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The Development of a Virtual Laboratory Based on Problems in the Circulatory System Matter

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Abstract: Practicum in biology learning is an important element that allows students to observe, try, and test scientific concepts directly. However, the problems faced such as limited equipment, costs and time are obstacles. Therefore, the use of a virtual laboratory is needed to overcome this problem. This research aims to develop a problem-based virtual laboratory on circulatory system material. This virtual laboratory not only presents practical simulations that are close to reality but also challenges in the form of problems related to blood circulation that students need to solve. The laboratory was developed with a menu containing competencies, materials, practicums, and evaluations. The research method used was Research and Development (R&D) with the ADDIE model. The instrument was a questionnaire for 20 Biology teachers, expert lecturers, and students. The results showed the validity results of media and material experts of 94% and a VCR value of 0.969 which means valid so that it can be concluded that the development of problem-based virtual laboratories on circulatory system material is suitable for use as a medium in the learning process in High School.

Keywords: Learning tools; Problem-based learning; Virtual laboratory

Introduction

In the ever-evolving world of education, 21st-century technology has become a major catalyst in changing the way we learn and teach. Biology education, as an important part of forming an understanding of the living world, has also experienced a significant shift. Particularly in the circulatory system, challenges regarding practicum in the laboratory and understanding complex concepts often arise. Practicums have a vital role in biology learning, allowing students to observe natural phenomena directly, and explore and maximize learning potential (Laelasari et al., 2019).

However, the problems found in the field based on the results of a preliminary study at Madrasahs in Bogor district, around 60% of Madrasah have limitations in laboratory infrastructure, practical materials are not affordable, laboratories are used as classrooms due to limited space and there are even schools that do not have them laboratory. This is in accordance with previous research (Sukenti, 2021; Syam & Kurniasih, 2023). In addition, understanding complex concepts in the circulatory system material can be an obstacle, because of its abstract nature. This problem can be helped by learning media that is integrated with technology (Hafzah et al., 2020; Kamaruddin et al., 2021).

21st-century technology, as the main pillar of educational transformation, carries great potential in helping to overcome barriers to learning. Teachers must be able to use appropriate technology (learning media) to support the biology learning process (Fuadi et al., 2021). The integration of technology in learning is an important aspect of achieving learning success (Irdalisa et al., 2022), one of the innovations carried out is the development of virtual laboratories, an interactive simulation platform where students can conduct virtual experiments and observations. Virtual laboratories not only overcome physical limitations, but also open doors to limitless exploration, allow for a wide variety of experiments, and provide clear visualization of complex concepts (Faour et al., 2018; Orobor & Orobor, 2020). A virtual laboratory is a series of laboratory tools in the

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form of interactive multimedia-based computer software, that is operated by a computer and can simulate activities in the laboratory as if the user were in a real laboratory or a stand-alone application (Aripin & Suryaningsih, 2020; Nirmala & Darmawati, 2021).

Virtual laboratories can be used to simulate practical activities before carrying out actual experiments in the school laboratory (Bunyamin et al., 2021; Faour et al., 2018). Because students feel more confident and comfortable after using a virtual laboratory using real laboratory equipment (Dyrberg et al., 2017). Using virtual laboratories as a learning medium can not only be used as a means of training critical thinking skills (Sari et al., 2022) but also improve student learning outcomes (Asrizal et al., 2019; Reny et al., 2018). These results are in line with previous research where virtual laboratories are effectively used to improve critical thinking skills as well as innovative thinking and problem-solving (Lutfi, 2017; Marks & Thomas, 2022; Sari et al., 2022).

However, the use of virtual laboratories can be further intensified by adopting a problem-based learning approach. Problem-based learning (PBL) is an approach that stimulates students to learn through involvement in real problems. The application of active problem-based learning is a learning model that has a positive influence on improving students' critical thinking skills (Putri et al., 2021), as well as being able to improve students' science process skills (Usman et al., 2021). In the context of biology learning, this approach allows students to be more involved in understanding blood circulation concepts. By being faced with contextual problems, students are expected to be able to relate these concepts to real situations and formulate relevant solutions. Through this process, they not only understand concepts in depth but also develop essential critical and analytical thinking skills. With this approach, biology learning is expected to become more interesting, interactive, and effective, as well as helping students develop a deep understanding of concepts and critical thinking skills that are relevant in the current era of technology and information.

Therefore, it is necessary to develop a virtual lab learning media based on contextual problems that can make students feel like they can do practical work like actual lab work in a laboratory studying the circulatory system material. This research aims to develop a problem-based virtual laboratory on circulatory system material.

Method

This study uses the Research and Development (R&D) method, in which certain new products are produced and tested for their effectiveness and quality (Gall et al., 2003; Soegiyono, 2011). Using the ADDIE model research design with the Analyze, Design, Development, Implementation, and Evaluation stages (Branch, 2009).

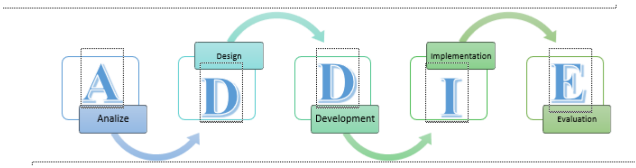

Figure 1. Adaption of the ADDIE instructional model by Branch

Data collection techniques were through questionnaires to material expert lecturers and media expert lecturers, questionnaires to students, and due diligence questionnaires to students, as well as due diligence questionnaires to 20 biology teachers. The rating scale used in each questionnaire to test the problem-based virtual laboratory consists of five range options, namely: Strongly Agree (SS), Agree (S), Undecided (R), Disagree (TS), and Strongly Disagree (STS). The scores obtained are then calculated on average by adding up the scores obtained dividing by the total score and multiplying by 100%. Quality assessment limits on score interpretation criteria for the Likert scale and using the Lawshe Content Validity Ratio (CVR) method with item testing criteria are said to be valid when the calculated CVR value is greater than the CVR critical Exact Value.

Result and Discussion

The development of a virtual laboratory is carried out by following the steps in the ADDIE model, namely:

Analyze

At the analysis stage, problem identification is carried out through analysis of student needs, teacher needs, literature review, and document study. From the results of the analysis of student needs, it was found that 64% of students felt that the conditions of their school laboratories were inadequate and 73.4% of students liked the use of virtual laboratories to help with the biology learning process. Meanwhile, the results of a teacher need questionnaire distributed to 5 Islamic Senior High Schools in the Bogor district showed that 60% of teachers felt that school laboratory conditions did not support practical activities in Biology subjects.

The results of literature reviews in previous research, virtual laboratories can foster students' creative thinking skills (Hirshfield & Koretsky, 2021); improve critical thinking skills (Lutfi, 2017; Sari et al., 2022); improve the quality of learning and students' metacognitive skills (Yusuf & Widyaningsih, 2020); on student learning outcomes (Verawati et al., 2022), and use of virtual laboratories as simulations of actual laboratories (Paxinou et al., 2020).

Design

The stages of designing a virtual laboratory begin with creating a flow chart which is then developed to form a storyboard in written and table form. Flowchart creation is carried out to describe the course of the learning process in a virtual laboratory. This storyboard is used as reference material for the next stage, namely the Development stage.

Development

The development stages are based on the storyboard that has been created, and then a virtual laboratory for the circulatory system is developed using contextual problem videos to stimulate students' critical thinking skills when doing practicum. The main menu in this problem-based virtual laboratory is a competency menu, a material menu equipped with animated videos, a practicum menu consisting of practicum testing for blood type, blood circulation, and blood pressure, as well as an evaluation menu that can measure students' level of understanding of the circulatory system material. The result of this stage is a problem-based virtual laboratory product. The results of the problem-based virtual laboratory can be seen in Figures 2, 3, and 4

Figure 2. Front cover virtual laboratory

Figure 3. Virtual laboratory scene

Figure 4. Contextual problem menu

This product was then tested for its suitability by material expert lecturers, media experts, and Biology teachers.

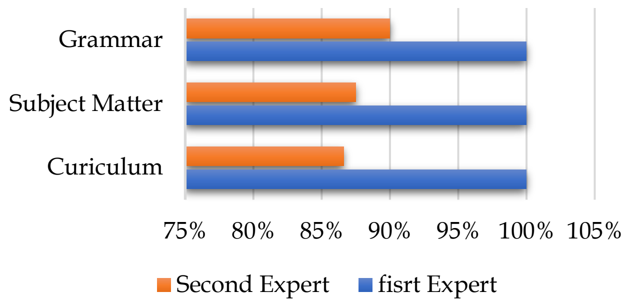

Figure 5. Material expert validation results

The results of the validation show that the percentage of the average score is 94% with the expert concluding that the material presented in the virtual laboratory is valid.

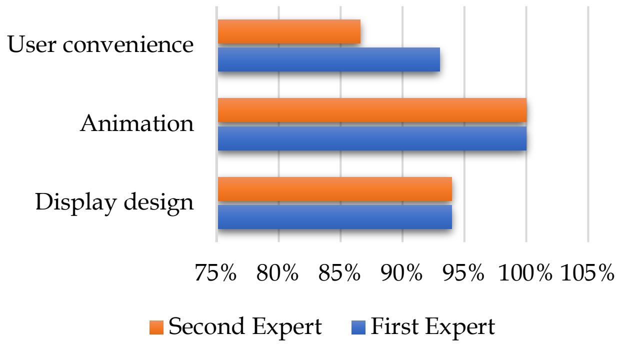

Figure 6. Media expert validation

The results of the validation show an average percentage of 94% with the conclusion that the experts stated that the developed media is valid with several revisions. Related to the display design which is not full screen and the location of the guiding questions in each practicum which is more enriched. Based on this input, revisions made included changing the screen display to full and then adding guiding analysis questions to each practicum menu. The results of the due diligence on Biology teachers were carried out by as many as 20 respondents. The conclusion of the validity results with the CVR formula can be that the CVR value is 0.969. Judging from the CVR critical Exact Value table (Ayre & Scally, 2014) with N totaling 20, the value is stated to be valid.

Table 1. CVRCritical One-Tailed Test (α = .05) Based on Exact Binomial Probabilities

N (Panel Size)	Proportion Agreeing Essential	$CVR_{critical}$ Exact Values	One-sided p Value	$N_{critical}$ (Minimum Number of Experts Required to Agree Item Essential)	$N_{critical}$ Calculated From CRITBINOM Function-Wilson et al. (2012)
5	1	1.00	.031	5	4
6	1	1.00	.016	6	5
7	1	1.00	.008	7	6
8	.875	.750	.035	7	6
9	.889	.778	.020	8	7
10	.900	.800	.011	9	8
11	.818	.636	.033	9	8
12	.833	.667	.019	10	9
13	.769	.538	.046	10	9
14	.786	.571	.029	11	10
15	.800	.600	.018	12	11
16	.750	.500	.038	12	11
17	.765	.529	.025	13	12
18	.722	.444	.048	13	12
19	.737	.474	.032	14	13
20	.750	.500	.021	15	14
21	.714	.429	.039	15	14
22	.727	.455	.026	16	15
23	.696	.391	.047	16	15
24	.708	.417	.032	17	16
25	.720	.440	.022	18	17
26	.692	.385	.038	18	17
27	.704	.407	.026	19	18
28	.679	.357	.044	19	18
29	.690	.379	.031	20	19
30	.667	.333	.049	20	19
31	.677	.355	.035	21	20
32	.688	.379	.025	22	21
33	.667	.333	.040	22	21
34	.676	.353	.029	23	22
35	.657	.314	.045	23	22
36	.667	.333	.033	24	23
37	.649	.297	.049	24	23
38	.658	.316	.036	25	24
39	.667	.333	.027	26	25
40	.650	.300	.040	26	25

Implementation

After the problem-based virtual laboratory was declared valid and feasible to use, a problem-based virtual laboratory trial was carried out on students in one of the Islamic Senior High Schools in Bogor district, West Java. Learning Biology using a problem-based virtual laboratory on the circulatory system material is carried out in 3 meetings, where each meeting is 2 x 45 minutes. The use of problem-based virtual laboratories is integrated with problem-based learning models. Problem Based Learning according to Arends is learning in which students work on authentic problems with the intention of constructing their own knowledge with relevant content, developing high-level inquiry, thinking skills, developing independence and self-confidence (Arsika et al., 2019; Putri et al., 2021). So that students can solve the problems they face by practicing their 4C skills (Weng et al., 2022).

Evaluation

The use of virtual laboratories in the learning process is also evaluated through questionnaires distributed to students. Then an analysis of student responses was carried out regarding the development and implementation of virtual laboratories in the learning carried out. The collection of student response data was carried out by distributing response questionnaires to 30 students who had implemented learning with the problem-based virtual laboratory that was developed. The results of the survey can be seen in Table 2.

In Table 2 students gave a positive response to the 3 aspects that were assessed from the virtual laboratory, namely the material aspect, the display design aspect, and the learning potential aspect. The material aspect obtained a score percentage of 97% in the very good category. Material aspects include suitability with learning objectives, ease of understanding material concepts, and suitability of evaluating material contained in virtual laboratories. The display design aspect obtained a percentage of 94% which is in the very good category. Aspects of display design cover the entire appearance of the virtual laboratory, namely color composition, image quality, video, fonts, and the use of buttons in the virtual laboratory. The final aspect is the learning potential which obtained a score percentage of 95% in the very good category. This aspect includes motivation, curiosity, independence, and interest in using virtual laboratories as a medium in the learning process. Based on these results as a whole the problem-based circulatory system virtual laboratory obtained a very good response from students by obtaining an average percentage score of 95% from the three aspects assessed. This is in line with research results that virtual laboratories are generally liked by students because of their flexibility and convenience (Makransky et al., 2019; Sommer & Sommer, 2019).

Table 2. Results of the Student Response Questionnaire

No	Statement	Strongly agree	Agree	Simply agree	Disagree	Strongly disagree
Material Aspects						
1.	The material in the virtual laboratory is in accordance with the learning objectives	71.4	28.6	3.6	0	0
2.	The concept of virtual laboratory material is easy to understand	50	50	0	0	0
3.	Evaluation according to the material in the virtual laboratory of the circulatory system	46.4	32.1	21.4	0	0
4.	Evaluation according to the material in the virtual laboratory of the circulatory system	46.4	50	3.6	0	0
5.	Virtual laboratories can be used to study the circulatory system	71.4	28.6	0	0	0
Display Design Aspects						
6.	Interesting virtual laboratory display	64.3	32.1	3.6	0	0
7.	Easy-to-use navigation buttons	35.7	42.9	21.4	0	0
8.	The color composition used is interesting	39.3	53.6	7.1	0	0
9.	Quality images. videos and clear instructions for use	42.9	39.3	17.9	0	0
10.	The use of language is easy to understand	60.7	35.7	3.6	0	0
11	The writing in the virtual laboratory is clearly legible	50	42.9	7.1	0	0
12.	The use of clue sentences is easy to understand	57.1	32.1	10.8	0	0
Aspects of Learning Potential						
13.	Practicum in a virtual laboratory can improve motivation to learn	50	32.1	17.9	0	0

14.	The use of virtual laboratories increased my curiosity	42.9	50	7.1	0	0
15.	I enjoy studying the circulatory system material in virtual laboratories	46.4	42.9	10.7	0	0
16.	Learning through a virtual laboratory is more interesting than regular lessons	42.9	50	7.1	0	0
17.	Using virtual laboratories can improve my skills in using laboratory tools and materials	35.7	64.3	0	0	0
18.	The use of the circulatory system virtual laboratory can be done independently	60.7	35.7	3.6	0	0

The overall results of the analysis carried out can be concluded that the aspects of all indicators in this problem-based virtual laboratory have fulfilled the requirements and are suitable for use as alternative learning media. Therefore, the research objective of developing a problem-based virtual laboratory on circulatory system material has been achieved.

Conclusion

A problem-based virtual laboratory on the circulatory system material has been successfully developed and obtained very good interpretation scores, so this problem-based virtual laboratory is suitable to be used as a learning medium in high schools.

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Conflicts of Interest
The authors declare no conflict of interest.

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