Vol. 11, No. 1, 2025, pp. 471-482
DOI: https://doi.org/10.29210/1202526145

Contents lists available at Journal IICET

Jurnal EDUCATIO (Jurnal Pendidikan Indonesia)
ISSN: 2476-9886 (Print) ISSN: 2477-0302 (Electronic)

Journal homepage: https://jurnal.iicet.org/index.php/jppi

Development and Effectiveness of MilleaLab-Based Virtual Reality Learning Media Integrated with Deep Learning in Biology Class

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Article Info

Article history:

Received Jun 24th, 2025
Revised Jul 26th, 2025
Accepted Aug 26th, 2025

Keyword:

Virtual Reality
MilleaLab
Circuatory system material
Deep learning
Mixed method

ABSTRACT

The biological concept of bioprocesses is abstract and difficult for students to comprehend because learning media have so far relied on textbooks and 2D images that do not depict in detail the bioprocesses occurring within the system, thus requiring supportive tools. Moreover, learning should not only focus on the cognitive domain but also on affective and psychomotor aspects. This study aims to develop and evaluate the effectiveness of MilleaLab-based Virtual Reality (VR) learning media integrated with deep learning. The research employed a mixed-method approach with an embedded design. The sample consisted of 40 eleventh-grade students and one biology teacher from MA Darul Falah. The research instruments included a preliminary study interview sheet, a product trial observation sheet, a product feasibility questionnaire for material, language, and media evaluation, a product feasibility questionnaire for small-group, large-group, and real-world testing, and a user response questionnaire. The results showed that the average product feasibility score was 91% (categorized as highly feasible). The effectiveness test yielded a score of 0.89 (high category), and the N-gain score was 0.48 (moderate category). Student responses to the learning media reached 94% (highly feasible), while teacher responses reached 95% (highly feasible). It is recommended that the product incorporate annotations and ensure the availability of smartphones capable of running MilleaLab effectively.

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Introduction

In the context of the modern era, education plays a fundamental role in preparing human resources who are not only technically competent (Mukhoyyaroh et al., 2023), but also equipped with strong soft skills and character values (Gonzales & Ramirez, 2022). The Deep Learning approach, or meaningful learning, has emerged as a catalyst to address these complex educational challenges. In 2025, the Directorate General of Primary and Secondary Education of the Ministry of Education of the Republic of Indonesia (Kemendikdasmen) introduced Deep Learning as a learning model that emphasizes conscious, meaningful, and enjoyable learning. This approach integrates cognitive, emotional, sensory, and physical engagement holistically (Suyanto, 2025). The model not only emphasizes cognitive development but also builds character and life skills through processes of understanding, application, and reflection (Wijaya et al., 2025). The successful implementation of Deep

Learning is supported by progressive pedagogical practices, safe and comfortable learning environments, and the integration of digital technology in the learning process.

The use of digital technology within the Deep Learning framework plays a crucial role in supporting interactive, collaborative, and contextual learning experiences. The availability of various learning media provides valuable opportunities to create more meaningful and impactful learning processes (Ministry of Communication and Information Technology, 2023). Technology tools are no longer limited to presentation media or mere information delivery, but function to visualize complex and abstract information to make it more easily understood (Julianingsih et al., 2021). Previous research revealed the challenges students face in visualizing abstract biology material (Mukhoyyaroh et al., 2023), particularly in the concept of bioprocesses (Azizah & Alberida, 2021). Biology topics such as the circulatory system are often difficult for students to understand if delivered solely through text explanations and two-dimensional images, which generally fail to depict the detailed processes occurring within the system. Therefore, appropriate learning tools are needed to support concept comprehension (Pariniti & Arjaya, 2024).

Virtual Reality is a digital technology that creates real-world simulations through interactive digital environments (Utami et al., 2021). In education, the application of Virtual Reality facilitates students' visualization of abstract and complex material that is otherwise difficult to grasp through text or two-dimensional illustrations alone (Sari et al., 2023). By presenting content in an interactive three-dimensional format, Virtual Reality can increase student motivation (Garduno & Martinez, 2021) and engagement in the learning process (Marougkas et al., 2023). The development of Virtual Reality media can be facilitated using the MilleaLab platform (Zulherman et al., 2021). MilleaLab-based Virtual Reality supports learning processes through several advantages, including a no-code design interface, access to a three-dimensional asset library (Sukirman et al., 2023), flexible user access, cloud-based integration (Zulherman et al., 2021), viewpoint-based interactions, and behavioral data features that enable educators to monitor student activities (Agusty & Anggaryani, 2021). This platform aligns with the Deep Learning framework introduced by the Ministry of Education as it supports immersive, meaningful, conscious, and enjoyable learning environments. Through MilleaLab-based Virtual Reality, students are directly involved in exploring the concept of the circulatory system, thereby enhancing the depth and retention of their understanding.

Based on this background, the research questions include: (a) How can MilleaLab-based Virtual Reality learning media integrated with Deep Learning be developed and evaluated for feasibility in biology learning (specifically on the circulatory system)?; (b) How effective is the implementation of MilleaLab-based Virtual Reality learning media integrated with Deep Learning on the circulatory system? The objectives of this study are: (a) to examine the development process and feasibility of MilleaLab-based Virtual Reality learning media integrated with Deep Learning in biology learning (specifically on the circulatory system); and (b) to assess the effectiveness of MilleaLab-based Virtual Reality learning media integrated with Deep Learning on the circulatory system.

This research produces the development of technology-based learning media that supports the teaching and learning process, thereby contributing to the realization of quality education. The urgency of this research lies in providing MilleaLab-based Virtual Reality media to help visualize abstract science materials. Virtual Reality offers representations of bioprocess concepts that go beyond text or static images, transforming them into interactive, immersive, flexible, and cloud-integrated learning experiences. In addition, the practical urgency addresses the needs of teachers and students for innovative, interactive, and contextual learning media, thereby increasing student motivation, engagement, and learning outcomes on difficult topics such as the circulatory system. From a policy perspective, this research supports the digital transformation of education and the Merdeka Belajar (Freedom to Learn) initiative, as well as providing a basis for recommendations to the government and educational institutions to expand the implementation of effective Virtual Reality-based learning media aligned with 21st-century curricula. Furthermore, MilleaLab-based Virtual Reality supports the application of the Deep Learning approach by directly involving students in the material, thus enhancing their understanding and long-term retention.

The novelty of this research lies in the integration of technology and learning approaches that have not been widely studied. Unlike previous studies that only developed Virtual Reality media separately, this study combines the cloud-based MilleaLab platform with the Deep Learning approach to create immersive, meaningful, and comprehensive biology learning experiences. This media is specifically developed for the abstract circulatory system topic, helping students understand biological processes that are difficult to visualize through text or 2D images. Moreover, this study not only evaluates the feasibility of the media but also tests its effectiveness using a mixed-methods design combining quantitative and qualitative data. By linking this innovation to the national digital education transformation policy, this research contributes not only to technical innovation but also to strengthening the strategic direction of 21st-century education.

Method

The type of research employed in this study is Research and Development (R&D) utilizing the ADDIE model (Analyze, Design, Develop, Implement, and Evaluate) (Hanida, 2023; Sari, 2021), which consists of five systematic stages (Figure 1). This model was selected for its numerous advantages, one of which is the interconnection between each stage. Although evaluation is positioned at the final stage, it is also conducted to assess every preceding phase, from analysis to implementation. Consequently, the resulting product is more valid and reliable because each stage is grounded in comprehensive processes of analysis, design, development, implementation, and evaluation (Waruwu, 2024). This study adopted a mixed-methods approach with an embedded design. The aim was to develop MilleaLab-based Virtual Reality learning media and test its effectiveness on learning outcomes. The qualitative method was prioritized during the development process of the MilleaLab-based Virtual Reality learning media, whereas the quantitative method was employed to test product feasibility, user responses, and product effectiveness on learning outcomes. The ADDIE model used in this study is presented in the following figure:

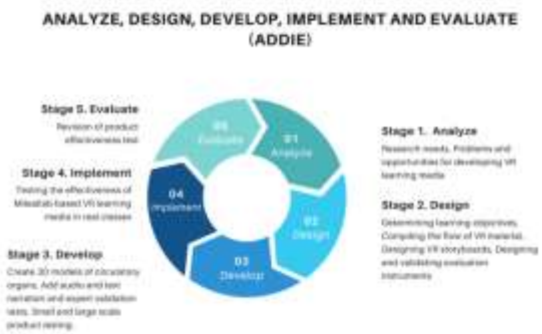

Figure 1. ADDIE model (Analyze, Design, Develop, Implement, and Evaluate)

The study was conducted from April to July 2025 at MA Nurul Falah Rangkasbitung, Lebak, Banten. The population of this study comprised all students of MA Nurul Falah Rangkasbitung, while the sample included 40 Grade XI MIPA students (28 females and 12 males) and one Grade XI MIPA biology teacher at MA Nurul Falah. The instruments used to collect qualitative data were: (1) a preliminary study interview sheet (open-ended interviews); and (2) a product trial observation sheet involving participants. Meanwhile, the instruments for quantitative data collection included: (1) a product feasibility questionnaire for the evaluation of content, language, and media; (2) a product feasibility questionnaire for small-group, large-group, and field testing; (3) a user response questionnaire; and (4) a cognitive test (quasi-experimental pretest–posttest). The data collection techniques employed were interviews, observations, questionnaires, and literature review.

Data processing techniques used descriptive analysis. Data obtained from interviews, literature review, and observations were analyzed through data reduction, data display, and conclusion drawing. Meanwhile, data from the questionnaires were converted using a reference conversion scale. The following table presents the score conversion guidelines and criteria used in the questionnaire analysis.

VR learning media feasibility test:

Formula

$$Persentase\ (\%) = \frac{N}{X}\ x\ 100\%$$

Explanation:

N = Feasibility test score or total score

X = Total score

Then, the avarage score is calculated using the formula:

$$Average\ score = \frac{Total\ score}{JNumber\ of\ evaluators}\ x\ 100\%$$

Table 1. Product Feasibility Categories

Persentase (%)	Criteria
80 – 100%	Very Feasible
60 – 80%	Feasible
40 - 60%	Sufficiently Feasible
20 – 40%	Not Feasible
0 – 20 %	Very mot Feasible

Hypothesis Testing

(1) Hypothesis Assumption Test: This includes testing for normality and homogeneity. Formulate the Hypotheses (a) Null Hypothesis (H_0): There is no significant difference between the means (or no effect). (b) Alternative Hypothesis (H_a): There is a significant difference between the means (or there is an effect). (2) Calculate the t-value (T-statistic): Compute the t-value using the appropriate formula for the type of t-test being performed. (4) Compare with the Critical Value or p-value (a) Using the t-table: Compare the calculated t-value with the critical t-value from the t-table at a specified significance level (α). (b) Using the p-value: Compare the obtained p-value with the significance level (α), commonly 0.05. (5) Make a Decision (a) If the calculated t-value > critical t-value or p-value < α, then H_0 is rejected and H_a is accepted. (b) If the calculated t-value < critical t-value or p-value > α, then H_0 is accepted and H_a is rejected.

○

Effectiveness test of VR learning media

Formula

$$N - Gain = \frac{Posttest\ score - Pretest\ score}{Ideal\ score\ - Pretest\ Score}\ x\ 100\%$$

The N-Gain value wiil be converted into several categories as follows:

Table 2. N-Gain Score Categories

Percentage (%)	Criteria
< 40	Not Effective
40 - 55	Moderately effective
65 - 75	Effective
> 76	Very Effective

User response (Teachers and students) to VR Learning media

Formula:

$$Response = \frac{Total\ score\ obtained}{Maximum\ scor\ obtainable}\ x\ 100\%$$

User response scores to the learning media will be converted into the following categories:

Table 3. User Response Categories

Persentage (%)	Criteria
81 – 100%	Very Suitable
61 – 80%	Suitable
41 – 60%	Fairly Suitable
21 – 40%	Not Suitable
< 21%	Very unsuitable

Results and Discussions

Development and Effectiveness of MilleaLab-Based Virtual Reality Learning Media Integrated with Deep Learning in Biology Class

Research and Development of VR-Based Learning Media Using MilleaLab on the Circulatory System Material with the ADDIE Model

Analyze.

The purpose of this stage is to identify research needs, problems, and opportunities for developing VR-based learning media relevant to the context of high school students. This includes an analysis of learning needs, student characteristics, basic competencies, facilities and infrastructure such as the potential of VR in learning through observation, teacher and student interviews, and literature review. Interviews were conducted with five students and one biology teacher. The results of the observations and interviews revealed that, in current learning conditions, teachers use learning media in the form of presentation slides and 2D images in textbooks, and the explanation of the circulatory system concepts is delivered through lectures accompanied by Q&A sessions. This is in line with research by Utami et al. (2021), which states that biology materials such as the circulatory system are difficult for students to understand because the explanations are presented in text and 2D images without depicting in detail the bioprocesses occurring in the system. Therefore, there is a need for supportive tools. The limitations of the current learning media include the inability of 2D media to show the structure of the heart organ in detail and interactively, and the absence of 3D learning facilities or simulations that allow students to see the blood circulation process dynamically. Further interviews regarding the potential of VR-based learning media in instruction revealed that teachers believe VR media provides an immersive learning experience, allowing students to see real-time blood flow simulations. This finding is consistent with research by Radianti et al. (2020), which states that VR in science education can improve learning outcomes through immersive visualization and direct interaction with learning objects.

Design.

The purpose of this stage is to design the structure and components of the VR media that support Deep Learning. The design phase includes determining specific learning objectives aligned with Deep Learning, arranging the VR material flow, designing the VR storyboard (layout of 3D objects, audio narration, interactive labels, and circulatory system animations), as well as designing and validating evaluation instruments (product feasibility questionnaire, learning outcome test, teacher and student response sheets).Details of the research instruments are as follows:

The product feasibility questionnaire is an instrument used to measure the feasibility of MilleaLab-based VR learning media in terms of content (biology material), presentation and graphics (learning media), and language. The purpose of this instrument is to ensure that the VR learning media is suitable for use before being tested on students. The testing scale refers to a Likert scale from 1 to 4. Indicators assessed in the aspects of content (biology material), presentation and graphics (learning media), and language can be seen in Table 4.

Table 4. Product feasibility indicators

Assessment Aspect	Assessment Indicators
Language	Clarity
	Suitability with students
	Dialogic and interactive style
Biological content	Relevance to basic competencies
	Accuracy of material
	Encouragement of coriosity
Learning media	Quality of visual appearance
	Software engineering
	Practical implementation

Learning Outcome Test. The learning outcome test is an instrument used to measure the effectiveness of MilleaLab-based VR learning media on students' learning achievements. The test consists of 25 multiple-choice questions, each with five answer options.

Teacher and Student Response Sheets. The teacher and student response sheets for MilleaLab-based VR learning media are questionnaires designed to gather teachers' and students' perceptions of the media after its implementation in the learning process. The purpose of this instrument is to assess the level of user acceptance and satisfaction with the MilleaLab-based VR learning media, as well as to identify the strengths and weaknesses of the product from the users' perspective. This instrument was administered to a Biology teacher and several high school students using a Likert scale ranging from 1 to 4. The indicators assessed in the response instrument are presented in Table

Table 5. Teacher and student response indicators toward the product

Response Questionnaire	Indicators measured
Teacher	Effectiveness of the learning media
	Relavance to elarning objectives
	Usefulness of the learning media
Student	Appearance of the learning media
	Benefits of the learning media
	Usability/operation of the learning media

Develop.

The objective of this stage is to transform the storyboard into MilleaLab-based VR media ready for testing. The development steps include creating 3D models of circulatory system organs, adding audio narration and text, conducting expert validation (Biology content, language, and learning media), and performing small-scale and large-scale product trials. The tangible form of the storyboard development is presented in Figure 2.

Figure 2. Transformation of the storyboard into the actual form of VR learning media

The feasibility of the product (MilleaLab-based Virtual Reality learning media on the circulatory system) was evaluated using a questionnaire that measured aspects of language, Biology content, and learning media. he product was evaluated by a panel of three experts: a subject-matter expert, a media expert, and a language expert. Based on Figure 3, the product feasibility score reached 91%, categorized as “highly feasible” for use (Table 1). This indicates that the MilleaLab-based VR learning media is appropriate and suitable for implementation.

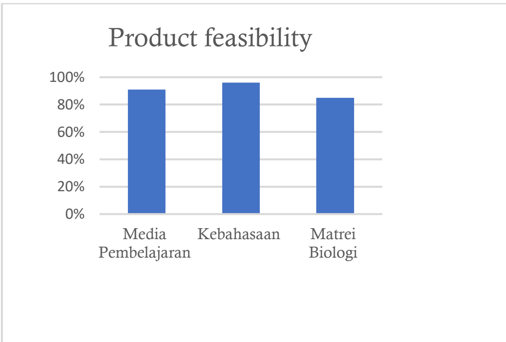

Figure 3. Product feasibility based on the assessment of learning media, language, and Biology content

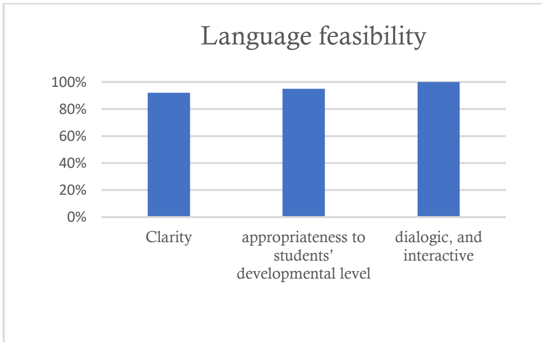

Figure 4. Product feasibility based on language aspects

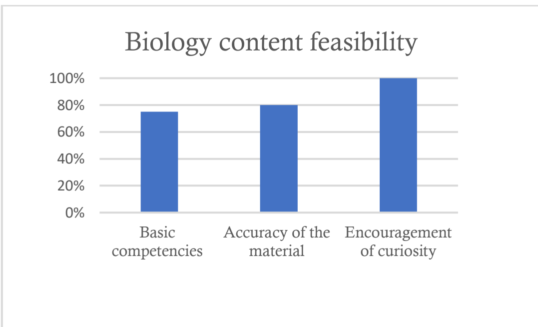

Figure 5. Product feasibility based on Biology content aspects

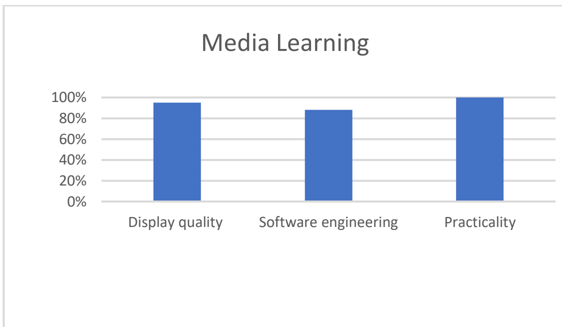

Figure 6. Product feasibility based on learning media aspects

The language aspect of the product feasibility (MilleaLab-based Virtual Reality learning media on the circulatory system) obtained an average score of 96%, categorized as highly feasible for use (Figure 4). The assessment indicators for the language aspect included clarity, appropriateness to students' developmental level, dialogic, and interactive style. However, several indicators were not fully met, such as sentence structure accuracy and the consistent use of precise terminology. Suggestions from language experts indicated the need for additional explanations of the scientific terms used in the learning process (Figure 7). Vogt et al. (2021) emphasized that the use of annotations (labels, explanatory text, or direct comments) is essential to help students construct a coherent mental model of scientific concepts.

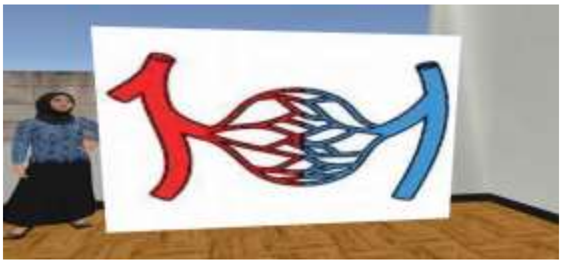
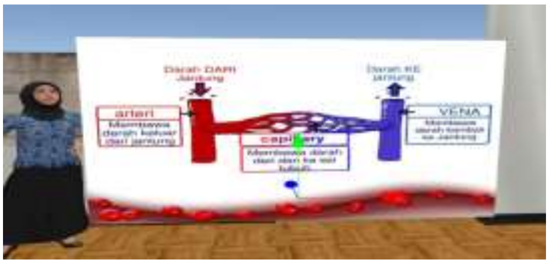

Figure 7 (a) Figure 7 (b)

Figure 7. (a) The image is not accompanied by a description; (b) Suggestions from the language expert indicate the need for additional explanations in the image description

The Biology content aspect of product feasibility (MilleaLab-based Virtual Reality learning media on the circulatory system) obtained an average score of 85%, categorized as highly feasible for use (Figure 5). The assessment indicators for the Biology content aspect included alignment with basic competencies, accuracy of the material, and encouragement of curiosity. However, several indicators were not fully met, such as the completeness of the material presented in the media, the breadth and depth of the content, and the accuracy of concepts, facts, and examples provided.

Suggestions from Biology content experts indicated the need for additional details in the circulatory system material (e.g., some circulatory organs have not yet been explained in terms of their functions) (Figure 8). Another recommendation was the inclusion of a supplementary table to differentiate the characteristics of blood, the heart, and blood vessels. Gregorcic and Torkar (2022) noted that the Structure–Behavior–Function (SBF) framework in the topic of the circulatory system has been proven to improve conceptual understanding when the material links structure (e.g., valves, heart chambers), behavior/process (flow), and function (physiological purpose).

Further suggestions included separating the explanations of pulmonary and systemic circulation, as well as ensuring that examples and case studies are more contextually relevant to students (Figure 9). Context-based science education has consistently been shown to enhance students' relevance, motivation, and scientific reasoning by employing case approaches closely related to students' everyday experiences (Kuhn et al., 2014; Abebe et al., 2023).

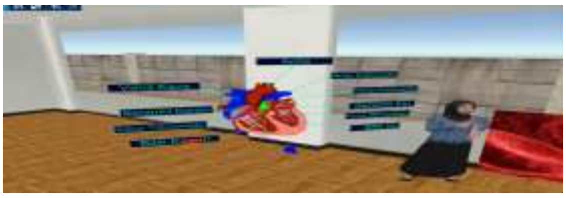
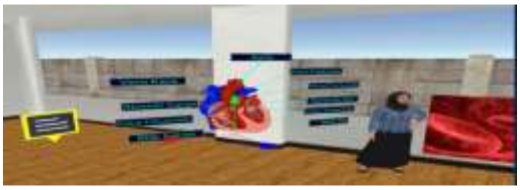

Figure 8 (a) Figure 8 (b)

Figure 8 (a) No explanation of the function of the heart chambers; **(b)** Addition of explanation regarding the function of the heart chambers


Figure 9 (a) Figure 9 (b)

Figure 9 (a) The apperception is not contextually appropriate; **(b)** Modification of the apperception theme to be contextually appropriate

The learning media aspect of product feasibility (Virtual Reality-based learning media using MilleaLab on the circulatory system topic) obtained an average score of 91%, categorized as highly feasible for use. The assessment indicators for this aspect included display quality, software engineering, and practicality. However, one indicator was not fully met, namely the ease of media management. The learning media expert stated that the VR media is relatively easy to manage but requires a compatible smartphone to implement MilleaLab.

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Figure 10. initial display of Millealab based VR learning media

Implement

The purpose of this stage is to test the effectiveness of MilleaLab-based VR learning media in a real classroom setting. The implementation steps include preparing the VR learning media devices and the MilleaLab software, conducting learning activities on the circulatory system material using MilleaLab-based VR learning media to support Deep Learning, collecting student and teacher responses through questionnaires and interviews, and measuring students' learning outcomes before and after using the MilleaLab-based VR learning media. The initial display of MilleaLab-based VR learning media is presented in Figure 10.

After preparing the MilleaLab-based VR learning media, the next step was to implement the media with a Deep Learning approach. Deep Learning emphasizes learning that is in-depth, contextual, and meaningful, thereby fostering critical thinking, creativity, and problem-solving skills. The learning principles applied in this approach are as follows: (a) Mindful Learning – providing space for students to recognize their emotions and interests. Before beginning the lesson, the teacher asked students to create a journal by writing down their feelings in sentences on a piece of paper (Figure 11.c). (b) Meaningful Learning – connecting the lesson with students' real-life experiences. The teacher gave students the opportunity to detect their heartbeat by feeling the pulse at their wrist using their index finger (Figure 11.a). (b) Joyful Learning – integrating elements of play, humor, creativity, and active engagement. Students were given the opportunity to use VR headsets as learning aids (Figure 11.b).

Figure 11 (a)

Figure 11 (b)

Figure 11 (c)

Figure 11. Biology learning using MilleaLab-based VR learning media to support Deep Learning: (a) meaningful learning activity; (b) joyful learning; and (c) mindful learning

Based on Figure 12 regarding the user response test (students) to MilleaLab-based VR learning media, an average score of **94%** was obtained, categorized as *highly feasible* (Table 3). A total of 30 students participated in this test. The indicators measured in the student response test to the VR learning media included display, operation, and utilization of MilleaLab-based VR learning media. Several indicators were not fulfilled, such as in the display aspect, particularly the clarity of the video. Students reported that the text size was too small and some text appeared reversed. In addition, in the operation aspect, a small number of students experienced difficulties in downloading the MilleaLab application. This was due to smartphones that did not support MilleaLab. The minimum device specifications required for *MilleaLab Creator* are: Processor: equivalent to Intel i5/i7 or higher, Operating System: Windows 8/10 - 64 bit, RAM: minimum 4 GB or more, Storage: minimum 4–8 GB, and Graphics Card: Internal or External Graphic Card. Meanwhile, *MilleaLab Viewer* requires minimum device specifications of: Processor: equivalent to Hexa-core 4x 1.4 GHz or higher, Operating System: at least Android Nougat, RAM: minimum 2 GB or more, Storage: minimum 1 GB or more, Graphics Card: Support Open GLES 3.1+, and Sensors: gyroscope or accelerometer.

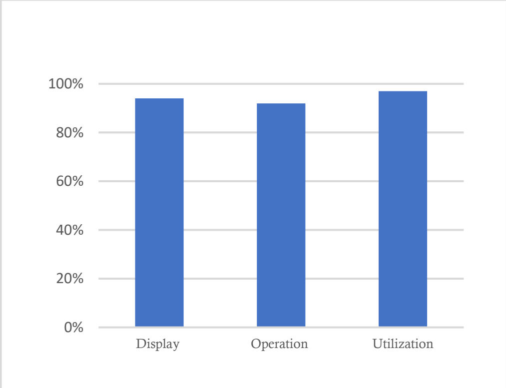

Figure 12. Students' responses to the MilleaLab-based VR learning media

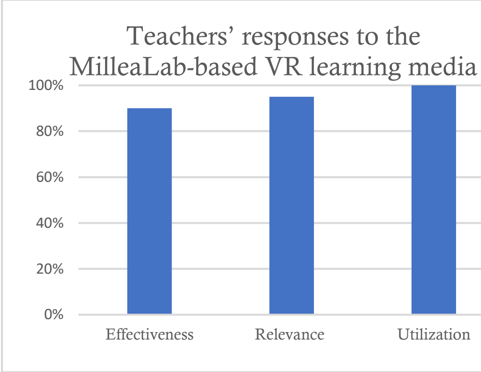

Figure 13. Teachers' responses to the MilleaLab-based VR learning media

Based on Figure 13 regarding the user response test (teachers) to the MilleaLab-based VR learning media, the average score obtained was 95% with a category of very feasible (Table 3). The indicators measured in the teacher response test to the VR learning media included effectiveness, relevance, and usefulness of the MilleaLab-based VR learning media. Some indicators were not met, such as the effectiveness aspect, specifically the indicator of material sequence suitability in VR. According to the users (teachers), the sequence of materials was not yet structured logically, which confused students. Sukaria (2024) stated that science learning studies should be organized logically (starting from prerequisite concepts, core concepts, to applications) so that students can understand the concepts vertically.

The MilleaLab-based VR learning media integrated with deep learning, after being developed and validated for feasibility by a team of experts (media, content, and language), was subsequently tested for its effectiveness on learning outcomes. This effectiveness test was conducted to determine the improvement in learning outcomes after instruction using the VR learning media through a comparison of pretest and posttest scores. The test employed 25 multiple-choice questions. The effectiveness test was preceded by prerequisite hypothesis testing, consisting of normality and homogeneity tests using SPSS 29. The results of these prerequisite tests are presented in Tables 6 and 7.

Table 6. Results of normality test

Score	Shapiro-Wilk			
	Statistic	**df**	**Sig.**	**Decision**
Pretest	0.928	26	0.068	Normal
Postest	0.924	26	0.055	Normal

Normality testing was conducted using the Shapiro–Wilk test because the sample size was small ($n < 50$). The sample used in this class consisted of 35 students ($n = 35$), with a significance level of $\alpha = 0.05$. Interpretation of the Shapiro–Wilk test was based on the significance value (p-value or Sig.) obtained. If the p-value/Sig. is greater than 0.05, the data are normally distributed; if the p-value/Sig. is less than 0.05, the data are not normally distributed. This test is useful for ensuring that the data meet the normality assumption before conducting further analyses. Based on Table 6, the normality test results for the pretest scores show a significance value (p-value or Sig.) of 0.068, which is greater than 0.05 (Sig. 0.068 > 0.05), indicating that the data are normally distributed. Similarly, for the posttest scores, the normality test results show a significance value (p-value or Sig.) of 0.055, which is greater than 0.05 (Sig. 0.055 > 0.05), also indicating that the data are normally distributed.

Tabel 7. Result of Homogeneity

Score	Levene statistic	df1	df2	Sig.	Decision
Pretest	0.000	1	24	0.996	Homogen
Posttest	0.001	1	24	0.978	Homogen

The next prerequisite test is the homogeneity test. This test aims to determine whether the samples come from populations with equal variances using Levene's statistic test. Interpretation of the Levene test is based on the significance value (p-value or Sig.) compared with a significance level of 0.05. If p-value > 0.05, the variances are considered homogeneous (equal), meaning the homogeneity assumption is met for further analysis. If p-value or Sig. < 0.05, the variances are considered not homogeneous (significantly different). Based on Table 7, the results of the homogeneity test for the pretest scores show a significance value (p-value or Sig.) of 0.996, which is greater than 0.05 (Sig. 0.996 > 0.05), indicating that the data are homogeneous. Meanwhile, for the posttest scores, the homogeneity test results show a significance value (p-value or Sig.) of 0.978, which is greater than 0.05 (Sig. 0.978 > 0.05), also indicating that the data are homogeneous.

Table 8. Hypothesis Testing

Nilai	Mean	N	Std. Deviation
pretest	57.23	26	13.27
Posttest	77.23	26	11.12

Based on the prerequisite tests, the data were normally distributed (Table 6) and homogeneous (Table 7). Therefore, the hypothesis test or further analysis used a paired t-test (parametric test). The purpose of this test is to compare the mean differences between two groups (pretest and posttest). According to Table 8, the hypothesis test shows that the mean score of the pretest (57.23) is lower than that of the posttest (77.23), indicating that there is a difference in the average learning outcomes between the two.

Table 9. N-Gain

N-gain Category	N	Mean	Std. Devision
N-gain	26	0.488	0.189
N-gain persen	26	48.87	18.92

Based on Table 9, the mean N-gain score was 0.48, indicating a moderate improvement between the pretest and posttest scores. The N-gain percentage in Table 9 also shows an average of 48.87, which falls into the less effective improvement category.

Evaluate.
The evaluation phase aims to ensure that the VR-based learning media using MilleaLab for circulatory system material supports Deep Learning, is suitable for use according to students' needs, and can deliver optimal learning outcomes before being implemented on a wider scale. This stage consists of formative and summative evaluations. The following describes each evaluation:

Formative Evaluation. Its purpose is to identify necessary revisions at each step of the ADDIE model: (1) Analysis stage: Evaluation is carried out by reviewing the development plan of the MilleaLab VR-based learning media to address the issues identified in the previous analysis. This ensures that the planned solutions align with students' needs and characteristics. (2) Design stage: Evaluation is obtained through feedback from expert validators of the research instruments, serving as the basis for improving the quality of the feasibility instruments for the MilleaLab VR-based learning media. (3) Development stage: Evaluation is conducted through assessments and suggestions from three expert judges during the feasibility test. The results are used as the basis for refinements and adjustments to ensure the developed learning media meets the desired standards before progressing to the next stage. (4) Implementation stage: Evaluation at this stage is conducted by analyzing the learning outcomes from the pretest-posttest and students' questionnaire responses.

Summative Evaluation. The improvement in learning outcomes between the pretest and posttest produced an N-gain score of 0.890, which falls into the high category. Therefore, it can be concluded that the MilleaLab VR-based learning media effectively improves students' learning outcomes on the circulatory system material. In addition, the student response test to the learning media was 94% (categorized as "highly feasible"), while the teacher response was 95% (also categorized as "highly feasible").

Conclusions

The MilleaLab-based VR learning media on the circulatory system material to support high school students' deep learning was developed using a Research and Development (R&D) approach with the ADDIE model (Analyze, Design, Develop, Implement, and Evaluate). The media's feasibility was assessed using questionnaires measuring aspects of language, biology content, and instructional media. The findings revealed that the average feasibility test score was 91%, which falls into the "highly feasible" category. The effectiveness test yielded a score of 0.89 in the "high" category, and the N-gain score was 0.48 in the "moderate" category. Student responses to the learning media reached 94% ("highly feasible"), while teacher responses reached 95% ("highly feasible"). Recommendations for the product include adding annotations, ensuring that smartphones used to run MilleaLab have adequate specifications, and expanding the circulatory system content (as some organs related to circulation have not yet been fully explained). Another suggestion is to include supporting tables to differentiate the characteristics of blood, the heart, and blood vessels. In addition, smartphones used to upload MilleaLab should meet sufficient hardware requirements.

Acknowledgments

The authors would like to express their gratitude to the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for funding this research through the Beginner Lecturer Research (PDP) scheme in the 2025 fiscal year, to the academic community of La Tansa Mashiro University for their support, and to MA Nurul Falah Rangkasbitung, Lebak Regency, Banten Province, for providing the research site.

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