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Augmented Reality Learning Media for Enhancing Elementary Students' Conceptual Understanding

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ABSTRACT
This study aims to examine the development process, validity, and practicality of Augmented Reality-based learning media in enhancing fifth-grade students' understanding of science concepts at SDN Inti Dolago on the topic "Seeing Because of Light." Issues in science education indicate that students still struggle to grasp abstract concepts because instruction is dominated by lecture-based methods and the limited use of visual media. This study employed the Research and Development (R&D) method using the ADDIE model, implemented through the implementation stage. The research subjects consisted of 20 students, a classroom teacher, and two expert validators. Data were collected via expert validation sheets and user response questionnaires, analyzed using percentage techniques based on a Likert scale to determine the media's validity and practicality levels. The novelty of this study lies in the development of Assemblr Edu-based Augmented Reality media on visual system material in elementary schools to support conceptual understanding through interactive three-dimensional object visualization.The results showed that the media received a validity score of 82.50% from subject matter experts and 84.00% from media experts, as well as positive responses from teachers and students, making it feasible and practical for use in IPAS learning.

INTRODUCTION

Digital technology plays a crucial role in 21st-century learning because it supports more meaningful and interactive learning (Albina et al., 2022). However, the reality on the ground shows that its use in elementary schools is still not optimal (Fahrudin et al., 2021). Many teachers still employ

conventional teaching methods, Masyhura & Ramadan (2021) also state that the development of digital technology in elementary education has not been optimally utilized because the learning process still tends to be teacher-centered and relies on conventional approaches. As a result, students merely act as passive recipients of material through activities such as listening to explanations, taking notes, and attending lectures without the opportunity to actively engage in learning (Anwar & Jasiah, 2024).

This issue was also identified during initial observations of the learning process in Grade 5 at SDN Inti Dolago. IPAS instruction still showed suboptimal use of teaching materials in helping students understand concepts concretely. Teachers tend to use the lecture method with a blackboard and images from textbooks, resulting in one-way instruction that fails to actively engage students. Learning that remains dominated by the lecture method leads to low student engagement in the learning process (Nguyen et al., 2021). This situation causes students to lack enthusiasm, lose focus easily, and struggle to connect the material to real-world phenomena.

Students' limited ability to understand concepts stems from the fact that science curriculum materials contain abstract concepts that require visualization and hands-on learning experiences. The use of visual aids and real-world examples in science learning helps students understand concepts better than simply listening to explanations or memorizing (Zheng et al., 2022). This aligns with Piaget's cognitive development theory, which states that elementary school children are in the concrete operational stage; thus, learning that effectively illustrates abstract concepts in a tangible way significantly supports the comprehension process (Syafawani & Safari, 2024).

Consequently, the limited use of visual media to support IPAS learning is one of the factors contributing to students' low conceptual understanding. Additionally, constructivist theory states that knowledge is actively constructed by students through experience and interaction with the learning environment, rather than simply being imparted by the teacher to the students. In constructivist science learning, students actively construct knowledge through experience, while new concepts are developed based on learners' prior knowledge rather than simply receiving information from the teacher (Rahadian & Utomo, 2023). Therefore, the lack of visual media that helps deepen conceptual understanding in IPAS learning is one of the main causes of students' low conceptual understanding.

One possible solution is to develop digital technology-based learning media that can create an active and engaging learning experience for students (Zamorano et al., 2021). Interactive learning media not only supports the learning process but can also enhance student motivation and learning outcomes when used appropriately and in line with learning needs (Efendi et al., 2023). Advances in digital technology have spurred the emergence of new forms of interactive learning media, one of which is Augmented Reality (AR)-based media. Augmented reality is a digital learning innovation capable of enhancing the learning process interactively (Batool, 2022).

The use of Augmented Reality (AR) technology enables the direct and interactive integration of three-dimensional visual elements into the real environment (Bakti et al., 2024). Through this interaction, students can gain a deeper learning experience because they not only passively receive information but also actively engage in the process of exploring concepts. This characteristic aligns with the principles of constructivism, which emphasizes the active role of learners in constructing knowledge through learning experiences. Additionally, the use of AR is supported by the Cognitive Theory of Multimedia Learning, which explains that the learning process becomes more effective when information is presented through a combination of images and words, rather than relying solely on text or verbal explanations.

Combining three-dimensional objects, images, and textual information in AR media helps students form a clearer mental picture, thereby facilitating their understanding of the concepts being studied (Lailli et al., 2025). Visualization helps students understand concepts that are difficult to grasp directly, making them clearer and allowing for a deeper understanding of those concepts (Gjoka & Pireva Nuci, 2025). Augmented Reality (AR) has a positive impact on the learning process, particularly in improving student learning outcomes, interest in learning, and science process skills (Abdullah et al., 2022). This medium also helps students grasp abstract concepts more easily because the material is presented visually, interactively, and more concretely, thereby enhancing students' conceptual understanding (Husna et al., 2025). Thus, the use of AR technology in science education is not merely viewed as a technological innovation but is grounded in a strong theoretical foundation for fostering students' conceptual understanding.

Research conducted by Lestari & Putra (2025) shows that the AR learning media developed is highly valid and practical, and significantly improves student learning outcomes. Furthermore, the AR-based STEM learning media developed by Krismapera et al. (2025) specifically the use of the Assemblr Edu application received a very high level of positive response and validity and was proven to significantly improve the learning outcomes of elementary school students. These two research findings indicate that AR-based learning media hold great potential for implementation in science education at the elementary school level.

However, although there has been extensive research on the use of augmented reality (AR)-based learning media in elementary schools, most previous studies have focused on improving students' learning motivation, learning outcomes, and thinking skills. For instance, research by Handayani and Asih (2024) found that the use of AR via Assemblr Edu primarily focused on enhancing student engagement and learning outcomes in science. Furthermore, studies specifically examining how AR impacts conceptual understanding of the visual system curriculum in elementary schools remain scarce. Previous research by Apsari et al. (2024) on the human visual system focused more on media development and overall learning effectiveness rather than students' ability to understand concepts.

This study aims to address this research gap by developing and testing an Assemblr Edu-based interactive augmented reality learning medium focused on improving students' conceptual understanding of the visual system in elementary school IPAS learning. The novelty of this study lies in the development of Assemblr Edu-based Augmented Reality media on the visual system curriculum in elementary school to support conceptual understanding through interactive three-dimensional object visualization.

Based on the issues and shortcomings identified in previous studies, this research aims to develop interactive learning media based on Augmented Reality (AR) technology using the Assemblr Edu application, specifically for the IPAS subject, in the chapter on the visual system, for fifth-grade students at SDN Inti Dolago. This study also aims to create appropriate learning media that can be used daily to help improve students' understanding of lesson concepts through images of real objects that are accessible and suitable for the needs of elementary school students. In addition to providing tangible benefits in the form of digital learning media, this study also offers theoretical contributions to the field of science education through the application of constructivism theory, Piaget's cognitive development theory, and cognitive multimedia learning theory in the development of AR-based learning media to aid in the formation of students' conceptual understanding. With this media, it is hoped that the IPAS learning process will become more engaging, more meaningful, and capable of making students more active and involved in the learning process.

METHOD

This study employed the Research and Development (R&D) method to develop interactive learning media based on Augmented Reality (AR) by applying the ADDIE development model. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) was chosen because it provides a systematic, structured, and flexible framework for developing learning products, thereby helping researchers produce media that meets user needs (Muryandari & Sujatmiko, 2025). Furthermore, the ADDIE model is widely used in development research because it allows the development process to be carried out in stages, from needs identification to product implementation (Sugihartini & Yudiana, 2018).

The stages of this model include: (1) analysis to identify learners' needs, user characteristics, and learning challenges; (2) design to develop the structure of the media, content, and product interface; (3) development to produce and refine the product through an expert validation process; (4) implementation to test the media's use among the target users; and (5) evaluation to assess the product's overall effectiveness. However, this study is limited to the implementation stage because the primary objective is to produce a valid and practical educational media product, not to test its effectiveness regarding learning outcomes or improvements in students' abilities. This limitation aligns with the view of Silitonga et al. (2023), who state that the ADDIE model is flexible and can be adapted to research objectives, particularly in development research focused on the validity and practicality of the product

before testing its effectiveness in subsequent research phases.

Although the evaluation phase was not conducted comprehensively, the quality of the product was still ensured through a validation process by subject matter experts and media experts, as well as pilot testing with teachers and students to gather data on the practicality of the media's use. Thus, this study has produced a product that meets the criteria for content appropriateness, media design, and ease of use. However, the failure to conduct a thorough evaluation phase implies that this study cannot yet provide empirical evidence regarding the media's effectiveness in improving student learning outcomes or conceptual understanding. Therefore, further research is needed to test the effectiveness of Augmented Reality (AR) media in enhancing students' conceptual understanding and to evaluate the sustainability of its use across various learning contexts. According to Zamsiswaya et al. (2024), the evaluation stage in the ADDIE model serves to assess the effectiveness of the product while providing a basis for continuous product improvement. The research steps are illustrated in the following framework diagram, see Figure 1.

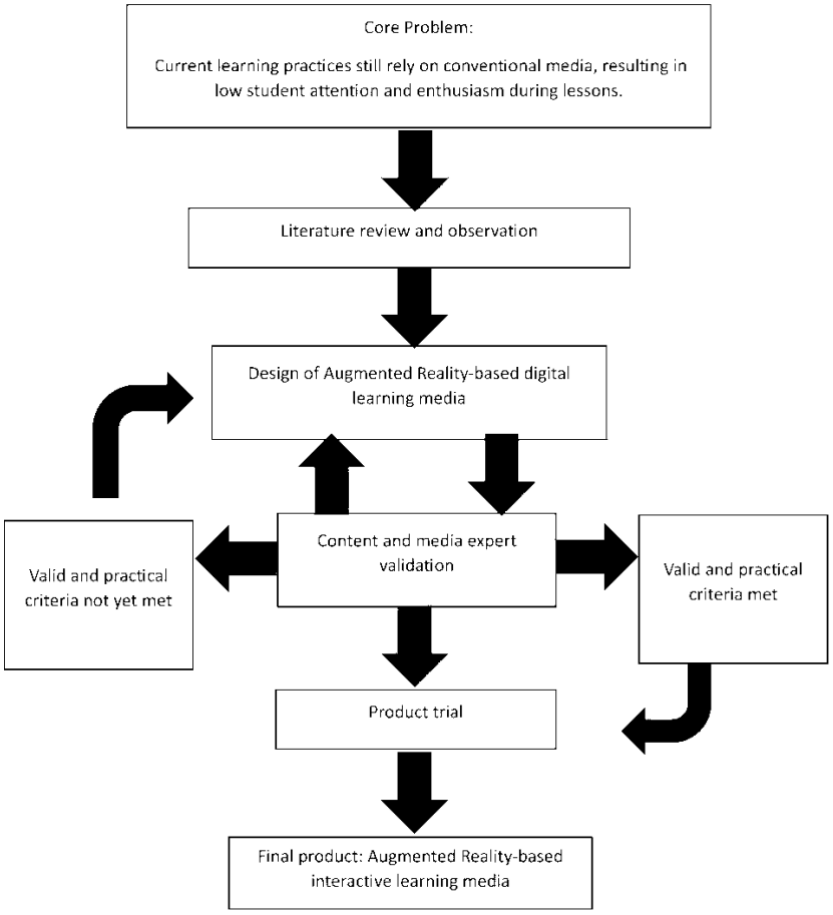


Fig.1. Framework diagram

The subjects of this study included all fifth-grade students at SDN Inti Dolago, totaling 20 students. This study was conducted during the odd semester of the 2025/2026 academic year, specifically from November to December 2025, at SDN Inti Dolago, located in Dolago Village, South Parigi Subdistrict, Parigi Moutong Regency, Central Sulawesi Province. The topic was selected because it aligns with the need to develop teaching materials for the visual system curriculum taught in fifth grade, and it allows for direct product testing with the intended users.

This study has limitations regarding the number of subjects and the context in which the research was conducted. The media trial was conducted only on 20 students in a single class at one elementary school; therefore, the results obtained are more representative of the conditions at SDN Inti Dolago. Consequently, the research findings regarding the validity and practicality of the media cannot

yet be generalized to all elementary school students, who possess varying characteristics, facilities, and learning environments. Nevertheless, the results of this study can serve as a starting point for developing learning media that utilize Augmented Reality technology in IPAS instruction at the elementary school level. Future research should involve a larger number of participants, various types of schools, and different locations to gain a broader understanding of media usage and enhance the applicability of the research findings across diverse situations.

The data collection methods used in this study were observation, interviews, and questionnaires. The data analysis methods employed utilized two approaches: quantitative data analysis and qualitative data analysis. Quantitative data analysis involves data obtained through calculations in the form of numbers or figures. This data is used to process data in the form of assessment scores from media experts, content experts, and users such as teachers and students. This data is used to determine the level of validity and practicality of the developed learning media. Qualitative data analysis is applied to interpret feedback from expert validators, teachers, and students. This feedback, which includes comments, critiques, and suggestions regarding the Augmented Reality-based IPAS learning media, is presented in the form of written descriptions that review various aspects of the product, ranging from design, interface, and programming to the scope of the content.

RESULTS AND DISCUSSION

This study was conducted at SDN Inti Dolago on Jl. Palila, Dolago Village, South Parigi Subdistrict, Parigi Moutong Regency, Central Sulawesi. The study's participants were 20 fifth-grade students. This study focused on the development of technology-based interactive learning media, specifically Augmented Reality (AR), with the topic "Seeing with Light."

In developing this media, the ADDIE model proposed by Latip (2022) was used, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation, which guide researchers in designing, developing, implementing, and evaluating learning media. However, the implementation of this study was limited to the implementation stage only, as the study focused on efforts to produce a learning media product that meets the criteria of validity and practicality for use in IPAS learning.

A comprehensive evaluation process was not conducted in this study, given that the primary objective was not to measure the effectiveness of the developed product, but rather to ensure that the learning material met the criteria for feasibility and ease of use in the learning process. The results of this study are outlined in the following sections.

Analysis

The analysis phase was conducted to identify the gap between the learning requirements of the Integrated Science, Mathematics, and Natural Sciences (IPAS) curriculum and the actual classroom learning conditions. The analysis results indicate that although SDN Dolago has implemented the Merdeka Curriculum, the "Seeing with Light" unit has not yet fully supported students' conceptual understanding. This material covers the function, structure, and workings of the sense of sight, which involve abstract concepts, thus requiring concrete and interactive visualizations. However, the material is still delivered primarily through verbal explanations via lectures and the use of simple media such as textbooks, worksheets, and a blackboard. This situation leads students to tend to receive information passively and struggle to visualize the eye's functioning process comprehensively.

These findings indicate that learning challenges stem not only from limitations in instructional media but also from a learning process that does not allow students to participate actively. The predominant lecture-based method limits student interaction with the subject matter. Consequently, learning focuses more on the delivery of information than on the process of building conceptual understanding. This situation is evidenced by low levels of attention, low engagement, and students' inability to fully grasp the topics. This indicates that learning media capable of connecting abstract ideas with more tangible visual representations are essential. The analysis results show that the interactive Augmented Reality (AR)-based learning media offered are relevant for use in IPAS instruction. Augmented Reality can serve as a variation in learning media and help students grasp

concepts through the visualization of three-dimensional objects they can observe and study directly. The interactive features of AR media enable students to engage in hands-on learning.

Design

The design phase was conducted to create instructional media that meets the characteristics of elementary school students and the concrete nature of IPAS material. The design of the media focused on interactive visual presentations that can help students understand the structure and function of the internal parts of the eye in greater depth. The results of the needs analysis indicate that students struggle to grasp concepts related to the visual system when the material is presented solely through verbal explanations and two-dimensional images. Therefore, the use of three-dimensional objects is considered essential to help students understand these concepts through more realistic and structured visualizations. At this stage, the media content is organized based on the learning outcomes for Grade 5 IPAS under the Merdeka Curriculum. The content in this media covers parts of the eye such as the cornea, retina, lens, pupil, iris, and optic nerve, as well as their functions. The purpose of developing systematic material is so that students not only know the names of the eye's components but also understand how each component relates to one another and their functions. The media not only serves to convey information but also helps students learn concepts step by step, see Figure 2.

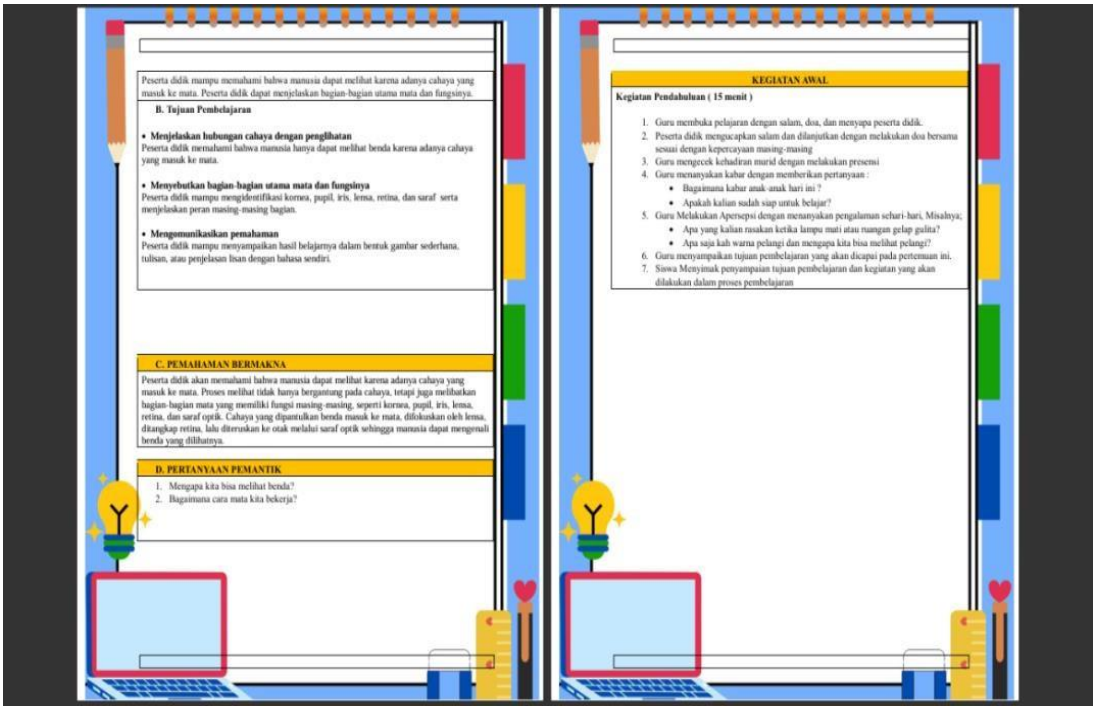


Fig.2. The stage of determining and selecting materials based on learning outcomes (LO)

The The marker design phase was carried out using the Canva app, taking into account visual clarity, color contrast, and ease of scanning. The design of the markers simple yet clear aims to minimize detection errors when using the media. Additionally, to help students more easily connect the virtual visualization with the material being studied, the relationship between the markers and the three-dimensional objects is designed consistently. This media features visual elements that capture students' attention and support their cognitive processes by making abstract concepts more concrete, see Figure 3.

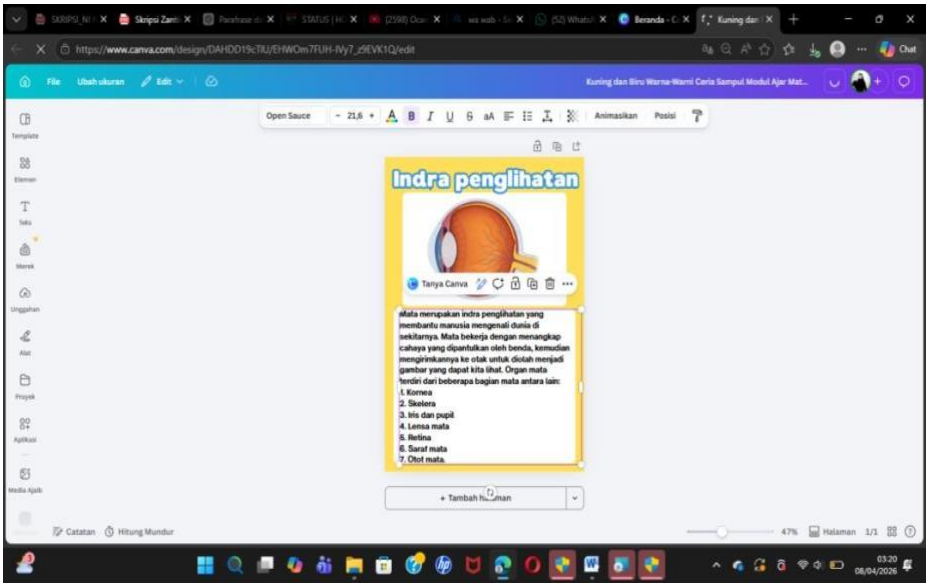


Fig.3. The process of creating a marker using the canva app

This platform was developed using the Assemblr Edu platform for Android smartphones because it is considered practical and easily accessible to students. The platform was chosen based on the belief that using devices familiar to students can increase their engagement in the learning process. In addition, IPAS learning is not merely theoretical; it also provides a more meaningful learning experience for students due to Assemblr Edu's ability to display three-dimensional objects interactively, see Figure 4.

Fig.4. Design of an augmented reality media marker

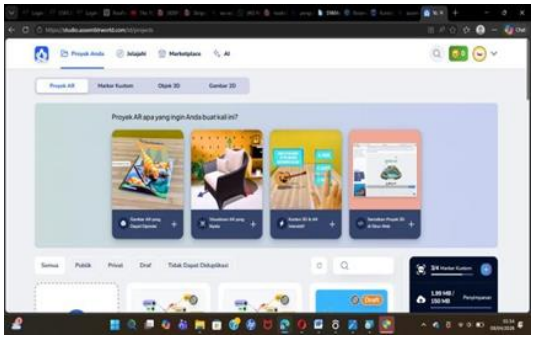
Development

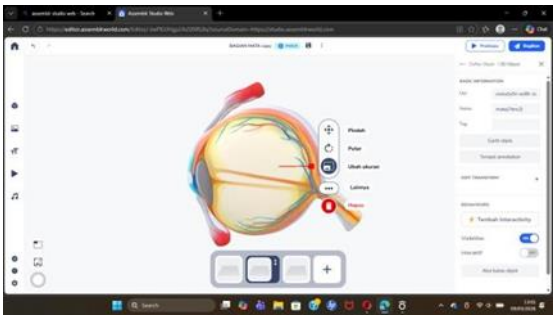
The development stage is the phase in which the media design is transformed into a usable learning product that can be tested for feasibility. In this stage, Augmented Reality (AR) media was developed using the Assemblr Edu platform, employing markers that trigger the appearance of three-dimensional virtual objects. The development process addresses not only the technical aspects of media creation but also how the visualizations align with the visual system and meet the learning needs of elementary school students. To provide a more tangible and easily observable representation of concepts, the three-dimensional internal structures of the eye and their functions are arranged and adjusted in terms of size, position, and visual clarity. These adjustments were made because

proportional and interactive visualizations are crucial for helping students understand abstract concepts in science curriculum content. Thus, the media not only serves as a visual aid but also helps students grasp concepts through a more interactive learning experience.

The development process also took into account how easy the media is to use for learning. This was achieved by simplifying the media's interface and navigation so that students can use it independently. These findings indicate that the practicality of the media is determined not only by its technological functions but also by its ability to facilitate learning interactions that are easy, clear, and aligned with the needs of elementary school students. To clarify the stages of the media development process, the steps for creating Augmented Reality media are presented in Table 1.

Table 1. Product Development Process

Appearance	Explanation
	The initial interface of the Assemblr Edu platform, which researchers used to create an augmented reality project as the first step in developing educational media.
	The first step in creating Augmented Reality media on the Assemblr Edu platform is to select the editor by clicking the plus (+) icon and choosing "Default Editor."
	The step for setting up markers on the Assemblr Edu platform involves selecting custom markers and uploading images to be used as markers in Augmented Reality.

Appearance	Explanation
	The process of adjusting the position and size of three-dimensional objects within the eye on the Assemblr Edu platform so that the objects appear balanced and appropriate when used in augmented reality.
	The process of placing three-dimensional objects, each accompanied by annotations to clarify their respective functions, within an augmented reality environment.

Next, initial product testing was also conducted to ensure that the Assemblr Edu-based Augmented Reality media was suitable for use. To conduct the evaluation, subject matter experts and media experts used a questionnaire to assess the quality of the content, the presentation, and the media's ease of use. The purpose of this validation process is not only to obtain a percentage score for suitability but also to identify the media's strengths and weaknesses in each evaluation aspect, thereby serving as a basis for product refinement.

Content validation was conducted by content experts by evaluating two main aspects: content appropriateness and alignment of the material with the characteristics of Augmented Reality media, which were broken down into ten evaluation indicators, see Table 2.

Table 2. Results of the Subject Matter Expert Validation Assessment

Assessment Criteria	Number of Indicators	Validation Score	Percentage	Criteria
Content appropriateness and material suitability for AR.	10 items	33	82,50%	Highly Valid

The validation results show that the media achieved a score of 82.50%, falling into the "highly valid" category. These results indicate that the media is suitable for use and that most indicators meet the learning needs of IPAS, which emphasizes the direct visualization of concepts. The alignment of the material with three-dimensional objects is considered capable of helping students understand concepts in a more contextual way than simply conveying them verbally. Nevertheless, the validation results also indicate that there are still some areas that need improvement. According to the validator, the annotation explanations regarding the 3D objects are still too lengthy. This could lead to a greater cognitive load for students when interacting with the media. Therefore, the validator recommends simplifying the annotation information so that the material is conveyed more efficiently, more simply, and is easier for elementary school students to understand. These results indicate that it is not only

visual quality that determines the success of AR media, but also the media's ability to present information appropriate to students' cognitive development.

Media expert validation was conducted to assess the quality of the media in terms of design, appeal, and application, as outlined in eleven evaluation indicators. The results of the validation assessment by media experts are presented in Table 3.

Table 3. Results of The Media Expert Validation Assessment

Assessment Criteria	Number of Indicators	Validation Score	Percentage	Criteria
Design, appeal, and application.	11 items	37	84%	Highly Valid

The validation results yielded a score of 84%, classified as "highly valid." These results indicate that the media has met most of the feasibility indicators, particularly those related to visual presentation, navigation, and interactivity. The use of 3D objects and interactive features in Assemblr Edu is considered capable of making the learning experience more engaging and supporting students' active participation in the learning process.

However, the validation results also revealed weaknesses in the presentation of information. The validator found that presenting the material in a single view made the information appear too dense, which reduced user comfort when using the media. Based on these findings, the validators recommended dividing the material into several scenes to create a more structured layout and improve interaction with 3D objects. This recommendation indicates that aesthetic aspects are not the only factors influencing the success of interactive learning media, as user-friendly interface design and data management also play a role.

Implementation

During the implementation phase, the Assemblr Edu-based Augmented Reality media—which had been deemed suitable by subject matter experts and media experts—was pilot-tested with teachers and fifth-grade students at SDN Inti Dolago to analyze the media's practicality in IPAS instruction. This pilot test involved 18 students who were present during the lesson. In this activity, the researcher acted as the instructor, and the classroom teacher acted as an observer who assessed the use of the media during the learning process.

The implementation of the lesson demonstrated that Augmented Reality media is capable of creating a more interactive learning environment compared to conventional learning, which was previously dominated by lecture-based methods. Students appeared more active while observing three-dimensional objects through their smartphones and engaged in group discussions while exploring the visual system material. This indicates that AR-based visualization can help students connect abstract concepts with more concrete representations, making it easier for them to understand the concepts, see Table 4.

Table 4. Results of The User (Student) Response Assessment

No	Aspect	Score	Percentage	Criteria
1.	Content	211	97,68%	Highly Valid
2.	Visual presentation media	277	96,18%	Highly Valid
3.	Ease of media presentation	203	93,98%	Highly Valid
4.	Applications	59	81,94%	Highly Valid
5.	Language	71	98,61%	Highly Valid
6.	Motivation to learn	72	100%	Highly Valid
	Average	893	95,40%	Highly Valid

According to the students' responses in Table 4, the learning motivation aspect had the highest percentage at 100%. This indicates that the use of AR media can increase students' interest and engagement during learning. The 98.61% percentage for the language aspect indicates that elementary school students easily understand the language used in the media, thereby helping them follow the

learning process independently. The 97.68% percentage for the content aspect indicates that the material is considered relevant and aligned with the IPAS learning objectives.

Regarding the visual display aspect, the 96.18% percentage indicates that viewing three-dimensional objects in the media can capture students' attention and help them understand the material more comprehensively. Meanwhile, the ease of media use aspect received a percentage of 93.98%, indicating that most students can use the media effectively, although they may need assistance during the initial stages. The application aspect had the lowest percentage at 81.94%. These results indicate that there are still some technical barriers to using the application; for example, limitations in students' smartphones and the marker scanning process which requires adjusting the camera position to display objects most accurately are among these technical barriers. Overall, the average student response rate reached 95.40%, falling into the "highly valid" category. These results not only indicate that the media is easy to use but also suggest that interactive visualizations can help students become more engaged and better understand the concepts.

Teachers, as users of the media, also evaluated the responses to determine the level of practicality and suitability of the media for use in the learning process. The aspects evaluated included ease of use, clarity of display, alignment with learning objectives, and the media's benefits in supporting learning activities. The results of teachers' responses to the Assemblr Edu-based Augmented Reality media are presented in Table 5.

Table 5. Results of The User (Teacher) Response Evaluation

Assessment Aspect	Number of Indicators	Validation Score	Percentage	Criteria
Content, alignment of content with AR, visual design, user-friendliness and appeal of the media, applications, and language.	15 items	50	83,33%	Highly Valid

Teacher feedback also yielded positive results, with 83.33% of responses falling into the "highly valid" category. This percentage indicates that teachers found the media to be aligned with the learning material, visually appealing, and easy to use in classroom activities. Additionally, teachers noted that the use of AR media helped make abstract concepts more concrete, thereby facilitating the delivery of material to students. However, teachers also provided feedback regarding the need for initial guidance for students in using the application so that the learning process can be more effective. Thus, the implementation results show that the Assemblr Edu-based Augmented Reality media not only meets practicality requirements but also has the potential to support more interactive, concrete, and student-centered IPAS learning.

This study successfully produced an Augmented Reality (AR)-based interactive learning tool focused on the visual sense, following a process of analysis, design, development, and implementation. The development of this medium was prompted by students' lack of understanding of IPAS material, which is highly abstract because it is delivered solely through lectures and textbooks. This situation makes it difficult for students to visualize the internal structure of the eye in a tangible way, resulting in learning that tends to be rote memorization rather than conceptual understanding. Therefore, Augmented Reality (AR)-based media can serve as an alternative to provide concrete visualizations that enable students to gain understanding through a more interactive and realistic learning experience.

The results of the needs analysis indicate that the lecture method still dominates the learning process, resulting in low student engagement. Limited use of media causes students to be less active in exploring content and makes it difficult for them to connect ideas to real-world situations. This situation indicates that IPAS learning requires media that can not only convey information but also help students visualize abstract concepts in a tangible way. This aligns with Piaget's theory of cognitive development, which states that elementary school students are in the concrete operational stage. They find it easier to understand ideas through direct experience, real objects, and visualization rather than through verbal

explanations. Therefore, the use of Augmented Reality media in this study is relevant to the cognitive development of elementary school students.

The developed media is designed using 3D visualizations of the internal structures of the eye, which can be displayed through a marker-based scanning process using a smartphone. These 3D visualizations not only serve as visual elements but also help students understand how the different parts of the eye relate to one another. From a multimedia learning perspective, the combination of images, animations, text, and visual interactions allows information to be processed simultaneously through verbal and visual channels, which helps learners reduce cognitive load and strengthen conceptual understanding. Therefore, 3D visualizations in Augmented Reality media can aid conceptual understanding because learners not only read the material but also see the shape of the object step by step.

The results of the content expert validation achieved a percentage of 82.50%, classified as "highly valid," while the media expert validation achieved a percentage of 84%, also classified as "highly valid." These results indicate that the media can be effectively utilized and that the content, when combined with Augmented Reality visualizations, is relevant to IPAS learning in elementary schools. The aspects of content suitability and ease of use demonstrate that the media content is linked to learning outcomes. On the other hand, the aspects of appearance and ease of use indicate that the media is capable of effectively supporting student interaction. These findings suggest that technological sophistication is not the sole factor influencing the success of Augmented Reality media; visual design and content presentation must also align with the characteristics of elementary school students.

The results of this study align with research by Khairunnisa & Apoko (2023), which states that digital learning media can be considered valid if they meet the criteria of content appropriateness, visual presentation, and ease of use. However, in this study, Augmented Reality media not only met the validity criteria but also helped students understand concepts. This was demonstrated by the media's ability to visualize the internal structure of the eye, which was previously difficult to observe directly. In other words, three-dimensional Augmented Reality visualization serves as a bridge between abstract ideas and students' real-world learning experiences. A similar view is expressed by Peng et al. (2021), who state that digital learning media must have an attractive interface, a clear structure of content, and ease of use to effectively enhance student engagement and learning outcomes.

The results of the implementation showed a teacher response rate of 83.33% and a student response rate of 95.40%, both of which fall into the "very good" category. The high student response rate indicates that Augmented Reality media is capable of capturing students' attention and increasing their engagement during learning. This high practicality score is influenced by several factors, namely the ease of using the media via smartphones which are already familiar to students the visualization of three-dimensional objects that makes the internal structures of the eye easier to observe, and the interactive nature of the media that allows students to explore objects directly. These factors help transform abstract concepts into more concrete ones, thereby supporting students' conceptual understanding. Nevertheless, the high student response may also be influenced by enthusiasm for the use of relatively new technology, so these results need to be interpreted with caution.

These findings are consistent with research conducted by Apsari et al. (2024) and Wiraha & Sudarma (2023), which indicates that the use of Augmented Reality in science education can help students understand concepts more concretely by viewing interactive three-dimensional objects. Augmented Reality-based learning media can create a more interactive and engaging learning experience, helping students understand the material more deeply (Syarif et al., 2025). In this study, Augmented Reality visualization helped transform abstract material into something more tangible, making it easier for students to understand the structure and function of the eye's internal parts. This demonstrates that Augmented Reality serves not only as a learning support tool but also as a means to build conceptual understanding through interactive visual experiences.

This study contributes to the development of science education in elementary schools, particularly through the use of interactive learning media based on Augmented Reality to enhance students' conceptual understanding. Previously, science education largely focused on delivering content through lectures and relied solely on textbooks, causing students to struggle with understanding abstract concepts. The Augmented Reality media developed in this study provides three-dimensional visualizations of materials related to the sense of sight, allowing students to observe the structure of

objects in a more concrete and interactive manner. This approach supports IPAS learning, which emphasizes hands-on learning experiences, observation, and active student participation in understanding concepts (Muspiroh et al., 2025).

Another contribution of this study lies in the use of the Assemblr Edu platform as a tool for developing digital learning in elementary schools. Assemblr Edu allows teachers to create 3D visual objects that are easily accessible via smartphones without requiring complex equipment. This is a distinct advantage because, even when used in schools with limited facilities, this platform can still provide a creative and interactive learning experience. According to research conducted by Sudarno et al. (2025), the use of Assemblr Edu in science education can enhance student engagement and understanding of abstract concepts through an approach that combines questioning and interactive visualization.

Furthermore, the media developed in this study not only serves as a visual aid but also helps students better understand concepts. Thus, this study also contributes to new developments in science education media. Augmented Reality media allows students to view objects from various perspectives, making the learning process more contextual and active. This distinguishes it from conventional media, which only displays static images. In multimedia learning, the integration of text, audio, visuals, and three-dimensional objects helps students process information through verbal and visual channels simultaneously. This aids in the understanding of abstract concepts (Muspiroh et al., 2025).

This study is relevant to the demands of 21st-century education, which emphasizes critical thinking skills, creativity, digital literacy, communication, and collaboration. Assemblr Edu-based Augmented Reality media encourages students to use digital technology as a learning tool and to engage more actively with the subject matter. Thus, this medium not only helps students understand IPAS concepts but also supports the use of technology in 21st-century learning. Rahmawati and Utami (2026) state that by using Assemblr Edu-based Augmented Reality, students can have a more concrete, interactive, and meaningful learning experience. This will make learning more aligned with 21st-century standards.

There are several similarities and differences between this study and previous research. This study shares similarities with the research by Pohan et al. (2025), Husna et al. (2025), and Rahmah and Amalina (2025) regarding the use of Assemblr Edu-based Augmented Reality media in IPAS instruction in elementary schools. These three studies indicate that Augmented Reality media can improve learning outcomes and student engagement. However, most previous studies focused more on learning outcomes, media validity, and student motivation, whereas this study focuses more on students' conceptual understanding of visual perception. Thus, this study places a more specific emphasis on the process of conceptual understanding rather than merely improving test scores.

Differences in context are also evident in the subject matter and characteristics of the media developed. Previous research has developed augmented reality for general science topics such as the digestive system or the concept of light, whereas this study specifically developed media for the inner workings of the visual system, which require detailed and concrete visualizations. This material has a high level of abstraction because the internal structure of the eye cannot be directly observed by students. Therefore, the use of three-dimensional visualization in this study plays a more important role in helping students understand the relationship between the structure and function of the visual system (Sudarno et al., 2025).

The strength of the media developed in this study lies in the integration of interactive 3D visualization into science curriculum materials tailored to the cognitive developmental characteristics of elementary school students. The media not only presents visual objects but also allows students to explore them directly via smartphones, making learning more concrete and realistic. Interactive visualization in Augmented Reality media has been proven to help students understand abstract concepts through a more contextual and meaningful learning experience (Apsari et al., 2024). Additionally, the media is designed to be simple so that it is easy and more practical for elementary school teachers to implement. Implementation results show that, compared to conventional lecture-based learning, students are more active, more enthusiastic, and find it easier to understand the material when using Augmented Reality media.

On the other hand, previous research still has several limitations. Most studies have emphasized quantitative measures of learning outcomes and product validity without thoroughly examining how

AR aids students' conceptual understanding (Pohan et al., 2025). Additionally, some studies have focused solely on the effectiveness of the technology without considering learning theories such as Piaget's theory of cognitive development and multimedia learning. This study aims to address these limitations by demonstrating that three-dimensional interactive visual experiences in AR help students at the concrete operational stage understand abstract concepts.

Thus, the Augmented Reality-based interactive learning media developed is not only practical and feasible but also helps elementary school students better understand IPAS concepts. The use of interactive three-dimensional visualizations helps elementary school students understand abstract concepts more concretely, in line with Piaget's theory of cognitive development and the principles of multimedia learning. Therefore, Augmented Reality media can serve as an innovative alternative for creating IPAS learning that is more meaningful, contextual, and student-centered.

CONCLUSION AND SUGGESTION

An Augmented Reality (AR)-based interactive learning tool using Assemblr Edu for lessons on the inner workings of the visual system has met validity and practicality standards, making it suitable for use in science education at SDN Inti Dolago's fifth-grade level. The tool received a 84.00% rating from media experts and an 82.50% rating from subject matter experts, placing it in the "highly valid" category. Meanwhile, the response rate from teachers reached 83.33% and from students 95.40%, indicating a "highly practical" category. These findings demonstrate that the developed media meets the criteria for content appropriateness, visual quality, and ease of use, and has received a positive response from users. Thus, the AR media developed can serve as an educational innovation that makes the IPAS learning process more engaging and relevant to real-world contexts. However, this study has several limitations, including a small sample size, the fact that the research was conducted at only one school, the absence of tests to assess the media's effectiveness in terms of its impact on student learning outcomes or conceptual understanding, and the fact that development stopped at the implementation stage without completing the evaluation phase of the ADDIE model. Therefore, future research should use a larger sample size, be conducted in various types of schools, and test the quality of the media to gain a more comprehensive understanding of the impact of media use in the learning process.

CONFLICT OF INTEREST

The author declares that this research was conducted without any conflict of interest. This study on the development of interactive learning media based on augmented reality was conducted independently and was not influenced by the personal, business, or financial interests of any party. All stages of the research from the creation of the media and the conduct of the pilot study to the writing of the research report, were carried out objectively for academic purposes and the advancement of learning.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, P.N.S., H., S.L..; methodology, P.N.S., H., S.L.; investigation, P.N.S.; data collection, P.N.S.; formal analysis, P.N.S.; supervision, H. and S.L.; validation, H. and S.L.; writing—preparation of the original draft, P.N.S.; review and editing, H., S.L., M.M.G., and S.W. All author have read and agreed to the published version of the manuscript.

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DECLARATION OF GENERATIVE AI SOURCES

The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in the preparation of this manuscript.

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