning motivation.

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