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Development of FAZAR ALIRA Assisted PBL Materials to Enhance Students' Scientific Literacy on the Human Circulatory System

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ABSTRACT

Objective: *Innovative digital learning media are increasingly needed to help students understand complex biological concepts and develop scientific literacy. This study aimed to develop and evaluate the validity and practicality of FAZAR ALIRA, a learning media that integrates augmented reality (AR) visualization and virtual laboratory simulations within a PBL framework for teaching the human circulatory system.* ***Method:*** *The study employed a research and development approach consisting of analysis, design, development, and evaluation stages. The developed media includes AR visualizations of laminar and turbulent blood flow, contextual learning materials related to lifestyle and cardiovascular health, and interactive virtual laboratory simulations that allow students to investigate the relationship between blood vessel resistance, blood pressure, and heart workload.* ***Results:*** *The validity of the media was evaluated by science education experts and practitioners, while its practicality was examined through teacher and student responses during implementation. The results indicate that FAZAR ALIRA achieved high validity across content, construct, and language aspects and was considered practical and easy to use in classroom learning.* ***Novelty:*** *This study lies in integrating AR-based blood flow visualization, contextual health narratives, and virtual laboratory inquiry within a PBL environment to support students' scientific literacy in learning the human circulatory system.*

INTRODUCTION

Scientific literacy has become one of the essential competencies required for students in the 21st century (Koumpouros, 2024). It enables learners to understand scientific concepts, interpret evidence, and apply scientific knowledge to solve problems encountered in everyday life. Students with strong scientific literacy can explain scientific phenomena, evaluate scientific information critically, and make informed decisions based on evidence. Therefore, developing students' scientific literacy has become a major goal in science education worldwide (Auralia & Juliani, 2024; Saragih & Pratama, 2026; Sari et al., 2026).

However, many studies indicate that students' scientific literacy levels are still relatively low, particularly in learning science topics that involve abstract concepts and complex systems. One example is the topic of the human circulatory system, which requires students to understand the relationship between anatomical structures, physiological processes, and physical principles such as pressure, flow, and resistance (Rusid et al., 2024; Yaumi & Rohmah, 2024). These concepts are often difficult for students to visualize and comprehend when learning relies primarily on conventional teaching methods and textual explanations. As a result, students tend to memorize information rather than develop a deeper conceptual understanding and scientific reasoning skills (Gunturu et al., 2025).

Preliminary studies conducted in junior high school also revealed similar problems. Students experienced difficulties in explaining scientific phenomena, designing simple investigations, and interpreting scientific data related to the circulatory system. The

results showed that students' competence in explaining scientific phenomena reached only 57.2%, while skills related to evaluating investigations and interpreting data were even lower, at 48.6% and 52.0%, respectively. These findings indicate that students' scientific literacy in this topic still requires significant improvement.

One of the learning approaches that has been widely recommended to improve students' scientific literacy is PBL. PBL encourages students to actively engage in solving authentic problems through investigation, discussion, and evidence-based reasoning (Ahmady et al., 2025). Through this process, students develop the ability to analyze information, construct explanations, and connect scientific knowledge with real-life situations (Mercan & Selçuk, 2024). Previous studies have reported that PBL can enhance critical thinking, scientific reasoning, and students' engagement in science learning (Praja & Andriani, 2025).

In addition to pedagogical approaches, the integration of digital technology has also shown significant potential in supporting science learning. Technologies such as Augmented Reality (AR) and virtual laboratories can help students visualize complex and abstract scientific processes more concretely (Saragih & Pratama, 2026). AR enables the visualization of three-dimensional objects that can be observed interactively, while virtual laboratories allow students to simulate scientific experiments and explore scientific phenomena in a safe and flexible learning environment (Coştu, 2025). The integration of these technologies can provide meaningful learning experiences and improve conceptual understanding in science education (Muspiroh et al., 2025).

To address these challenges, a technology-assisted learning medium named FAZAR ALIRA was developed. FAZAR ALIRA integrates Augmented Reality with a virtual laboratory to visualize the structure and processes of the human circulatory system, including three-dimensional representations of the heart, blood vessels, and blood flow simulations. This integration allows students to explore scientific phenomena interactively while engaging in PBLactivities (Dehghani et al., 2023). Through this approach, students are expected to better understand complex biological concepts and strengthen their scientific literacy skills (Wilsa et al., 2025).

Although previous studies have explored the use of PBL and augmented reality in science education, research that integrates PBL with Augmented Reality and Virtual Laboratory within a structured learning material design is still limited (Li & Taber, 2022). Furthermore, few studies have specifically examined the development and validation of such integrated learning materials for improving students' scientific literacy on the topic of the human circulatory system (Thangavel, 2025). Therefore, this study aims to develop and validate PBLmaterials assisted by FAZAR ALIRA to improve students' scientific literacy on the topic of the human circulatory system. The study focuses on evaluating the validity, practicality of the developed learning materials as an innovative approach to support meaningful science learning.

RESEARCH METHOD

General Background

This study employed a research and development (R&D) approach to develop and evaluate the quality of PBL materials assisted by FAZAR ALIRA for improving students' scientific literacy on the topic of the human circulatory system. The development process followed the ADDIE instructional design model, which consists of five stages: analysis, design, development, implementation, and evaluation (Matos et al., 2023). This study focused only up to the development stage. Therefore, the procedures described in the

methods section are limited to the activities carried out during the analysis, design, and development stages, without proceeding to the implementation and evaluation stages. The results presented in this study are aligned with the scope of the development stages conducted based on the ADDIE model (Figure 1).

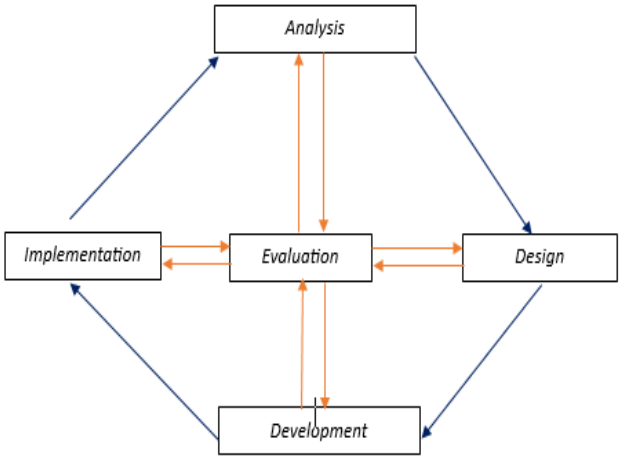


Figure 1. Research Design

In the analysis stage, a needs assessment was conducted through teacher interviews, preliminary studies, and student questionnaires to identify students' difficulties in understanding the circulatory system. The results showed that students often experienced difficulties in explaining scientific phenomena, designing scientific investigations, and interpreting scientific data. Learning activities were still dominated by textual explanations with limited use of technology and visualization, resulting in students relying more on memorization than conceptual understanding (Chali et al., 2022).

Based on these findings, the design stage focused on developing learning materials that integrate PBL with the FAZAR ALIRA platform, which combines augmented reality and a virtual laboratory to support interactive learning experiences. The learning design emphasized scientific literacy competencies, including explaining scientific phenomena, evaluating scientific investigations, and interpreting scientific evidence (Coe et al., 2025). The development stage involved producing the learning materials, including lesson plans, student worksheets, teaching materials, augmented reality media, and scientific literacy assessment instruments. The developed materials were then evaluated through expert validation and limited classroom trials to determine their validity and practicality. This study mainly focused on examining the validity and practicality of the developed learning materials before broader implementation.

Sample / Participants / Group

The participants in this study consisted of expert validators, observers, and students. The validation process involved three experts, including two science education lecturers and one science teacher, who evaluated the developed learning materials in terms of content accuracy, instructional design, language clarity, and media integration. The practicality test was conducted with eighth-grade students at SMPN 21 Surabaya during the 2024/2025 academic year. A limited trial was implemented in one class to examine the usability and practicality of the developed learning materials during the learning process.

In addition, three observers participated in monitoring the implementation of the learning activities and students' participation during the classroom trial.

Instrument and Procedures

Several research instruments were used to collect data related to the validity and practicality of the developed learning materials. The validation sheet was used to assess the validity of the developed learning materials. The instrument evaluated several aspects, including the relevance of learning objectives, content accuracy, alignment with the PBL model, integration of FAZAR ALIRA media, clarity of language, and suitability of assessment instruments. The validation process was conducted by three experts using a four-point Likert scale ranging from very invalid to very valid. This instrument was used to measure the practicality of the learning materials by observing the implementation of learning activities in the classroom. Three observers assessed the extent to which each stage of the PBL learning process was carried out according to the designed learning scenario (Hiver et al., 2024).

Data Analysis

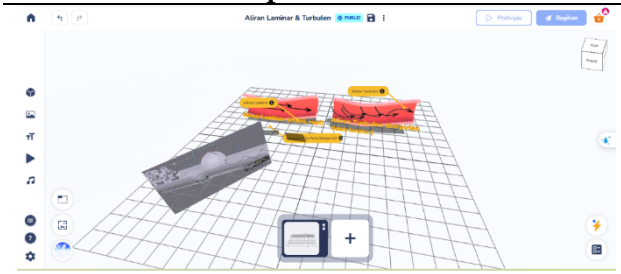
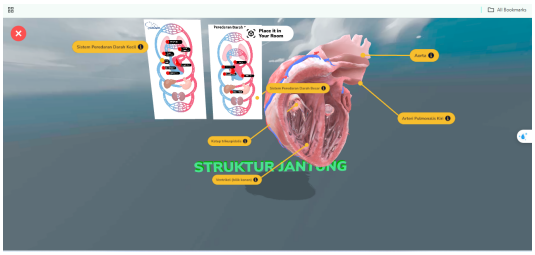
The collected data were analyzed using descriptive quantitative analysis. The validity of the learning materials was determined based on the scores provided by the expert validators. Each indicator was assessed using a four-point Likert scale. The mode score from the validators was used to determine the level of validity for each component of the learning materials. The learning materials were categorized as very valid, valid, fairly valid, or invalid based on the obtained scores. To ensure consistency among validators, inter-rater agreement was calculated using the Percentage of Agreement (PoA). The instrument was considered reliable if the agreement level exceeded 75%, indicating strong consistency among the validators. he practicality of the developed learning materials was evaluated based on the results of classroom observations and student activities. The percentage of implementation and student participation was calculated using descriptive statistics. The results were then categorized into levels such as very practical, practical, fairly practical, or less practical based on the obtained percentage values. Through these analyses, the study aimed to ensure that the developed FAZAR ALIRA-assisted PBL materials met the criteria of validity and practicality, making them suitable for supporting meaningful science learning on the topic of the human circulatory system (Privitera, 2024).

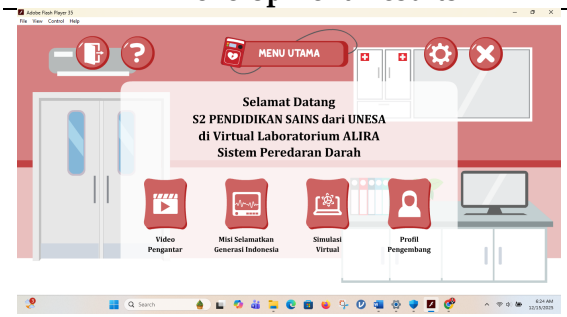
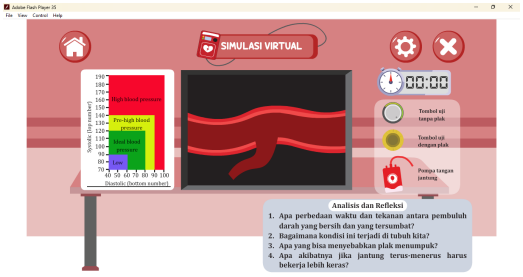
RESULTS AND DISCUSSION

Results

The results of the development stage produced several key features of the FAZAR ALIRA learning media, including augmented reality (AR) visualizations, contextual learning materials, and interactive virtual laboratory simulations. These components were designed to support PBL and facilitate students' understanding of the human circulatory system. The detailed description of the developed features is presented in Table 1.

Table 1. Features and description of the developed FAZAR ALIRA learning media

Development Results	Description
 AR visualization of laminar and turbulent blood flow	The AR models visualize laminar flow with parallel arrows and stable colors indicating uniform velocity in normal vessels, while turbulent flow is shown through swirling arrows and darker colors representing increased resistance and pressure in narrowed vessels, and together with the interactive 3D heart structure display, these visualizations help students understand cardiovascular mechanisms and scientifically explain blood circulation phenomena in accordance with scientific literacy competencies
 AR animation of systemic and pulmonary circulation	The AR media presents two main animations systemic and pulmonary circulation showing oxygenated blood flowing from the left ventricle through the aorta to the body and returning to the right atrium via the vena cava with a color change from bright red to dark blue, while pulmonary circulation illustrates blood moving from the right ventricle to the lungs through the pulmonary artery and returning to the left atrium via the pulmonary vein with a color change from dark blue to bright red, accompanied by heartbeat effects that clarify the coordinated mechanisms of blood circulation and gas exchange.
 Interactive AR display of blood circulation	Both animations are presented simultaneously in an interactive AR display, allowing students to visually and dynamically observe the direction and sequence of blood flow, with color changes and clickable hotspots that explain each stage, making abstract concepts such as blood oxygenation, cardiac pressure, and double circulation easier to understand.
 Initial interface of ALIRA Virtual Laboratory	The initial display of the ALIRA Virtual Laboratory for the human circulatory system prompts students to enter their name and school before accessing the learning media, using a laboratory-themed interface and friendly blood character illustrations to create an engaging orientation that supports motivation and readiness for problem-based learning.

Development Results	Description
 Main menu of ALIRA Virtual Laboratory	The main menu of the ALIRA Virtual Laboratory includes key features such as an introductory video, learning missions, virtual simulations, and developer profiles, designed with a simple and intuitive interface to support easy navigation, independent exploration, and guided learning aligned with the PBL (PBL) syntax.
 Contextual learning page "Mission: Save the Indonesian Generation"	The material page titled "Mission: Save the Indonesian Generation" presents a contextual narrative about unhealthy habits such as high-fat foods, sugary drinks, and low physical activity to raise students' awareness of their impact on the circulatory system while supporting scientific literacy by linking biological concepts with real-life phenomena.
 Virtual simulation menu structure	The virtual simulation menu consists of three sections simulation objectives, tools and materials, and a virtual workbench designed to replicate real laboratory procedures in an interactive digital format that bridges theory and practice while guiding students to investigate how vascular resistance and fat accumulation affect blood flow and pressure through systematic inquiry aligned with the PBL approach
 Simulation analysis and control panel	The left side of the screen displays a blood pressure classification diagram as a reference for interpreting physiological conditions, while the right side provides simulation controls such as a digital stopwatch, plaque testing buttons, and a hand pump and the bottom section includes problem-based analysis and reflection fields to help students evaluate plaque causes and impacts while developing scientific literacy skills.

After the development stage, the validity of the FAZAR ALIRA learning media and learning materials was evaluated through expert validation involving science education experts and practitioners. The validation focused on content, construct, and language aspects to ensure the feasibility of the developed materials for classroom implementation. The validation results are presented in the following section.

Table 2. Tables and figures should be valuable, relevant, and visually attractive.

Aspects Assessed	Media Validity			Mode	Category	PoA (%)
	V1	V2	V3			
FAZAR ALIRA Media is in line with learning objectives and learning outcomes	3	4	4	4	Very Valid	85.71
FAZAR ALIRA visualization is relevant to the problem-oriented PBL syntax	3	4	4	4	Very Valid	85.71
FAZAR ALIRA supports a deep learning approach (concept understanding, analysis, real application)	3	3	4	3	Valid	85.71
The relationship between FAZAR ALIRA (anatomy of the heart, blood flow) and circulatory system material is clear	3	3	4	3	Valid	85.71
Visually appealing, proportional, and contextual in junior high school	4	4	3	4	Very Valid	85.71
Color, shape, and anatomical/fluid details are easily recognizable	4	4	4	4	Very Valid	100.00
The FAZAR ALIRA object can be rotated, zoomed in, and viewed from various angles clearly	4	4	4	4	Very Valid	100.00
FAZAR ALIRA design motivates students to learn actively and explorate	4	3	3	3	Valid	85.71
FAZAR ALIRA is easily accessible with the available markers/QR codes	4	3	4	4	Very Valid	85.71
Media can be run on standard devices (school Android/iOS phones) without major problems	4	4	4	4	Very Valid	100.00
Media runs stable, no frequent errors/lags	4	4	4	4	Very Valid	100.00
FAZAR ALIRA objects (anatomy of the heart, laminar-turbulent flow) according to scientific concepts	3	3	4	3	Valid	85.71
FAZAR ALIRA media does not cause misconceptions (e.g.: blood flow direction, heart valve function, pressure)	3	4	4	4	Very Valid	85.71
FAZAR ALIRA complements, not replaces, teachers' explanations or LKPD	3	4	4	4	Very Valid	85.71
The narration/text in FAZAR ALIRA is PUEBI and easy to understand	4	4	3	4	Very Valid	85.71
The language of instruction is unambiguous and appropriate to the junior high school	4	4	4	4	Very Valid	100.00
Reliabilitas				90.18		
Percentage of Agreement				90,18%		
Category				Very High		

Based on Table 2, the FAZAR ALIRA media developed has very good validity with modes 3-4 and an average Percentage of Agreement (PoA) of 90.18%, including a very high category, so it is reliable with strong agreement between validators. This AR media is feasible in terms of construction, content, and language, supporting conceptual understanding, learning engagement, and improving students' science literacy, in line with the findings of previous research (Wang et al., 2024). The suggestions and improvements provided by the three validators on the developed teaching materials are presented in Table 3.

Table 3. FAZAR ALIRA suggestions and improvements

Validator	Suggestions	Repairs Made
Validator 1	AR media is already very good and interactive. It is recommended to add a brief technical instruction at the beginning of the display so that users (teachers and students) understand the steps to use AR without direct assistance, including camera settings and the position of 3D objects.	An "FAZAR ALIRA User Guide" opening page has been added at the beginning of the device that contains activation steps, how to point the camera, and tips for 3D objects to perform optimally on the device screen. The guide is equipped with visual icons and simple language to make it easier for junior high school students to understand.
Validator 2	Visualization of the heart and blood flow in AR is already interesting, but it is recommended that it be equipped with a brief scientific narrative or labels of important concepts (e.g. pressure, speed, cross-section) so that students not only focus on the visuals but also understand the science concepts being displayed.	It has been revised by adding scientific labels and contextual narratives in each AR scene (e.g.: "Blood pressure increases as cross-section area shrinks"). This narrative helps students connect visual experiences with fluid physics concepts relevant to the human circulatory system.
Validator 3	The AR display is attractive and responsive, but it is recommended to add interactive instructions to make it easier for new users to understand how to scan QR codes and move between scenes.	On the initial view of AR, a help icon is added as well as step-by-step visual instructions ("Scan the code in the LKPD," "Swipe to see the 3D heart," "Press to rotate the blood flow"). This addition improves user experience and learning engagement

A limited trial of AR-assisted problem-based learning tools was conducted in 8G classrooms (28 students) with implementation observations by three observers using sheets representing the suitability between the implementation and design of the devices during the two meetings. The results of the observation of the implementation of learning in the limited trial for both meetings are shown in full in the following Table 4.

Table 4. Results of limited trial class learning implementation

Learning Stage	P1 Percentage	PoA P1 (%)	P2 Percentage	PoA P2 (%)
Early Activities	81.48	90.48	85.19	92.06
Student Orientation on Problems	81.67	91.43	88.33	88.57

Learning Stage	P1 Percentage	PoA P1 (%)	P2 Percentage	PoA P2 (%)
Organizing Students to Learn	83.33	90.48	86.11	95.24
Guiding Research/Group Work	86.11	85.71	88.33	85.71
Developing & Presenting Works	86.67	88.57	87.50	85.71
Analyzing & Evaluating Problem Solving	83.33	85.71	87.50	85.71
Closing Activities	89.58	89.29	91.67	89.29
Average of All Implementations	85.10	89.50	88.23	90.59

Description: P1 = Meeting 1, P2 = Meeting 2

The results of the analysis showed that the implementation of PBL assisted by FAZAR ALIRA was in the very high category, increasing from 85.10% (PoA 89.50%) to 88.23% (PoA 90.59%). The largest increase occurred in the problem orientation (6.66%) and analysis and evaluation (4.17%) stages, which reflected the development of students' high-level thinking skills and cognitive engagement. The integration of FAZAR ALIRA in PBL encourages students to be more active, collaborative, and analytical, so that it can effectively increase science literacy and scientific thinking skills on circulatory system materials (Auralia & Juliani, 2024; Zhang et al., 2022).

Table 5. Cronbach alpha test results of learning implementation

Reliability Statistics	
Cronbach's Alpha	N of Items
.888	2

Cronbach's Alpha value of 0.888 shows that the observation instrument for learning implementation is very reliable (Table 5), so that the assessment items are consistent and able to measure the PBL syntax assisted by FAZAR ALIRA. These observational data are valid for assessing the feasibility and effectiveness of the device, while the constraints and efforts to address them are listed in Table 6.

Table 6. Obstacles, solutions, and evidence of the success of FAZAR ALIRA assisted PBL learning

No	Obstacles That Arise in the Trial Class	Impact	Solutions	Proof of Success
1	Some students still have difficulty understanding the steps to use AR and V-Lab media at the beginning of learning.	The onboarding time is a little longer, some groups are slow to start the activity.	The teacher gave a brief re-demonstration, showed examples of use through the projector, and accompanied the group with technical difficulties.	After the re-explanation, the entire group was able to run the AR/V-Lab correctly and the core activities ran more smoothly.
2	Discussions in several groups are	There is an inequality of	The teacher reminded the division of roles	The discussion becomes more

No	Obstacles That Arise in the Trial Class	Impact	Solutions	Proof of Success
	less effective because the division of roles is not optimal.	contribution; Some students are more dominant than others.	according to the rubric (chairman, recorder, analyst, presenter), and reinforced the importance of collaboration.	balanced, and each member is involved in data collection and report preparation.
3	Students are still not thorough in reading the graph of the simulation results so that the initial interpretation of some groups is not accurate.	The initial data analysis was not accurate; the provisional conclusions were not in accordance with the science literacy indicators.	The teacher provides limited guidance (scaffolding) in the form of examples of how to read graphs, as well as guiding students to compare data patterns with real phenomena.	Students were able to improve the interpretation of the data, and the final report showed an increase in the accuracy of the analysis.

Discussion

The findings of this study indicate that the FAZAR ALIRA learning media, which integrates augmented reality (AR) and virtual laboratory simulations within a PBL framework, demonstrates strong validity and practicality for use in junior high school science learning. The high validity scores obtained from expert evaluations suggest that the developed media meet the criteria of content accuracy, construct appropriateness, and language clarity. From a content perspective, the concepts embedded in the media particularly those related to blood circulation mechanisms, blood flow resistance, and cardiovascular health are scientifically consistent and aligned with the junior high school science curriculum (Uriarte-Portillo et al., 2023). This alignment ensures that the learning media can support students in constructing scientifically accurate explanations of biological phenomena (Faria, 2024).

The construct validity results further indicate that the integration of AR visualization, contextual learning narratives, and virtual simulations forms a coherent instructional design. The AR visualization of laminar and turbulent blood flow enables students to observe how changes in vessel diameter influence blood flow patterns and pressure. Such visualization transforms abstract physiological processes into concrete representations that are easier for students to understand. Additionally, the contextual narrative used in the learning materials particularly the theme "Mission: Save the Indonesian Generation" connects biological concepts with students' daily experiences, such as unhealthy dietary habits and lack of physical activity. This contextualization supports the development of scientific literacy by encouraging students to interpret real-world phenomena through scientific reasoning (McBain et al., 2022; Putra et al., 2025).

The practicality results also indicate that the FAZAR ALIRA media is feasible and easy to implement in classroom settings. Teachers reported that the interface design and menu structure are intuitive and user-friendly, allowing students to navigate the learning environment independently. The organization of learning features including introductory videos, learning missions, AR visualization, and virtual simulations follows a clear learning flow that corresponds with the stages of the PBL model. As a result, the media not only facilitates concept visualization but also supports inquiry-based learning

activities that encourage students to analyze problems, interpret data, and construct explanations (Gasmi & Benlamri, 2022; Jadhav, n.d.; Taghian et al., 2023).

These findings are consistent with previous research highlighting the effectiveness of augmented reality in science education. Studies have shown that AR-based learning environments can enhance students' conceptual understanding by providing immersive visual representations of complex scientific processes. In biology learning, AR technology has been found to improve students' comprehension of anatomical structures and physiological mechanisms that are difficult to observe directly. Similarly, research on virtual laboratories suggests that interactive simulations can provide meaningful experimental experiences when access to physical laboratory facilities is limited. The combination of AR visualization and virtual experimentation in the FAZAR ALIRA media therefore represents a promising approach to bridging theoretical knowledge and scientific inquiry in science classrooms (Fajrianti et al., 2022; Praja & Andriani, 2025; Şimşek & Koparan, 2025).

From a theoretical perspective, this study contributes to the growing body of research on technology-enhanced learning in science education, particularly in the context of scientific literacy development. The integration of AR visualization with a PBLframework reflects constructivist learning principles, in which students actively construct knowledge through interaction with learning environments and contextual problems (Amanda et al., 2022). The use of contextual narratives further aligns with the scientific literacy framework emphasized in international assessments such as PISA, which highlights the importance of connecting scientific knowledge with real-life issues. By enabling students to observe, analyze, and interpret circulatory system phenomena through interactive simulations, the FAZAR ALIRA media supports the development of core scientific literacy competencies. (Stanič & Špernjak, 2025)

In terms of educational implications, the results of this study suggest that AR-based virtual laboratories can serve as an effective alternative or complement to conventional laboratory activities in science learning. In many schools, limited laboratory equipment and time constraints often restrict opportunities for students to conduct experiments related to physiological processes (Ali et al., 2022; Anudu et al., 2025; Thangavel, 2025; Veza et al., 2022). The FAZAR ALIRA media addresses this limitation by providing a digital environment where students can explore cause effect relationships between blood vessel resistance, blood pressure, and heart workload through simulation-based inquiry. Furthermore, the integration of contextual health issues in the learning materials can help students develop awareness of the relationship between lifestyle and cardiovascular health, thereby promoting meaningful and socially relevant science learning (Muspiroh et al., 2025; Rahmat et al., 2023).

Despite these promising results, several limitations should be acknowledged. First, this study primarily focused on evaluating the validity and practicality of the developed learning media and therefore did not yet measure its effectiveness in improving students' learning outcomes or scientific literacy levels. Second, the implementation of augmented reality technology requires compatible devices and sufficient technological infrastructure, which may not be equally available across schools. These factors may influence the scalability and accessibility of the learning media in different educational contexts (Rosyid & Setyasto, 2024; Sahria & Utami, 2026).

Future research should therefore investigate the effectiveness of the FAZAR ALIRA media through experimental or quasi-experimental studies involving larger and more diverse student populations. Such studies could examine the impact of AR-based virtual

laboratories on students' conceptual understanding, scientific literacy, and critical thinking skills. In addition, future development could incorporate more advanced interactive features, such as adaptive feedback systems, gamification elements, or data analytics tools that allow students to visualize simulation results more comprehensively. Longitudinal research may also be conducted to explore whether sustained use of AR-supported learning environments contributes to long-term improvements in students' scientific reasoning and health-related decision-making (Luck, 2024; Ullah et al., 2022).

Overall, the results of this study suggest that the FAZAR ALIRA learning media provides a valid and practical digital learning environment that integrates augmented reality visualization, contextual learning, and virtual laboratory simulations. This combination offers significant potential to support innovative science learning practices and foster students' scientific literacy in understanding the human circulatory system.

CONCLUSION

Fundamental finding: This study developed the FAZAR ALIRA learning media that integrates augmented reality (AR) visualization and virtual laboratory simulations within a PBL framework to support learning on the human circulatory system. The results indicate that the developed media achieved high levels of validity and practicality, demonstrating that the integration of AR visualization, contextual learning narratives, and interactive simulations can effectively transform abstract physiological processes into observable and meaningful learning experiences. Through these features, students are supported in interpreting scientific phenomena, analyzing cause–effect relationships, and connecting biological concepts with real-life health issues, thereby strengthening the development of scientific literacy. **Implication:** The findings imply that AR-based virtual laboratories have strong potential to serve as innovative learning resources that bridge theoretical understanding and inquiry-based exploration in science education. **Limitation:** This study is limited to evaluating the validity and practicality of the developed media, and therefore further research is needed to examine its effectiveness in improving students' learning outcomes and scientific literacy through experimental studies involving larger and more diverse samples. **Future research:** are also recommended to explore the integration of more advanced interactive features and to investigate the long-term impact of AR-supported learning environments on students' scientific reasoning and health-related decision-making.

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