

Augmented Reality-Based Interactive Science Module for Teaching the Circulatory System in Elementary Schools

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Article Info	Abstract
Article history: Received: June 15, 2025 Accepted: August 22, 2025 Published: August 29, 2025 Keywords: Augmented reality Elementary school students Interactive module Science learning This article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. © 2025 Journal of Mathematics, Science, and Computer Education	The rapid development of science and technology today has significantly influenced various aspects of life, including the world of education. This research aims to develop an interactive module based on Augmented Reality (AR) for elementary school students, focusing on the circulatory system, and to evaluate the module's feasibility in terms of validity, practicality, and effectiveness. The method used in this research is Research and Development (R&D) employing the ASSURE development model. Data collection techniques include observation, interviews, and questionnaires. The data analysis used consists of two types, namely quantitative and qualitative data analysis. This research was conducted at SDN Cilenggang and SDN Warnasari, West Java, Indonesia. The subjects of this research are fifth-grade students from SDN Cilenggang and SDN Warnasari, with 30 students and two teachers. The research results indicate that the Augmented Reality-based Interactive module on circulatory system material for elementary school students, which has been developed, is very feasible and effective. The material validation and module validation achieved scores of 100% and 87%, respectively. Meanwhile, the teachers' response to the practicality of the printed AR module yielded an average score of 98%. Students' responses to the practicality of the printed AR module scored 93% in the small-group trial, while the large-group trial received a score of 94%. In the effectiveness test, the module scored 93. Based on the scores obtained, the Augmented Reality-based interactive module on the circulatory system material for elementary school students is highly feasible in terms of validity, practicality, and effectiveness for use by fifth-grade students of SDN Cilenggang and SDN Warnasari.
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INTRODUCTION

The rapid development of science and technology today has significantly influenced various aspects of life, including the education sector. The education sector has undergone significant changes that require adaptation to keep up with existing dynamics (Wang et al., 2024). Such adaptation is very important so that the outcomes of education can be globally

competitive. Technological advancements have led to changes in qualifications and adjustments in the education system to prepare students for the 21st century. They need to have technological skills and understand global economic developments. The advancement of educational technology has a significant impact on the quality of a nation's education (Machmud et al., 2021). The progress of educational technology facilities, including the use of smartphones, can shape human resources that evolve in line with the demands of the modern era (Ibda, 2022). These developments contribute to improving the quality of education that can compete effectively.

Smartphones and the internet are two interconnected technologies that play a crucial role in technological advancements in various fields, including education, social issues, and the economy (Haleem et al., 2022). The integration of internet technology and smartphones is particularly significant in the context of education. This integration can lead to advancements in the understanding of science, including the concepts of science subjects in schools. This development encourages educators to continue innovating and to strive to utilize engaging learning media that are in line with technological advancements and scientific knowledge.

Natural science is one of the main subjects in the elementary education curriculum. IPA is a knowledge that focuses on the analysis of data from natural phenomena, produced through observation, experimentation, drawing conclusions, and systematically organizing theories. Learning IPA involves events that commonly occur in the surrounding nature. During the learning process, students are given direct insights to develop their ability to think, work, and act scientifically (Andriani, 2025).

Based on interviews with fifth-grade teachers and students at SDN Cilenggang and SDN Warnasari, the material on the circulatory system is one of the more complex topics in science. This is because the material requires a profound understanding of abstract concepts such as blood flow, circulation, and the functions of body organs. This difficulty is also influenced by the fact that the circulatory system material explains various processes that occur in the human body, involving various organs that are hard to explain without adequate tools or technology. Therefore, the integration of internet technology and smartphones in learning could be a solution to present this material more interactively and support students' understanding (Agustina et al., 2023).

Teaching materials for teachers and students are a fundamental necessity that greatly assists in the teaching and learning process. One of the learning resources that teachers often use is the module (Sundari et al., 2024). With the advancement of technology today, modules are not only presented in print, but there are also non-print versions, or electronic modules, that can be integrated with various graphic application technologies, making the images in the module appear more attractive and easier to understand. Electronic modules enable students to study independently at any time and from anywhere, as they can access learning materials without needing to carry books, and these materials can be accessed from any location (Cynthia et al., 2023).

Moreover, the results of interviews with 50% of the fifth-grade students from SDN Cilenggang and SDN Warnasari, totaling 30 students, revealed that the learners hope for learning to be presented in the best and most engaging way possible, with the addition of elements such as 3D images and videos to make learning more interesting. In this context, the interview results indicated that 68% of the students have a visual learning style, which means they tend to learn through visual observation. Learning styles, as a means of absorbing and processing information, can be divided into three types based on learning modalities: visual, auditory, and kinesthetic. Students with a visual learning style are more effective in retaining information when they can directly observe the sources of that information.

Based on the results of the needs analysis conducted with 30 fifth-grade students from SDN Cilenggang and SDN Warnasari, it was found that 90% of the students need supplementary learning materials, and 87% are interested in learning materials such as modules equipped with 3D or Augmented Reality content. Therefore, there is a need for engaging learning media or materials that help students remember the material, especially on the topic of the circulatory system.

Students have varying speeds and abilities in understanding learning material. Not only that, but the limited time in class can also hinder students from achieving learning goals optimally. Therefore, a learning aid is needed that enables students to learn independently. One solution is to use modules.

The module is a learning device in written or printed form with a systematic arrangement, containing learning objectives based on basic competencies or indicators of competency achievement, methods, learning materials, and guidelines for independent learning practice. Thus, this module can provide students with opportunities to test their abilities independently through the training available within it. Augmented Reality-based interactive modules refer to modules that are developed and enriched with the results of computer software programs. There are several advantages to using Augmented Reality in education. For example, Augmented Reality can help minimize students' misconceptions caused by their inability to visualize concepts such as the circulatory system. Augmented Reality has been proven relevant in many educational learning processes ([Andrian et al., 2023](#)).

Augmented Reality-based learning modules are expected to provide an innovative learning experience. Their ability to offer visualization similar to the experience of viewing objects directly allows learners to see objects from different perspectives, even from all directions. Unlike conventional modules, which are generally in the form of two-dimensional images, Augmented Reality modules provide an additional dimension, enabling learners to see the entire object more comprehensively ([Karuni, 2021](#)).

The research results of [Liang et al. \(2023\)](#) in their journal explain the user experience and access using augmented reality and multimedia technology, specifically the advancements in technology related to the multimedia framework that have transformed the way users interact with and access various types of content. Due to the popularity of Augmented Reality and its proven ability to provide positive effects and save costs by not having to be physically present to see objects directly in the field, AR has significantly developed in our society. AR-based media is also seen as easier, more efficient, and gives students more freedom to design. With this media, students also learn more about teamwork with their classmates ([Cheng et al., 2024](#)).

These results are also in line with the research by [Avila-Garzon et al. \(2021\)](#), which, in the journal *Augmented Reality Trends in Education*, explains that AR makes explanations more effective when applied in laboratory demonstrations. The research results, according to [Pierdicca et al. \(2024\)](#) from the Università Politecnica Delle Marche, Italy, reveal that there are many advantages of using Augmented Reality for visitors and scientists, including providing additional information during tours, attracting visitor interest, supporting user interaction, enhancing the learning process, and providing enjoyable entertainment for children.

Research conducted by [Wijayanti et al. \(2024\)](#) demonstrates that the use of Augmented Reality (AR)-based learning media has consistently been proven to improve conceptual understanding and motivate students' interest in learning, particularly for materials that are difficult to visualize. This study concludes that AR technology has enormous potential in supporting the learning process in the modern era. However, its implementation still requires the availability of adequate infrastructure. These findings will likely encourage the

wider and more optimal use of AR in the educational world. Additionally, other studies indicate that the use of Augmented Reality technology as an interactive learning medium has a significant positive impact on the learning motivation of students in Software Engineering Technology at the IPB Vocational School. This can be seen from the T-count value, which is greater than the T-table value, which is $-3.9783 > 2.036933$, and the significance value is $0.0003722 < 0.05$. Additionally, the average pretest and post-test values increased from 9.48 to 11.36. Thus, the average pretest and post-test values increased by 19% (Putra et al., 2023). Based on several previous studies related to the trial of AR in learning, the innovation in this research is the development of an augmented reality-based module, aiming to enhance the effectiveness of the learning process.

Additionally, based on the explanations above, there is a need to provide teaching materials or interactive modules utilizing Augmented Reality technology in science education, particularly on the topic of the circulatory system. Accordingly, this study aims to develop and evaluate the feasibility of an augmented reality-based interactive module on the circulatory system for elementary school students.

METHODS

The research conducted uses research and development or Research and Development (R&D) methods. The subjects of the trials in this study are fifth-grade students from SDN Cilenggang and SDN Warnasari, with a breakdown of 6 students in the small-scale trial and 60 students in the large-scale trial.

The data collection techniques employed by the researchers include observation, interviews, questionnaires, and document analysis from fifth-grade teachers and students at SDN Cilenggang and SDN Warnasari, using instruments developed by the researchers. The instruments include media and material validation, as well as validation questionnaires from teachers and experts. The data analysis techniques used are qualitative and quantitative. The focus of this development research is not to formulate or test a hypothesis, but to obtain new products or innovative processes.

The model used in this research, developed by Heinich et al. (2002), illustrates that the ASSURE model comprises six stages. The steps of the ASSURE development model can be seen in Figure 1.

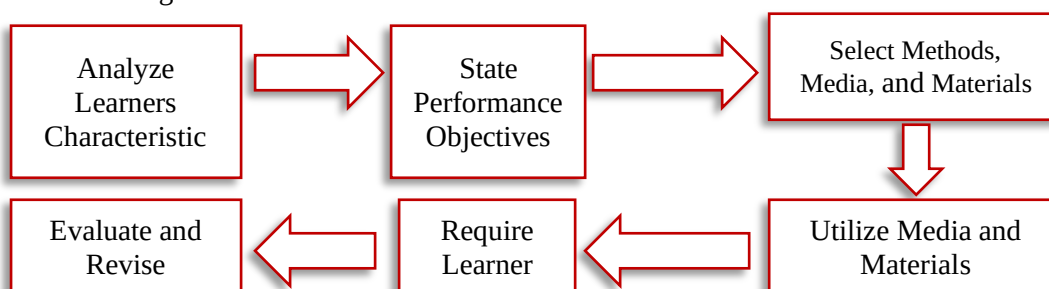


Figure 1 Flowchart of the ASSURE model

Based on Figure 1, the ASSURE development model is a systematic approach to designing technology and media-based learning that is more effective and learner-centered. The first step is to analyze learners by considering their characteristics, backgrounds, learning styles, and initial abilities so that learning strategies can be tailored accordingly. Next, teachers formulate clear, measurable, and specific learning objectives using the ABCD format (Audience, Behavior, Condition, Degree). Once the objectives have been set, teachers must select the most appropriate methods, media, and teaching materials to

support the achievement of these objectives. In the next stage, which involves using media and teaching materials, teachers prepare, test, and implement the media in the learning process to ensure optimal operation. Then, teachers must engage students in active participation through discussions, practices, simulations, or other interactive activities, so that they are genuinely involved in the learning process. The final stage is evaluation and revision, which involves assessing the success of learning in terms of goal achievement, evaluating the effectiveness of methods and media, and improving future learning quality.

RESULTS AND DISCUSSION

Through analyzing learners' characteristics, the first thing to be done is to observe the characteristics of the students who are the subjects of the research. At the state performance objectives, an objective assessment of the students' needs in the field is conducted. Selecting methods, media, and materials involves choosing methods and approaches in the research process, as well as determining the materials that were selected during the research process. Utilize media and materials; the use of media and materials in this research aims to integrate existing materials and media, specifically augmented reality. It requires the participation of students; the next step taken is to determine the subject of the research, in this case, a total of 30 students. Evaluate and Revise: The final stage of research involves evaluating and revising the produced module.

The participants in this study are fifth-grade students from SDN Cilenggang and SDN Warnasari. The students, aged 10-11 years, are at the concrete operational stage of cognitive development according to Jean Piaget. Based on the interview results regarding the students' initial abilities concerning science material, they are already familiar with the topic of the circulatory system. Before studying this material, the students had learned about the organs of the circulatory system. However, students struggle to understand the concept of the circulatory system, solve problems related to it due to its abstract nature, and utilize contextually inadequate teaching materials, with insufficient in-depth discussion, as well as illustrations that lack color and variation.

The formulation of learning objectives from established basic competencies, which are then developed into indicators. The process of formulating learning objectives involves developing basic competencies into specific, measurable, and evaluable indicators to achieve the desired learning outcomes. These indicators serve as benchmarks for achieving basic competencies in learning. The developed module focuses on explaining the circulatory organs and their functions in animals and humans, as well as how to maintain the health of human circulatory organs.

The review conducted by the teacher obtained an average percentage of 98%. Limited user reviews by six students from grade V of SDN Cilenggang and SDN Warnasari achieved a percentage of 93%. After the developed module was reviewed and revised according to the suggestions, the module could be tested on a larger group of students. The stage involves preparing students mentally before the learning process by communicating the learning objectives and competencies to be achieved, then presenting the knowledge and skills developed systematically (Idris et al., 2022).

The evaluation stage involves examining the feasibility of the module in terms of validity, practicality, and effectiveness. The evaluation of the learning product includes validity (consistency and relevance to theory and practice), practicality (ease of use and application in the field), and effectiveness (positive impact on student learning outcomes). The feasibility of the module in terms of validity can be seen from the results of validation by media and material experts, while the feasibility of the module in terms of practicality can be observed from the feedback from teachers and students regarding the module. The percentage of module feasibility, as assessed by material and media experts, is 100% and

87%, respectively, and is categorized as very feasible based on the scoring criteria according to Khoirot (2015). The percentage of module feasibility in terms of practicality obtained from responses from teachers and students is 98% and 93%, categorized as very feasible based on suggestions during the validation stage, and user reviews by teachers and students. The presentation of the module's effectiveness, based on formative tests and final module tests, is 83%, categorized as 'Very Effective'.

Product revisions are made based on suggestions from material experts, media experts, and user experts, as well as during small-scale trials. Several parts need to be revised, including the structure of writing and numbering which needs to be corrected, the bibliography should be revised to conform to APA Style, the module size should be changed to B5 size, the font should be replaced with a better one, do not print double-sided, all learning activities must include Augmented Reality content, the module should have a minimum of 60 pages, and the QR Code should be made relatively large to facilitate scanning. The results of the revision to the interactive science module product are shown in Figure 2.



Figure 2 The display of the developed interactive science module

Figure 2 shows an interactive science module on the Circulatory System for fifth-grade elementary school students, designed with an attractive, communicative appearance tailored to the students' needs. This module contains learning objectives, material descriptions, illustrations of body organs, and learning activities, ensuring the material's presentation is informative and motivates students to be actively engaged. The illustrations displayed, such as pictures of the anatomy of the heart, brain, and blood circulation, clarify abstract concepts, making them easier to understand. Additionally, a "Let's Observe" section invites students to observe the images directly, encouraging critical and analytical thinking skills. The main advantage of this module is the inclusion of a QR code that can be scanned using a smartphone.

Through the QR Code, students can be directed to learning videos, interactive animations, or more detailed explanations, reinforcing their understanding of the circulatory system. The integration of print media with digital technology makes the module more interactive, modern, and in line with the characteristics of the digital generation, so that students not only read and observe images, but can also see real simulations of how blood flows, how organs work, and the circulatory process in the body. Thus, this module can be an effective learning tool because it combines written explanations, visuals, observation activities, and digital access via QR codes to deepen students' understanding of the circulatory system.

Feasibility Test of AR-Based Interactive Science Module

Subject matter experts and media experts review the developed module to assess its feasibility. The module is reviewed by two individuals: a subject expert lecturer and an elementary school teacher with a master's degree, as well as six fifth-grade students from SDN Cilenggang and SDN Warnasari, to assess its practical feasibility.

To conclude, the results from the validation conducted by the experts, the criteria for validation, or the level of achievement in the media development in this research were used. These criteria are based on references by [Pugu et al. \(2024\)](#), and their interpretation is provided in Table 1.

Table 1 Criteria for validity of percentage analysis

No	Criteria (%)	Validation Level
1	$75 \leq P \leq 100$	Very valid (can be used without revision)
2	$50 \leq P \leq 75$	Quite valid (can be used with minor revision)
3	$25 \leq P \leq 50$	Not valid (cannot be used)
4	$P \leq 25$	Very invalid (prohibited to used)

([Pugu et al., 2024](#))

The module review uses a Likert scale questionnaire instrument. Assessment for the validation sheet using the Likert scale as provided in Table 2.

Table 2 Likert scale criteria

No	Alternative Answers	Score
1	Very worthy (excellent)	5
2	Very good	4
3	Good	3
4	Fair	2
5	Poor	1

([Fikriyah & Sukmawati, 2022](#))

The assessment of the interactive module based on Augmented Reality for material experts aims to determine the validity of the material in terms of content feasibility, presentation feasibility, and language aspects. The teacher conducted the assessment with the guidance of the material expert. The results of the material expert assessment are detailed in Table 3.

Table 3 Expert material validation

Aspects	Scores	Maximum Score	Percentages	Criteria
Material feasibility	55	55	100%	Very Valid
Presentation feasibility	90	90	100%	Very Valid
Linguistic feasibility	55	55	100%	Very Valid
Score Total	200	200	100%	Very Valid

Based on Table 3, it is known that the feasibility level of the module material is 100%, indicating that the material falls into the very feasible category. Therefore, the Augmented Reality-based interactive module that has been developed can be used without any revisions.

The assessment of an interactive module based on Augmented Reality for media experts aims to determine the feasibility of performance, graphic feasibility, and language

feasibility. The media expert assessment was conducted by a lecturer on May 21, 2025. The results of the material expert assessment are described in Table 4.

Table 4 Media expert validation

Aspects	Scores	Maximum Score	Percentages	Criteria
Performance feasibility	112	130	86%	Very worthy
Graphic feasibility	88	90	98%	Very worthy
Linguistic feasibility	45	55	82%	Very worthy
Score Total	240	275	87%	Very worthy

Based on Table 4, it is evident that the feasibility level of the media in the module is 87%, indicating that the media falls into the category of being very feasible to use. Therefore, the Augmented Reality-based interactive module that has been developed can be used without any revisions.

User validation by fifth-grade teachers from SDN Cilenggang and SDN Warnasari aims to assess the feasibility of the module from a practical standpoint. The teachers filled out a Likert scale questionnaire. The number of teacher respondents is 2. The user validation instruments encompass aspects of content feasibility, presentation feasibility, language, and graphic aspects. The results of the user validation are explained in Table 5.

Table 5 Validation of teacher response

Aspects	Scores		Percentages		Maximum Score	Criteria
	I	II	I	II		
Content feasibility	34	35	97%	100%	175	Very worthy
Feasibility of presentation	15	14	100%	93%	75	Very worthy
Linguistic feasibility	15	15	100%	100%	75	Very worthy
Graphic feasibility	15	14	100%	93%	75	Very worthy
Score Total	79	78	99%	97%	80	Very worthy

Based on Table 5, it is known that the feasibility level of the module is 99%, indicating that the media is classified as very feasible to use. Therefore, the Augmented Reality-based interactive module that has been developed can be used without any revisions.

Based on Table 5, it is known that the feasibility level of the module is 97%, indicating that the media falls into the very feasible category for use. Therefore, the Augmented Reality-based interactive module that has been developed can be used without any revisions. The product validation graph, as provided by the expert, is shown in Figure 3.

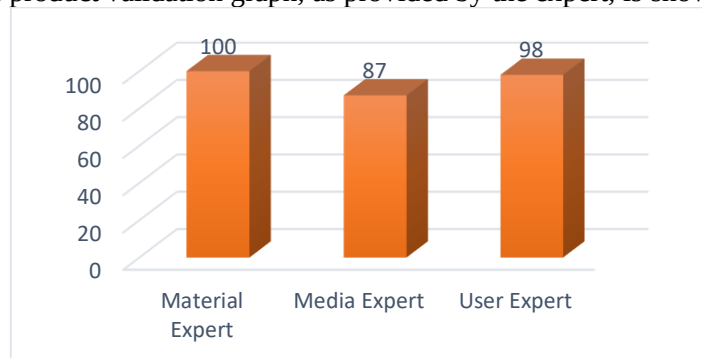


Figure 3 Expert validation results graph

Learning in the current digital era requires innovation and the effective use of technology to enhance students' engagement and interest in the learning process. This is in line with [Lee et al.'s \(2024\)](#) view that today's youth are 'digital natives' who are accustomed to technology and can easily adapt to the digital environment. One technology with potential applications in learning is augmented reality (AR). AR can visualize 3D objects interactively in the real world, thus providing a more engaging and easier-to-understand learning experience. Augmented reality (AR) has the potential to be applied in learning due to its ability to visualize 3D objects interactively within the real world, creating a more engaging and understandable learning experience ([Nistrina, 2021](#)). This is in line with the research conducted by [Mukhooyaroh et al. \(2023\)](#), which shows that the use of interactive AR modules can improve students' learning outcomes on the human digestive system material. For the circulatory system material, AR can help students visualize the organs involved, blood flow, and their functions more tangibly. This is expected to enhance students' understanding of the material and motivate them to pursue further learning.

The AR-based interactive module on the circulatory system material for elementary school students can be considered feasible based on the following aspects: The AR module can be designed to meet the learning objectives set in the basic education curriculum ([Fajriati, 2023](#)). The module content can include information about the organs of the circulatory system, their functions, and how they work together to deliver blood throughout the body. The AR module must be designed with consideration of the cognitive and visual development levels of elementary school students ([Suryana et al., 2024](#)).

The user interface should be simple and easy to understand, and the visualization should be attractive and age-appropriate. Research has shown that AR can enhance the effectiveness of learning in various subjects, including science ([Zafeiropoulou et al., 2021](#)). The AR module on the circulatory system material is expected to help students understand complex concepts more easily and improve their learning outcomes.

The Practicality of AR-Based Interactive Science Modules

At this stage, a field trial is conducted involving 60 fifth-grade students from SDN Cilenggang and SDN Warnasari. The students used an interactive module based on augmented reality for the digestive system material, designed for elementary school students. This module aimed to test the appeal of the developed interactive augmented reality module by analyzing aspects of attractiveness, content, and language, and then completing a response questionnaire on the module's use. The results of the large-scale trial are explained in Table 6.

Table 6 Large group test

Aspects	Scores	Percentages	Criteria
Attraction	376	94%	Very worthy
Material	564	94%	Very worthy
Language	285	93%	Very worthy
Score Total	1225	94%	Very worthy

([Purnasari, 2021](#))

Based on Table 6, the scores obtained from the responses of 60 students are 373 for attractiveness, 564 for content, and 285 for language. The total score from these three aspects is 1225. The percentage obtained from the 60 respondents is 94%, indicating that the augmented reality-based interactive module on the circulatory system material for elementary school students falls within the very good criteria range. Thus, the developed

augmented reality-based interactive module can be utilized in science learning for materials related to the circulatory system.

The small group test involved six students from grade V of Cilenggang Elementary School and Warnasari Elementary School. The first product trial, a small-group trial, was conducted to assess the readability of the developed teaching materials in the form of an interactive module based on Augmented Reality. This trial was assessed from three aspects: the attractiveness aspect, the material aspect, and the language aspect, involving six students from grade V of Cilenggang Elementary School and Warnasari Elementary School. The results of the small group trials are explained in the table as follows:

Table 7 Large group test

Aspects	Scores	Percentages	Criteria
Attraction	114	95%	Very worthy
Material	165	92%	Very worthy
Language	84	93%	Very worthy
Score Total	363	93%	Very worthy

(Purnasari, 2021)

Based on Table 7, the percentage obtained from 6 respondents is 93%, indicating that the printed module of the interactive augmented reality-based module on the circulatory system material for elementary school students falls within the criteria of very good. Therefore, the interactive augmented reality module that has been developed can be used in large group trials. The graph of the product test results is provided in Figure 4.

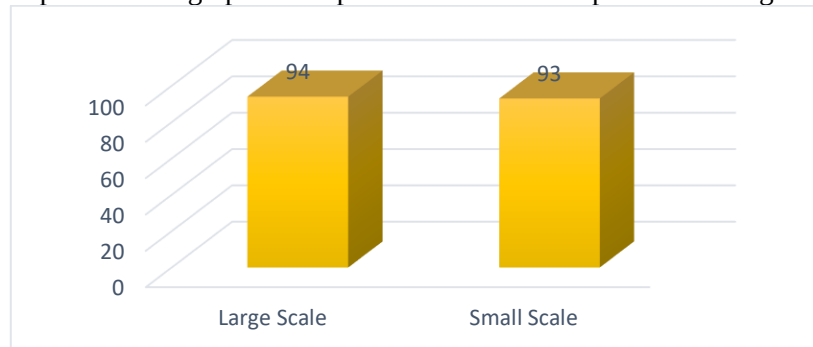


Figure 4 Product test results chart

The advancement of information and communication technology has brought significant changes in the world of education. One prominent innovation is the use of augmented reality (AR) in the learning process (Simaremare et al., 2022). AR technology can transform the way learning materials are delivered, making them more interactive and engaging (Lampropoulos et al., 2022). This research aims to test the appeal, content, and language of an interactive module based on Augmented Reality (AR) that has been developed for elementary school students' material on the circulatory system. A field trial was conducted with 60 fifth-grade students from SDN Cilenggang and SDN Warnasari. At this stage, the data collection instrument uses a questionnaire. The questionnaire is designed to measure students' responses to three main aspects of the AR module, namely attractiveness, content, and language. Evaluating the attractiveness of the interactive module is very important because visual appeal and interactivity can enhance students' motivation and engagement in learning. The use of technology such as Augmented Reality in learning can make the material more appealing and encourage active participation from students (Avila-Garzon et al., 2021). The quality and clarity of the content are critical aspects in the success of an Augmented Reality-based learning module. Augmented Reality

can help visualize complex concepts, making them easier for learners to understand. This is important to ensure that all learners can understand the material presented. The use of simple and clear language in learning modules is crucial to ensure that all learners can understand instructions and content without difficulty. The effective use of language in educational technology, such as Augmented Reality, can enhance learning effectiveness and ensure that learners can easily follow the material (Liang et al., 2023).

The scores from each aspect are collected and calculated to determine the percentage of the module's eligibility criteria. Table 5 presents the results of a large-scale trial, including scores for each aspect, total scores, and eligibility percentages. The research results indicate that the Augmented Reality-based interactive module received very positive feedback from the students. Here are the details of the trial results based on Table 5. The Augmented Reality module received a score of 376 in the aspect of attractiveness, with a percentage of 94%, classified as Very Feasible, indicating that students are very interested in the use of Augmented Reality in learning. The interactive 3D visualization and the use of animation in this module make learning more engaging and enjoyable. The material aspect scored 564 with a percentage of 94% under the Very Feasible Criteria, indicating that the content presented in the module is very clear and easy to understand. The use of Augmented Reality helps visualize abstract concepts about the circulatory system, making it easier for students to grasp the material presented. The language aspect received a score of 285 with a percentage of 93% under the Very Feasible Criteria, showing that the language used in the Augmented Reality module is very appropriate and easily understood by fifth-grade students. The use of simple and clear language facilitates students' understanding of the material more effectively. The effective use of language in educational technology, such as augmented reality, can enhance learning effectiveness and ensure that students can easily follow the material. This is very important to ensure that all students can understand instructions and content without difficulty (Liang et al., 2023).

The results show that the interactive module based on AR on the circulatory system material is very feasible to be used in science learning in elementary schools. Based on the research results, it can be concluded that the interactive module based on Augmented Reality for circulatory system material is highly suitable for use in elementary school learning. The 94% feasibility percentage indicates that this module is effective in enhancing students' understanding and interest in the learning process. The success of this module can serve as a reference for the development of similar teaching materials in the future.

Effectiveness of Interactive Science Modules Based on AR

At this stage, an effectiveness test of the module was conducted involving 60 fifth-grade students from SDN Cilenggang and SDN Warnasari. The students used an interactive module based on augmented reality on the circulatory system material for elementary school students, aimed at testing the effectiveness of the interactive augmented reality module that had been developed by reviewing the Formative Tests of Learning Activities 1, 2, and 3, and the Final Test of the Module, and then filling out the test on the interactive augmented reality module on the circulatory system material for elementary school students.

The results of the post-test are used to measure the effectiveness level of the interactive module, using the Minimum Completeness Criteria (KKM) scores in the Natural Science subject at SDN Cilenggang and SDN Warnasari for comparison. If 75% of the students' scores subjected to the trial have reached KKM, it can be concluded that the developed product is suitable and effective to be used as a module. The results of the module effectiveness test are explained in Table 8.

Table 8 Testing the effectiveness of the module

Minimum Grade	Average Student Score	Scores	Criteria
75	93	93	Very effective

Based on Table 8, the effectiveness scores were obtained from the post-test of 60 participants. The score obtained from 60 respondents is 93, indicating that the augmented reality-based interactive module on the circulatory system material for elementary school students falls within the very effective criteria range. The interactive module is stated to be effective as a learning medium based on the results of student learning that achieved an average score of 93 with a 100% graduation percentage in the field test involving fifth-grade students from SDN Cilenggang and SDN Warnasari; thus, the augmented reality-based interactive module that has been developed can be used in science learning on the topic of the circulatory system.

Effectiveness can be described as the impact or result arising from an action, in this case, the impact of the use of interactive modules on learning outcomes. The effectiveness test is conducted as a measure of the success level of a learning process. An interactive module is effective if it has a positive impact on students' learning outcomes. The effectiveness of the learning module is assessed based on the extent to which the module can improve students' understanding and skills in accordance with the previously established learning objectives (Wilson, 2016). The effectiveness test results are obtained by combining the post-test results with the formative test and final module test results. The effectiveness of the interactive module is evident from the classical completion rate, which is obtained by comparing the post-test results with the minimum completion criteria set by the school. The effectiveness of learning can be measured through classical test completion, which involves comparing the final evaluation results (post-test) with the completion standard set to determine whether the module is effective in achieving its learning objectives. If the classical completion of students has been achieved, then the learning module is categorized as effective. It can be concluded based on the minimum completeness criteria scores that the learning outcomes after using the interactive module are stated to be complete (Wulandari et al., 2019).

At this stage, it evaluates the effectiveness of an interactive module based on Augmented Reality designed for elementary school students to learn about the circulatory system. The evaluation is conducted through formative tests and a final module test to determine how well this module helps students understand the material taught. To assess the effectiveness of the module, this research uses two types of tests: formative tests conducted during the learning process to evaluate students' understanding of each stage of the material, and the final module test conducted after all the material has been completed to measure the overall understanding of students about the circulatory system. The results of the formative tests and final tests indicate that the AR-based interactive module has an effectiveness level of 93, which is categorized as "Very Effective." This percentage indicates that the majority of students effectively understood the material and demonstrated significant improvements in their learning outcomes. The evaluation results can be used to refine the module and make it more beneficial for students.

Augmented Reality-based interactive modules are highly effective in enhancing elementary school students' understanding of circulatory system material. With an effectiveness reaching 93%, this module not only helps students understand the material better but also makes the learning process more engaging and interactive. The AR module will be more effective if supported by teachers and parents (Fajriati, 2023). Teachers need to be trained to use the module well and integrate it into classroom learning (Nurhayati &

[Handayani, 2020](#)). Parents also need to be involved in their children's learning process by encouraging them to use the AR module at home ([Suryana et al., 2024](#)).

CONCLUSION

The utilization of media and learning materials is based on core competencies and basic competencies and formatted into interactive modules based on augmented reality. Evaluation involving students in small group trials shows that the module receives high scores in aspects of attractiveness, content, and language, with a total score of 93%, indicating that the module is highly suitable for use. Expert validation of the module material is stated to be very valid with a score of 100% in aspects of material feasibility, presentation, and language, indicating that the module content is very good and meets the standards. Media expert validation shows a score of 87%, with a very feasible criterion. User validation from teachers shows that the module falls into the very feasible category with a percentage between 97% and 99%. In a large-scale trial involving 60 participants, the module achieved a total score of 94%. The effectiveness of the module, measured by effectiveness tests, indicates an average student score of 93, exceeding the minimum completeness criterion of 75%. The module is very effective in enhancing students' understanding of the material on the circulatory system with a 100% passing rate on the post-test.

The limitations in the development of the module in this research are that the interactive module was developed based on the 2013 curriculum, which was revised in 2017. In addition, this interactive module is only suitable for fifth-grade elementary school students. The material developed explains the circulatory system organs and their functions in animals and humans, as well as how to maintain the health of the human circulatory system. It does not cover other scientific subjects due to time constraints during the research.

The results of this study have positive implications for the development of technology-based learning media, particularly Augmented Reality, at the elementary school level. This module can serve as an innovative alternative to enhance student engagement and understanding of complex material, such as the circulatory system. For teachers, the use of this module can enrich learning methods and encourage technology-based active learning. Institutionally, these findings highlight the need for teacher training and the provision of adequate technological infrastructure to ensure the optimal implementation of AR. This research also opens opportunities for the development of AR modules on other learning topics, as well as further studies to assess the long-term impact of this technology on student learning outcomes.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

The first, second, and third authors jointly conducted the experiments and wrote this manuscript with support from the Prima Bangsa Institute, which provided supervision for this project. All authors also jointly reviewed and revised the entire manuscript.

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