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Development of Science Learning Media Assisted by Augmented Reality Based on the Problem Based Learning (PBL) Model to Improve Critical Thinking Skills of Elementary School Students

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Abstract: This study aims to develop an Augmented Reality (AR)-assisted science learning media based on the Problem Based Learning (PBL) model to improve critical thinking skills of fourth-grade elementary school students. This study uses the Research and Development (R&D) method with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. The subjects of the study were 72 students from three elementary schools in Padang City, namely SDN 09 Korong Gadang, SDN 04 Pasar Ambacang, and MIN 3 Padang City. Data collection instruments included expert validation sheets, teacher and student practicality questionnaires, and pre-test and post-test questions. The results of the study showed: the validity of the media was assessed as very valid by language experts (92%), material experts (97%), and media experts; the practicality of the media was very practical according to teacher (96%) and student (95.64%) assessments; The effectiveness of the media is proven by the increase in student learning outcomes with an average pre-test of 59.31 increasing to 92.11 in the post-test, with an N-Gain value of 0.81 in the high category. It is concluded that PBL-based AR learning media is feasible, practical, and effective for use in improving the critical thinking skills of fourth grade elementary school students in the Science subject of the Five Senses material, in accordance with the demands of the Independent Curriculum.

Keywords: Augmented reality; Critical thinking; Independent curriculum; Problem-based learning; Science

Introduction

The Society 5.0 era has brought fundamental transformations to education, demanding the integration of advanced technology into the learning process to prepare a competent, adaptive, and critical-thinking generation. In this context, the Independent Curriculum (Currikullum Merdeka) is a response to these needs, placing students at the center of learning while emphasizing the development of 21st-century competencies, including critical, creative, collaborative, and communicative thinking skills (Herlinawati et al., 2024; Dilekçi & Karatay, 2023). Natural and Social Sciences (IPAS) is a new subject in the Independent Curriculum that integrates science and social studies. In fourth-grade elementary school (SD) science lessons, the Five Senses topic is one that demands in-depth conceptual understanding. However, various observations and interviews in the field indicate that conventional module-based learning and worksheets (LKS) tend to be monotonous, making it difficult for students to grasp abstract concepts about how the senses work (Muassomah et al., 2025). This situation is exacerbated by students' low critical thinking skills,

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characterized by a lack of analytical, evaluation, and scientific reasoning skills. Augmented Reality (AR) is a technology capable of interactively and immersively displaying three-dimensional objects over real environments, thereby bridging the gap between abstract concepts and students' concrete understanding. In line with Piaget's (1958) theory of cognitive development, elementary school students are at the concrete operational stage and therefore require media that can present concrete visualizations of scientific concepts (Agustin et al., 2025). Various studies have demonstrated that AR media can increase student motivation, engagement, and learning outcomes (Kazlaris et al., 2025).

The Problem-Based Learning (PBL) model is a relevant approach to integrate with AR media because PBL focuses on solving authentic, real-world problems that encourage students to think actively, critically, and reflectively (Wardani & Fiorintina, 2023). Integrating AR into PBL scenarios can provide learning experiences that are not only visually engaging, but also cognitively challenging. Research by Uliyanti et al. shows that the use of AR media based on PBL can improve the critical thinking skills of fifth-grade elementary school students in science lessons. However, research specifically developing and testing AR media based on PBL for the Five Senses in fourth-grade elementary school is still very limited. Therefore, this study aims to develop AR-assisted science learning media based on the PBL model that is valid, practical, and effective for improving the critical thinking skills of fourth-grade elementary school students. This study aims to develop Augmented Reality (AR) learning media as an innovation to improve students' critical thinking in science lessons, taking into account the characteristics of Gen Z, the challenges faced by teachers in the independent curriculum, and the weaknesses of evaluations that focus on more than memorization. Learning media can be one way to achieve successful learning processes by integrating technology-based learning media and computer information.

ICT-based media that can be accessed anytime, anywhere, and by any means is the basis for effective student learning (Sundari et al., 2024; Ramakrishnappa et al., 2025). Learning media can be made more engaging and concise, without compromising the essence of the material (Zou et al., 2025; Qin, 2025). An example of contemporary learning media today is Augmented Reality. With the increasingly massive development of technology, learning media in education has also evolved. According to Aidoo & Chebure (2024), the role of information technology as a learning medium, besides assisting students in learning, also has an impact on teachers, particularly in the use of facilities to enrich teaching skills. Furthermore, the learning expected in the Merdeka curriculum is student-centered. Teachers are no longer the sole source of knowledge for students but rather serve as motivators and facilitators in learning (Harjanti et al., 2026). Augmented Reality is a technology that can seemingly merge the real world with the digital world, where the real world becomes a platform where digital objects such as images, three-dimensional objects, sounds, and so on are added (Saca, 2021). During independent learning, students often feel confused, frustrated, and dissatisfied with their learning experience. However, by utilizing Augmented Reality, these issues can be minimized, allowing students to develop their learning independence, ultimately improving their academic performance (Subandiyah et al., 2025). Augmented Reality (AR) is an IT-based learning medium that provides 3D visualization of objects to make them appear more realistic. This aligns with the opinion of Ningrum et al. (2021) that Augmented Reality provides users with new freedom and experiences by allowing them to move virtual 3D images and view them from any point, just like in the real world (Rauschnabel et al., 2022; Al Qwaid et al., 2026). Therefore, it can be concluded that Augmented Reality is a technology that can integrate 3D models with the real world.

The use of Augmented Reality as a learning medium will provide a new learning environment, allowing students to directly see and interact with the objects or material being discussed. Augmented Reality has the potential to be used in learning, making learning more engaging and clearer through the use of Augmented Reality. Currently, almost all students, including teachers, have access to mobile phones, so there will be no significant obstacles if they want to use Augmented Reality for learning (Marques & Pombo, 2021). Based on the above opinions, the author can conclude that the use of Augmented Reality media will create a pleasant atmosphere for teachers and students, thereby increasing student understanding and enhancing critical thinking skills in science learning. Based on the above background, the researcher decided to conduct a study entitled, "Development of Augmented Reality-Assisted Science Learning Media Based on the Problem-Based Learning (PBL) Model to Improve Critical Thinking Skills in Elementary School Students."

Method

This research is a research and development (R&D) study using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. The ADDIE model was chosen because it is systematic, flexible, and oriented towards continuous improvement, making it suitable for

developing high-quality learning media (Nasrillah et al., 2025).

Research Subjects and Location

The research subjects were 72 fourth-grade students from three elementary schools in Padang City: SDN 09 Korong Gadang (17 students), SDN 04 Pasar Ambacang (26 students), and MIN 3 Kota Padang (29 students). These three schools were selected using purposive sampling based on the representativeness of public and private schools, as well as the availability of mobile devices for AR media trials.

Development Procedure

The Analysis stage included an analysis of student needs, an analysis of the curriculum (Science Learning Outcomes for Grade IV), an analysis of student characteristics, and an analysis of available technology. Observations and interviews were conducted with teachers and students at the three schools to identify learning challenges: The Design phase included the creation of a printed book, "Five Senses Augmented Reality," containing five sub-chapters (eyes, ears, nose, tongue, and skin), accompanied by an Android-based AR application. Each page of the book features a special "Scan here" marker that activates interactive 3D objects through the AR application. The design also included five interactive scene scenarios that visualize the physiological processes of each sense organ; The Development phase included the creation of a media prototype, the development of 3D objects using Unity 3D and the Vuforia SDK, and the development of a validation sheet. The media was validated by linguists, content experts, and media before being piloted. Product revisions were made based on validator input. The Implementation phase was conducted in three partner schools. Teachers integrated AR media into a PBL scenario with five phases: problem orientation, learning organization, independent/group investigation, development and presentation of results, and analysis and evaluation. Practicality testing was conducted through questionnaires with teachers and students after the learning process. The evaluation phase used a pre-test and post-test design to measure the effectiveness of the media in improving students' critical thinking skills. Learning outcomes were calculated N-Gain formula.

Instruments and Data Analysis

The research instruments consisted of an expert validation sheet with a Likert scale of 1–5; a practicality questionnaire for teachers and students; and pre-test and post-test questions based on critical thinking indicators (analyzing, evaluating, concluding, and reflecting). Validity and practicality data were analyzed using a percentage formula, while effectiveness was calculated using the N-Gain Score, with the following criteria: high (≥ 0.70), medium (0.30–0.69), and low (<0.30).

Result and Discussion

Developing AR Media Based on Problem-Based Learning (PBL)

The results of a field need analysis revealed that science learning in fourth-grade elementary school is still dominated by conventional methods with static modules and worksheets. Students have difficulty understanding the abstract and microscopic physiological processes of the sense organs. Curriculum analysis indicates that the Learning Outcomes (CP) for fourth-grade science require students to be able to describe the function and operation of the five senses scientifically, necessitating media that can visualize these processes concretely and interactively. The product developed is the "Five Senses Augmented Reality" book, integrated with an Android-based AR application. This book contains five sub-chapters, each equipped with AR markers to activate interactive 3D objects (Kim & Kim, 2024; Juniawan et al., 2023). Users simply download the app, scan the barcode on the book, and then point the camera at the markers to witness live 3D animations of the sensory organs in action. The PBL model is implemented in six learning syntaxes, systematically encouraging students to identify problems, conduct investigations, and present solutions based on evidence from AR explorations (Ayu et al., 2024; Roza et al., 2023).

Validity of AR Learning Media

Table 1. Validation results of augmented reality learning media

Validation Aspects	Percentage (%)	Category
Language Expert	92	Very Valid
Material Expert	97	Very Valid
Media	74	Valid

The validation results showed that the AR media was deemed highly valid by all validators. Linguists gave a score of 92%, indicating that the language and readability of the text in the book and the application interface were communicative and appropriate for the language development level of fourth-grade elementary school students. Material experts gave the highest score of 97%, indicating that the five-sensory content presented was scientifically accurate, relevant to the Science and Education Core (CP IPA), and able to encourage critical thinking skills through problem-based questions. Media gave a score of 74% (Valid), with noted improvements in the clarity of the user guide and

device compatibility. After revisions, the media was declared suitable for testing. These findings align with research by Ningrum et al. (2021), Karini et al. (2022), and Lutfi et al. (2023) who developed AR media for Hydrocarbons and received a very valid rating from the experts. High validity confirms that the developed AR media meets the quality standards of content, design, and readability required for learning (Prasetya et al., 2024; Guo et al., 2025).

Practicality of AR Learning Media

Table 2. Results of the practicality test of AR learning media

School	Number of Students	Teacher Practicality (%)	Student Practicality (%)	Category
SDN 09 Korong Gadang	17	96.00	96.00	Very Practical
SDN 04 Pasar Ambacang	26	96.00	95.00	Very Practical
MIN 3 Kota Padang	29	96.00	96.00	Very Practical
Average	72	96.00	95.64	Very Practical

Practicality tests showed that PBL-based AR media was considered very practical by all teachers (96%) and students (95.64%) in the three schools. The high practicality scores from teachers indicate that this media is easy to integrate into lesson plans, does not require complex technical preparation, and supports the teacher's role as a facilitator in accordance with the Independent Curriculum philosophy. From the students' perspective, high practicality scores reflect that AR media is able to encourage active engagement, increase intrinsic motivation, and facilitate conceptual understanding through interactive visualizations. These results are consistent with the findings of Alkhabra et al. (2023) and Liang et al. (2023) who stated that AR media is considered very practical by users due to its ability to present content visually and interactively without the need for special hardware. Fourth-grade students, belonging to the digital generation (Gen Z), naturally respond positively to smartphone-based technology, resulting in rapid adoption of AR media without significant obstacles.

Effectiveness of AR learning media in improving critical thinking

Table 3. Result of effectiveness of AR learning media in improving critical thinking

School	Number of Students	Pre-test Average	Post-test Average	N-Gain	Category
SDN 09 Korong Gadang	17	55.29	89.41	0.77	High
MIN 3 Kota Padang	29	63.10	92.75	0.79	High
SDN 04 Pasar Ambacang	26	67.69	92.30	0.83	High
Average	17	55.29	89.41	0.81	High

Effectiveness data shows a significant improvement in learning outcomes across all partner schools. The average pre-test score of 59.31 increased to 92.11 in the post-test, with an average N-Gain of 0.81, which is considered high. The highest improvement was achieved at SDN 04 Pasar Ambacang (N-Gain = 0.83), followed by MIN 3 Kota Padang (0.79), and SDN 09 Korong Gadang (0.77). This significant improvement in critical thinking skills occurred because the integration of AR into the PBL model created a learning cycle that encouraged students to: identify problems from 3D visual stimuli presented by AR; conduct independent and group investigations through exploration of the application's interactive features; evaluate information obtained from sensory visualizations; and formulate conclusions based on concrete scientific evidence. This process directly trains dimensions of critical thinking that include interpretation, analysis, evaluation, and inference (D'Northwood & Rattray, 2025; Febintatias et al., 2025). These findings reinforce and extend the research findings of Sánchez-García & Reyes-de-Cózar (2025) and Atmojo et al. (2025) which demonstrated that digital-oriented AR media enhances motivation and understanding of science concepts in sixth-grade elementary school students.

The strength of this research lies in the integration of AR with structured PBL scaffolding, thus not only enhancing conceptual understanding but also specifically developing students' critical thinking skills through systematic problem-solving stages (Arthana et al., 2025). Interactive 3D visualizations presented through AR have been shown to overcome the limitations of conventional learning in presenting abstract physiological concepts (Yunus et al., 2025; Chen et al., 2025; Ziden et al., 2022). When students can "see" how light waves enter the eye and form images on the retina, or how odor molecules interact with the olfactory nerves in the nasal cavity, their conceptual

understanding becomes much deeper and more meaningful (Shepherd et al., 2021). This aligns with the principles of concrete-semi-concrete-abstract (CSA) learning relevant to elementary school students (Iyamuremye & Burns, 2025; Putri, 2019).

Conclusion

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section. This development research produces a valid, practical, and effective Augmented Reality-assisted Science learning media based on the Problem Based Learning model to improve the critical thinking skills of fourth-grade elementary school students. Based on the results of the study, it can be concluded as follows: The PBL-based AR learning media developed through the ADDIE model produces a product in the form of the "Five Senses Augmented Reality" Book equipped with an Android AR application, containing five sub-chapters of sensory organs with interactive 3D visualizations integrated in the PBL learning scenario.; The media is declared very valid based on the assessment of language experts (92%), material experts (97%), and valid by media/design experts (74%), indicating that the media meets the required quality standards of content, language, and design; The media is considered very practical by teachers (96%) and students (95.64%), indicating ease of implementation in learning and high acceptance from users; The media has proven effective in improving students' critical thinking skills, as demonstrated by an increase in the average score from 59.31 (pre-test) to 92.11 (post-test) with an N-Gain of 0.81, a high category, among 72 students from three elementary schools in Padang City. These findings confirm that the integration of AR technology into problem-based learning models is a significant and relevant innovation in the context of implementing the Independent Curriculum. The developed media is recommended for dissemination to other elementary schools as an innovative, interactive, and effective alternative for science and science learning.

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Conflicts of Interest
The authors declare no conflict of interest.

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