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# Development of IPAS worksheets using augmented reality to enhance critical thinking skills

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**ABSTRACT**

The use of innovative media, such as Augmented Reality (AR)-based Student Worksheets (LKPD), is a solution to improve the quality of 21st-century learning, especially in addressing the limitations of conventional media in elementary schools. AR technology enables the visualization of concepts contextually and interactively, promoting student engagement and developing critical thinking skills. This study aimed to develop an AR-based LKPD for the IPAS subject on the human digestive system for Grade 5 students. It employed a Research and Development (RnD) approach using the ADDIE model at UPT SD Negeri 067250 Medan. The subjects included Grade V students, classroom teachers, and three expert validators (subject matter, design, and language). Data were collected through expert validation sheets, practical questionnaires, observation, and documentation, and were analyzed using descriptive and quantitative techniques. Product trials were conducted in two stages: a small group (9 students) and a field trial (30 students). Validation and revision ensured the quality of content, design, language, and media display. The final product was tested for practicality and effectiveness in enhancing students' critical thinking. The integration of AR in LKPD IPAS enhanced students' critical thinking through interactive visuals, expert validation, and positive trial results. The developed AR-based LKPD proved to be valid, practical, effective, and aligned with the Kurikulum Merdeka and the contextual digital learning needs.

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***ABSTRAK***

*Penggunaan media inovatif seperti LKPD berbasis Augmented Reality (AR) menjadi solusi untuk meningkatkan kualitas pembelajaran abad ke-21, terutama dalam mengatasi keterbatasan media konvensional di sekolah dasar. Teknologi AR memungkinkan visualisasi konsep secara kontekstual dan interaktif sehingga mendorong keterlibatan serta kemampuan berpikir kritis peserta didik. Penelitian ini bertujuan mengembangkan LKPD IPAS berbasis AR pada materi sistem pencernaan untuk peserta didik kelas V. Penelitian ini merupakan RnD dengan model ADDIE untuk mengembangkan LKPD berbasis AR di kelas V UPT SD Negeri 067250 Medan. Subjek meliputi peserta didik kelas V, guru kelas, dan tiga validator (ahli materi, desain, dan bahasa). Data dikumpulkan melalui validasi ahli, angket kepraktisan, observasi, dan dokumentasi, lalu dianalisis secara deskriptif kuantitatif. Uji coba dilakukan dalam dua tahap: kelompok kecil (9 peserta didik) dan lapangan (30 peserta didik). Validasi dan revisi dilakukan untuk memastikan kelayakan isi, desain, bahasa, dan tampilan media. Produk akhir diuji untuk menilai kepraktisan dan efektivitasnya dalam meningkatkan kemampuan berpikir kritis peserta didik. Integrasi teknologi AR dalam LKPD IPAS meningkatkan kemampuan berpikir kritis peserta didik melalui penyajian visual interaktif, validasi ahli, serta uji kepraktisan dan efektivitas dengan hasil positif. Pengembangan LKPD IPAS berbasis AR terbukti valid, praktis, dan efektif serta sesuai dengan Kurikulum Merdeka dan kebutuhan pembelajaran digital kontekstual.*

***Kata Kunci:*** *Assemblr Edu; augmented reality; berpikir kritis; IPAS*

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## INTRODUCTION

Low student engagement in higher-order thinking activities remains a global issue that has yet to be resolved. The development of digital learning technology has tended to be virtual and has not been fully integrated into classroom learning. According to the Programme for International Student Assessment (PISA), as reported in the OECD's "Education at a Glance 2023", 71% of Indonesian students have not reached the minimum level in critical thinking and problem-solving skills, with an average score of 396, compared with the global average of 489. The integration of technology in education remains dominated by passive approaches, such as visual presentations that lack multisensory engagement or independent exploration (Humam & Hanif, 2025; Umroh et al., 2024). Non-interactive learning negatively impacts students' ability to construct arguments, analyze information, and develop reflective thinking (Ramdani et al., 2020). Research indicates that technology-based learning environments should not only present visualizations but also foster authentic engagement through contextual learning experiences (Godsk & Møller, 2025; Pan, 2023). This situation underscores the importance of educational technology innovations that provide deep and interactive learning experiences.

The use of technology-based Augmented Reality (AR) media has demonstrated significant effectiveness in optimizing learning motivation and conceptual understanding, and in facilitating students' active and sustained cognitive engagement (Mayer, 2024; Phong et al., 2024; Vari et al., 2023). Empirical findings indicate that AR-based learning environments foster reflective and investigative learning experiences and provide opportunities for exploration through the virtual manipulation of objects (Andriani & Ramadani, 2022; Salsabila & Muqowim, 2024; Zaid et al., 2022). However, most of these studies have focused primarily on content visualization and have not systematically integrated critical-thinking indicators into instructional media design. The predominant emphasis on visual aspects, without assignments aligned with critical thinking indicators, reveals a research gap in the development of structured learning media (Maimuna et al., 2024; Nusroh et al., 2022). This gap highlights the need for an AR-based learning model that explicitly directs students' activities toward critical thinking skills, in accordance with the characteristics of elementary school students.

The learning conditions in Grade V at UPT SD Negeri 067250 indicate that a conventional, teacher-centered approach continues to predominate in science (IPA) instruction. Students tend to be passive during lessons and are rarely involved in exploratory activities that encourage critical thinking. The use of technology to support understanding of scientific concepts is also very limited; even visual media, such as two-dimensional images, have not been sufficient to facilitate students' comprehensive understanding of the digestive system. Classroom observations indicated that most students had difficulty connecting the functions of digestive organs to their roles in biological processes in a logical, sequential manner. These findings were reinforced by interviews with the class teacher, who stated that the limited instructional media is one of the causes of students' low reasoning and critical thinking skills. This situation underscores the importance of developing innovative media that are not only visually appealing but also capable of stimulating active engagement and critical thinking processes.

Critical thinking is an essential component in developing 21st-century life skills, particularly in science learning, which requires analytical, evaluative, and logical reasoning abilities (Setiawan et al., 2024). Critical thinking encompasses skills such as identifying problems, interpreting data, making inferences, and constructing and evaluating arguments objectively (Sapitri et al., 2022; Sari & Fathurrahman, 2024). These skills serve as indicators of students' success in understanding scientific concepts and applying them in real-life contexts. Mastery of critical thinking not only enhances academic achievement but also contributes to the development of scientific character and reflective attitudes among elementary school students (Halimah et al., 2023; Parisu et al., 2025). Implementing approaches that encourage students to



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ask questions, reason, and draw independent conclusions is a vital strategy for supporting meaningful science learning.

This study makes a scientific contribution by developing Augmented Reality (AR)- based Student Worksheets (LKPD) integrated into the Assemblr Edu platform. The developed product is explicitly designed to strengthen critical thinking skills through activities grounded in critical thinking indicators. Unlike previous studies that focused solely on visualization, this development emphasizes the LKPD structure, which guides students in identifying problems, analyzing information, evaluating arguments, and drawing logical conclusions. The main issue addressed in this study is the lack of AR-based instructional materials that are valid, practical, and effective in supporting elementary school students' critical thinking skills regarding the human digestive system.

The primary objective of this study is to design and develop an AR-based LKPD using the Assemblr Edu platform as a learning medium for the IPAS subject. The primary focus of the development is to enhance elementary students' critical thinking skills, particularly regarding the human digestive system. The developed product is expected to serve as a valid, practical, and effective learning aid in supporting IPAS learning outcomes in accordance with the demands of the Kurikulum Merdeka. Validity is demonstrated by aligning the LKPD's content and design with pedagogical principles and students' characteristics; practicality is reflected in the ease of use for both teachers and students; and effectiveness is measured by the improvement in fifth-grade students' critical thinking skills following use of the LKPD in the learning process.

## LITERATURE REVIEW

### Augmented Reality Technology with Assemblr Edu

The use of Augmented Reality (AR) technology in elementary education has shown high effectiveness in enhancing conceptual understanding, particularly for abstract topics. This technology enables the integration of three-dimensional objects into the real world through digital devices, making the learning experience more concrete and engaging (Rahmayani et al., 2024). One platform widely used in elementary schools is Assemblr Edu, which allows teachers and students to access interactive visual content without requiring advanced technical skills. The integration of this application into science learning has been shown to improve students' focus, understanding, and engagement through dynamic visualizations based on QR codes in Student Worksheets (LKPD) (Marini et al., 2022; Najib & Suprihatiningrum, 2025).

The implementation of Assemblr Edu aligns with the principles of the Merdeka Curriculum, as it supports differentiated, exploratory, and project-based learning (Ilafi et al., 2023). AR-based learning activities encourage students to independently observe, analyze, and evaluate information, thereby strengthening critical thinking skills. Research findings indicate that higher-order thinking skills can develop significantly when students engage in contextual visual learning experiences (Diani & Wulandari, 2025; Suharti et al., 2024). The success of implementing this technology depends heavily on teacher readiness and the availability of digital resources, underscoring the need for ongoing training to maximize its pedagogical potential.


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### Student Worksheet (LKPD)

Student Worksheets (LKPD) are printed or digital instructional materials that systematically guide students' learning activities (Anbiya et al., 2023). LKPD serves as a means of empowering students through active, exploratory, and independent learning. Its structure typically includes activity instructions, guiding questions, observation columns, and reflection spaces, thereby facilitating comprehensive student engagement in learning (Handayani et al., 2025). Materials presented through LKPD provide opportunities for students to construct their own understanding through direct interaction with objects, phenomena, or data provided by the teacher.

The role of LKPD becomes increasingly strategic when aligned with problem-based, project-based, or inquiry-based learning approaches (Hafsah et al., 2024). Alignment between LKPD content and learning objectives facilitates the development of meaningful, contextual learning activities (Supriatna et al., 2024). LKPD is designed using differentiation principles and the integration of digital technologies, such as Augmented Reality (AR), to enhance the material's appeal and improve students' critical and creative thinking skills (Anggraini et al., 2024). Findings from various studies indicate that technology-based LKPD significantly increases students' motivation and learning outcomes by providing a more authentic and reflective learning experience (Ahmadiah et al., 2023; Santi et al., 2024).

### Critical Thinking Ability

Critical thinking ability is a cognitive competence that reflects an individual's capacity to analyze information, evaluate arguments, and make decisions logically and reflectively (Azhar et al., 2024). The elementary education environment is a strategic setting for developing this skill, as early-stage learning significantly shapes the quality of students' thinking processes at later educational levels (Dezola et al., 2023). Critical thinking involves higher-order mental activities, including interpretation, reasoning, and judgment based on objective evidence (Sidiq et al., 2021). Strengthening this ability requires exploratory learning strategies, problem-solving activities, and the use of visual media that actively stimulate cognitive processes.

The main factors influencing the development of critical thinking include the design of learning activities, social interactions, and the media used during the learning process. Learning that employs problem-based approaches and interactive digital media, such as AR and digital student worksheets (LKPD), has been shown to enhance students' critical-thinking indicators significantly. Research findings indicate that learning strategies that involve direct exploration, drawing conclusions from data, and reflecting on observational results positively contribute to the development of students' analytical and evaluative skills (Daga et al., 2022; Sarıcan & Güneş, 2021). This ability is highly relevant to the Merdeka Curriculum, which emphasizes the strengthening of higher-order thinking as part of 21st-century competencies.

## METHODS

This study is a Research and Development (R&D) study that adapts the ADDIE model, comprising five stages: analysis, design, development, implementation, and evaluation. The research was conducted at UPT SD Negeri 067250 Medan during the even semester of the 2024/2025 academic year, focusing on IPAS learning in Grade V. The research participants included fifth-grade students, class teachers, and validators comprising subject-matter experts, media design experts, and language experts. The selection of subjects was purposive, based on their direct involvement in the media implementation process and their understanding of the human digestive system. Nine students participated in the small-group trial, whereas the field trial included all students from classes V-A and V-C, totaling 30 students. The sampling technique for students in the field trial used a convenience sampling approach based on students'



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readiness and availability during the learning process. The main objective of this study was the media product, an Augmented Reality (AR)- based Student Worksheet (LKPD) developed using the Assemblr Edu application, designed to enhance elementary school students' critical thinking skills on the topic of the digestive system.

Data collection in this study employed multiple techniques to obtain comprehensive information, including expert validation sheets, practicality questionnaires for teachers and students, classroom observations, and documentation during the implementation stage. The primary instrument was the validation sheet, which was developed using a four-point Likert scale ranging from 1 to 4, representing categories from "very inappropriate" to "very appropriate." The aspects assessed by the validators included content feasibility, language, presentation, and graphics. In addition, teacher and student practicality questionnaires were used to evaluate the extent to which the LKPD media was easy to use, engaging, and aligned with the learning objectives. The product trial was conducted in two stages: a small-group trial involving nine students from Grade V-C and a field trial involving 30 students from Grades V-A and V-C. Each implementation session consisted of two 35-minute meetings. The product feasibility assessment was based on the percentage interpretation standards outlined by Sani (2022) in *Metodologi Penelitian Pendidikan*, namely: very feasible (≥ 80%), feasible (60–79%), quite feasible (40–59%), and not feasible (< 40%). Data analysis was conducted quantitatively, using descriptive statistics, with percentage scores calculated according to the following formula.

$$Percentage = \frac{Score\ obtained}{Maximum\ score} \times 100$$

The resulting percentages were then interpreted according to predetermined criteria. This analytical technique was applied across all stages of validation, implementation, and evaluation to provide an objective assessment of the validity, practicality, and effectiveness of the AR-based LKPD media. The media development procedure in this study referred to the ADDIE model as outlined by Branch in his book "*Instructional Design: The ADDIE Approach"*, which consists of five systematic stages: analysis, design, development, implementation, and evaluation. The analysis stage began with the identification of learning needs, student characteristics, and the suitability of IPAS materials for Augmented Reality technology, based on curriculum studies and classroom observations. The design stage involved planning the LKPD structure, developing indicators for critical thinking skills, and selecting Assemblr Edu as the main media platform.

During the development stage, the LKPD was fully compiled and visualized using AR elements enabled by QR Codes. The initial product was then validated by three experts: a subject matter expert, a media design expert, and a language expert. The validation process used a four-point Likert scale assessment sheet. The product was considered feasible if the percentage score fell into the "feasible" or "highly feasible" category (≥ 60%). If any aspect scored below the standard, revisions were made in accordance with the experts' recommendations. Revisions included improvements to graphic design, alignment of content with the curriculum, language adjustments in accordance with standard Indonesian (EBI), and consistency in AR elements across all pages of the LKPD. The product deemed feasible was then tested during the implementation stage through small-group and field trials to assess its practicality and effectiveness in enhancing students' critical thinking skills.

## RESULTS AND DISCUSSION

### Analyze Stage (*Analyze*)


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The analysis stage is the foundational step in the media development process, aiming to identify learning needs and to align the curriculum with the development of AR-based student worksheets (LKPD). The needs analysis revealed that IPAS learning in Grade V at UPT SD Negeri 067250 continues to rely on conventional, teacher-centered methods, with minimal use of interactive learning media. Learning activities are dominated by verbal explanations and two-dimensional images, resulting in limited active student engagement in concept exploration. Classroom observations indicated that students possess strong visual and kinesthetic characteristics, enjoy activities involving visual manipulation, and are easily distracted during monotonous lessons. Based on interviews with the classroom teacher, students also demonstrated high enthusiasm for the use of technology in learning; however, digital-based learning facilities and resources are not yet optimally available. These conditions highlight the need for learning media that can facilitate interaction, concept visualization, and active student engagement directly through the integration of AR-based technology.

Curriculum analysis was conducted with reference to the Merdeka Curriculum, specifically for the fifth-grade IPAS subject. The basic competencies underpinning the development of the LKPD are students' ability to analyze the functions of the human digestive organs and to maintain digestive system health. The developed learning indicators include students' ability to identify the structure and functions of the digestive system, explain the process of food digestion, and evaluate healthy lifestyle habits that support digestive health. This material is highly suitable for AR-based development, as it enables interactive three-dimensional visualization of digestive organs, allowing students to observe, manipulate, and understand processes in concrete terms. The integration of IPAS content with AR technology through the Assemblr Edu platform is designed to reinforce conceptual understanding and promote students' critical thinking skills through exploratory and contextual learning experiences.

### Design Stage (*Design*)

The design stage was conducted after obtaining an overview of learning needs and students' characteristics during the analysis stage. The main activities at this stage included developing the instructional design, formulating learning objectives, determining teaching materials, and designing the AR-based LKPD structure using the Assemblr Edu application. The LKPD was designed to cover the human digestive system and comprises learning objectives, usage instructions, brief material summaries, activity steps, observation sheets, and reflective questions that guide students to think critically.

Visual design and interactive components were developed with attention to the integration of text, illustrations, and 3D objects displayed via QR codes. Each activity in the LKPD was designed using a scientific approach that integrated the observing, questioning, exploring, reasoning, and communicating phases. The design process also considered readability, layout neatness, and alignment with fifth-grade students' cognitive development levels. The main objective of this stage was to produce an LKPD design that facilitates active student engagement and promotes analytical and reasoning skills through immersive, digitally based learning experiences.

The initial design of the LKPD developed at this stage reflects the outcomes of the conceptual and visual processes, taking into account curriculum requirements, students' characteristics, and the potential of AR technology for IPAS learning. This design serves as the foundation for subsequent product development; therefore, it is essential to document the LKPD's structure, content, and appearance before validation and classroom implementation. **Figure 1** presents the initial appearance of the AR-based IPAS LKPD developed using the Assemblr Edu application.



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**Figure 1.** Initial View of the LKPD IPAS
*Source: Research 2025*

## Development Stage (*Development*)

The development stage began with the validation of the test instruments used to measure students' critical thinking skills. The instruments were designed as contextual essay questions based on material on the human digestive system, and they addressed critical-thinking indicators such as problem identification, analysis of arguments, evaluation of information, and drawing logical conclusions. The construction of the questions accounted for the characteristics of elementary school students and employed a contextual approach to stimulate reasoning and reflection. The detailed results of the instrument validation by each expert are presented in **Table 1**.

**Table 1.** Results of expert validation of the critical thinking ability instrument

| Aspect | Score Obtained | Maximum Score | Percentage (%) | Category |
|---|---|---|---|---|
| Question Instructions | 15 | 20 | 75.00 | Good |
| Material | 17 | 20 | 85.00 | Very Good |
| Question Structural | 22 | 25 | 88.00 | Very Good |
| Language | 14 | 15 | 93.33 | Very Good |
| **Total** | **68** | **80** | **85.00** | **Very Worthy** |

*Source: Research 2025*

**Description:**
Assessment scale: 1 = Poor; 2 = Less Good; 3 = Good; 4 = Very Good
Expert validator: Mr. HS (Instrument Expert)

The instrument validation process was conducted by two validators: a learning evaluation expert, a lecturer, and a classroom teacher with experience teaching the IPAS subject. The aspects assessed included the alignment of content with measurement objectives, the clarity of indicators, the accuracy of question wording, and the readability for students. Based on the validation results, the instrument achieved an average score of 94%, indicating very high validity. This indicates that the instrument is suitable for measuring critical thinking skills within the context of AR-based learning.

A subject-matter expert conducted content validation to assess the feasibility of the LKPD with respect to content accuracy, alignment with basic competencies, clarity of learning objectives, and the depth of


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material appropriate for fifth-grade students. Assessments were made based on 15 indicator items using a four-point scale. The recapitulated results showed that most aspects received a rating of "excellent," particularly for indicators related to the alignment between LKPD content and learning objectives and to the use of communicative language. The overall feasibility percentage reached 86.67%, which falls into the "highly feasible" category, as presented in **Table 2.** Nevertheless, the subject-matter expert provided several suggestions for improvement, including aligning the learning objectives with the official module's formulations, revising questions that did not fully reflect the follow-up activities, and restructuring the concept map to comply with proper structuring guidelines.

**Table 2.** Results of Material Expert Assessment

| Aspect | Score Obtained | Maximum Score | Percentage (%) | Category |
|---|---|---|---|---|
| Content/Material | 81 | 90 | 90.00 | Very Good |
| Presentation | 101 | 120 | 84.17 | Very Good |
| **Total** | **182** | **210** | **86.67** | **Very Worthy** |

*Source: Research 2025*
**Description:**
Assessment scale: 1 = Poor; 2 = Less Good; 3 = Good; 4 = Very Good
Validator: Prof. Dr. HS (Expert Lecturer); Prof. Dr. MS (Expert Lecturer)

Validation by media experts focused on the technical and aesthetic aspects of the LKPD, including visual design, page layout, visual integration, image quality, and the clarity of digital instructional navigation. The assessment also covered the integration of AR elements and the functionality of QR code features. The validation results indicated that this instructional media met the standards of visual feasibility and functionality, achieving an overall score of 82.5%, placing it in the very feasible category, as presented in **Table 3**. Nevertheless, the validators provided several suggestions for improvement, including a cover design and color composition that did not yet fully reflect the characteristics of elementary school students, the absence of an LKPD title in the table of contents, and inconsistencies in the typefaces used throughout the document.

**Table 3.** Design Expert Assessment Results

| Aspect | Score Obtained | Maximum Score | Percentage (%) | Category |
|---|---|---|---|---|
| Graphics | 107 | 130 | 82.31 | Very Good |
| Theme | 58 | 70 | 82.86 | Very Good |
| **Total** | **165** | **200** | **82.5** | **Very Worthy** |

*Source: Research 2025*
**Description:**
Assessment scale: 1 = Poor; 2 = Less Good; 3 = Good; 4 = Very Good
Validator: Prof. Dr. AHK (Expert Lecturer); Dr. Eng. M (Expert Lecturer)

Validation by a language expert was conducted to ensure text readability, accurate sentence structure, and appropriate language use in accordance with students' developmental levels. The assessment covered aspects of spelling, diction, clarity of instructions, and consistency of writing style across all sections of the LKPD. The validation results indicated that the language use met proper linguistic



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standards and was appropriate for the context of elementary education. The overall feasibility percentage was 83.33%, classified as very feasible, as shown in **Table 4.** The language expert also provided suggestions to improve sentence structure in several paragraphs that did not fully comply with the Indonesian Spelling Guidelines (EBI), and to correct inconsistent punctuation to align with standard writing conventions.

**Table 4.** Linguist Expert Assessment Results

| Aspect | Score Obtained | Maximum Score | Percentage (%) | Category |
|---|---|---|---|---|
| Accuracy with Indonesian language rules | 41 | 50 | 82.00 | Very Good |
| Language suitability to cognitive level | 34 | 40 | 85.00 | Very Good |
| Communicative | 18 | 20 | 90.00 | Very Good |
| Interactive | 32 | 40 | 80.00 | Very Good |
| **Total** | **125** | 150 | **83.33** | **Very Worthy** |

*Source: Research 2025*
**Description:**
Assessment scale: 1 = Poor; 2 = Less Good; 3 = Good; 4 = Very Good
Validator: Dr. AA (Expert Lecturer); Dr. SHH (Expert Lecturer)

### Implementation Stage (*Implementation*)

The implementation stage was conducted after the AR-based IPAS LKPD product was declared feasible by expert validators. The trial was carried out in two stages: a small-group trial and a field trial. The small-group trial involved nine fifth-grade students from class V-C, who were divided into three groups. The activity was conducted on May 26, 2025, in the school library, using Chromebooks and smartphones to access the QR codes embedded in the LKPD. Students participated fully in the learning process, starting from the introduction of the material to the reflection activities. The trial results indicated that the LKPD was highly practical, with an average practicality score of 88.18%. This assessment was based on four indicators: presentation (90.18%), ease of use (86.61%), attractiveness (88.57%), and the ability to promote critical thinking (87.38%).

A field trial was conducted to assess the practicality of the LKPD in a broader, more authentic learning context. The assessment was carried out by Grade V-A and V-C teachers at UPT SD Negeri 067250 Medan. The Grade V-A teacher received a score of 89.33%. In comparison, the Grade V-C teacher received 85.33%, resulting in an average teacher practicality score of 87.33%, which falls within the *very practical* category. The aspects evaluated included content feasibility, language use, material presentation, and media quality. Based on the overall results, the LKPD was deemed suitable for use in Grade V IPAS learning, as it effectively increased student engagement and fostered critical thinking skills.

### Evaluation Stage (*Evaluation*)

The evaluation stage in the development of the AR-based IPAS LKPD involved revising the product in response to validators' feedback and conducting a final feasibility assessment. The subject-matter expert recommended aligning the learning objectives with the teaching module, improving the wording of follow-up activity questions, and revising the presentation of concept maps that did not yet meet scientific representation standards. The design expert suggested improvements to the cover layout, the selection of colors appropriate for elementary school students, consistency in font usage, and the addition of the LKPD title to the table of contents. The language expert also provided feedback emphasizing the


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importance of revising sentence structure to comply with Indonesian spelling conventions (EBI), including corrections to punctuation.

The product's re-evaluation was conducted to assess its feasibility following refinement based on all feedback from the validators. The validation results showed that the subject matter expert assigned a score of 83.33%, the design expert a score of 86.67%, and the language expert a score of 86.67%. The overall average validation score was 85.56%, which falls into the *very feasible* category based on the feasibility interpretation criteria of ≥ 80% (Arikunto, 2021). These results indicate that the developed media meets the required standards for content, design, and language and is suitable for use in IPAS learning. The integration of AR technology through the Assemblr Edu platform was considered successful in presenting three-dimensional visualizations that optimally and interactively support students' critical thinking processes.

The evaluation was conducted to determine the effectiveness of using AR-based IPAS LKPD learning media through the Assemblr Edu application in improving students' critical thinking skills. The evaluation process involved comparing students' pretest and posttest results across five aspects of critical thinking, namely Elementary Clarification, Basic Support, Inferring, Advanced Clarification, and Strategies and Tactics. The test results showed significant improvements across all aspects following implementation of the LKPD. In the Elementary Clarification aspect, the pretest score of 62.50% increased to 80.36% in the posttest. A similar improvement was observed in the Basic Support aspect, which increased from 37.50% to 76.79%. The Inferring aspect also improved from 62.50% to 76.79%, while Advanced Clarification increased from 41.07% in the pretest to 83.93% in the posttest. Additionally, the Strategies and Tactics aspect rose from 35.71% to 80.36%.

These data indicate that the developed LKPD not only provides an interactive and engaging learning experience but also effectively encourages students to think deeply, construct arguments, evaluate information, and make logical decisions. The greatest improvement was observed in the *Strategies and Tactics* and *Advanced Clarification* aspects, which were previously categorized as low in the pretest. This finding suggests that the LKPD can strengthen students' strategic and reflective thinking, which are often challenging in conventional learning settings. Overall, the increase in scores across all critical thinking indicators demonstrates that the integration of AR-based interactive visual media into the LKPD has a tangible impact on improving students' cognitive quality. The activity design, which systematically facilitates exploration, discussion, and reflection, is a key factor contributing to the product's evaluative success in learning about the digestive system. The improvement is visualized in **Figure 2**.

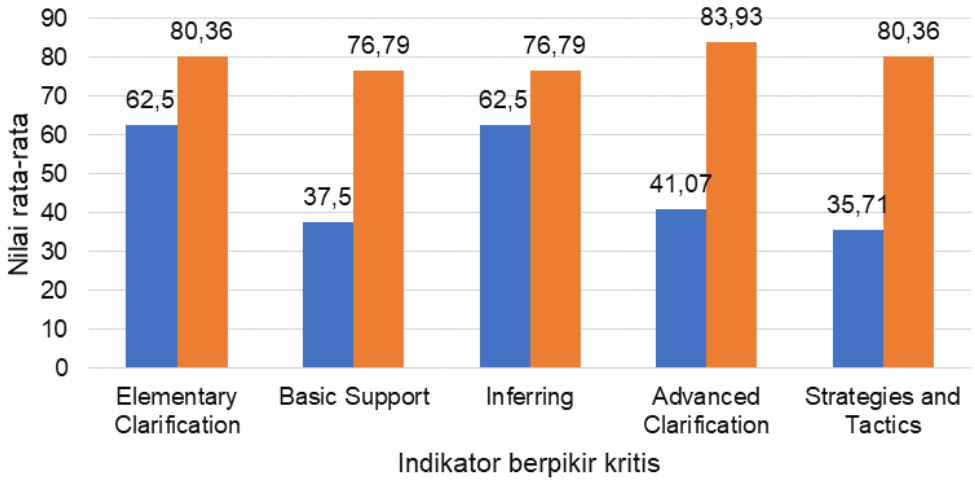


**Figure 2.** Percentage graph of the experimental group



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*Source: Research 2025*

## Discussion

Validation of the AR-based IPAS LKPD media yielded very high scores from four sources: subject matter experts (95.5%), media experts (90.6%), language experts (83.33%), and classroom teachers (93.7%). These scores indicate that the developed instrument meets the principles of content validity, presentation structure, and linguistic technicality consistently across evaluators. The high level of consistency among validators strengthens the inter-rater reliability, which is essential in the development of instructional media (Hidayat, 2024). According to the media feasibility standards established by the National Education Standards Agency (BSNP), products that achieve scores above 80% are considered eligible for use in learning activities. Qualitative feedback analysis revealed that several aspects, including cover design, font consistency, and the organization of concept maps, were improved in response to expert suggestions.

The practicality of the LKPD was demonstrated through limited and field trials, which yielded percentages of 88.18% from students and 87.33% from teachers. These data indicate that the media can be used independently and are easy to understand, with clear instructions and a logical sequence of activities. The practicality of the AR technology using Assemblr Edu was rated highly due to its accessibility via mobile devices and its engaging 3D visual integration (Ilafi et al., 2023; Maimuna et al., 2024). Differences in responses between teachers and students indicate that teachers tend to prioritize content usefulness, whereas students are more drawn to interactive visual elements. The suitability of AR implementation within elementary school infrastructure, such as internet connectivity and device availability, also contributes to its success.

The effectiveness of the LKPD is reflected in the results of the pretest and posttest evaluations. A significant improvement was observed in critical thinking aspects, including Elementary Clarification (62.5% to 80.36%), Basic Support (37.5% to 76.79%), Inferring (62.5% to 76.79%), Advanced Clarification (41.07% to 83.93%), and Strategies and Tactics (35.71% to 80.36%). The N-Gain value of 0.61 falls within the moderate to high category. The t-test results show a p-value < 0.05, indicating a statistically significant difference. These findings are supported by a meta-analysis indicating that AR-based learning media have effect sizes ranging from 0.65 to 0.89 for critical thinking skills and learning outcomes (Setiawan et al., 2024). Other studies indicate that AR-based learning can activate higher-order thinking through visual and exploratory representations. The use of AR in geography learning on the Solar System topic increased students' HOTS with an N-gain value of 0.58 (Ansori et al., 2025). Further studies also report significant improvements in elementary school students' critical thinking skills, particularly in clarification, inference, and argument evaluation (p = 0.0076), as well as increased interest in learning (Saki et al., 2025).

These findings are consistent with constructivist theory, which views learners as active agents in constructing knowledge through interaction with a contextual learning environment (Salsabila & Muqowim, 2024). The developed LKPD provides exploratory activities, group discussions, and independent reflection that strengthen cognitive engagement. From the perspective of multimedia learning theory, the integration of visual, spatial, and interactive elements in AR media supports the elaboration of information in long-term memory (Mayer, 2024; Vari et al., 2023). In addition, the structure of activities presented in the LKPD is based on task-oriented instructional design principles and a logical sequence that encourages deeper, more meaningful information processing. The integration of media with learning theories reinforces that the product is not only technically feasible but also pedagogically and conceptually relevant.

Data triangulation was conducted by confirming quantitative results, teacher and student responses, and observation findings during the trial implementation. The observation data indicated that students actively used the LKPD independently and participated in group discussions, thereby strengthening the validity of the questionnaire and test results. Cross-perspective validation involving teachers, students, and experts further confirmed that the developed product was not only feasible and practical but also pedagogically


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acceptable (Pigai & Yulianto, 2024). Augmented reality (AR) has been shown to enhance students' understanding of abstract concepts and increase their engagement (Hasannah et al., 2024; Nusroh et al., 2022). In addition, comparative studies have found that conventional LKPD tends to emphasize memorization, whereas AR-based LKPD encourages exploration and critical reasoning (Rahmayani et al., 2024). The development of LKPD to improve students' learning outcomes and competencies represents an effort to address gaps in the diversity of instructional media (Milala et al., 2024; Simanjuntak et al., 2025). This study occupies an important position in the field of technology-based instructional media development, particularly for elementary school students, for whom AR-based innovations have not yet reached widespread adoption.

The ADDIE model employed demonstrated effectiveness at each stage, particularly during the design and implementation phases. The analysis stage successfully identified learning needs; the design stage produced appropriate visual and digital media; and the evaluation stage indicated meaningful improvements in learning outcomes. These findings support modifying the ADDIE-based interactive model to enhance flexibility in digital media development, particularly AR-based media, to integrate technology into learning (Alfitriani et al., 2021; Najib & Suprihatiningrum, 2025). This process highlights that the development of technology-based media requires the involvement of multiple stakeholders, alignment between content and technology, and comprehensive validation to ensure optimal usability of the product.

The results of this study suggest that integrating AR technology into learning media, particularly AR-based LKPD, can significantly enhance elementary school students' critical thinking skills. AR-based interactive media not only increase student engagement but also support more contextual and exploratory learning processes. In practice, teachers can use AR-based LKPD as an alternative instructional medium to strengthen students' understanding of abstract concepts, such as the digestive system, thereby meeting the demands of the Merdeka Curriculum, which emphasizes active and reflective learning. Furthermore, the development of AR-based media has the potential to foster innovation in digital learning at the elementary school level, particularly in improving students' motivation and the quality of learning outcomes.

Although the research findings demonstrate success in terms of validity, practicality, and effectiveness, several limitations warrant careful consideration. First, the trial was conducted at a single school and had a small sample size; therefore, the findings cannot yet be generalized. Second, infrastructure limitations, such as device availability and internet access, may impede the successful implementation of AR-based media. Third, the effectiveness was measured only in the short term and did not include long-term effects on knowledge retention or transfer. These limitations serve as important reflections for further development.

## CONCLUSION

The development of an AR-based LKPD for the IPAS subject, using Assemblr Edu, on the topic of the digestive system has resulted in a product that is valid, practical, and effective in supporting the improvement of elementary school students' critical thinking skills. The validation process indicated that the instructional media met the criteria for content feasibility, visual appearance, activity structure, and language use in accordance with students' characteristics. The results of the practicality test and learning implementation indicated that the LKPD is easy to use and encourages active student engagement in the learning process. Improvements in critical thinking skills were observed across five main indicators, namely elementary clarification, basic support, inferring, advanced clarification, and strategies and tactics, with a significant increase in average posttest scores. The effectiveness of this AR-based LKPD demonstrates that integrating interactive and exploratory visual content into learning activities can meaningfully foster higher-order thinking.



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The developed product helps fill the gap in the availability of structured, applicable learning media, particularly AR-based media explicitly designed to develop critical-thinking indicators among elementary school students. The integration of a scientific approach, interactive technology, and the structured activities within the LKPD aligns this media with the demands of the Merdeka Curriculum while remaining relevant to the needs of reflective and contextual digital learning. Therefore, the findings of this study address the research problems and achieve the research objectives, namely, to develop an AR-based IPAS LKPD that is valid, practical, and effective in improving elementary school students' critical thinking skills regarding the human digestive system. However, this study remains limited, particularly by the narrow scope of implementation and the short-term measurement period. Consequently, further research is needed to include a broader population, examine long-term retention, and explore the effects of AR use on other cognitive domains, such as creativity and problem-solving. The development of additional interactive features and the integration of artificial intelligence into AR-based learning media may also serve as promising directions for future innovation.

## AUTHOR'S NOTE

The authors declare that there are no conflicts of interest related to the publication of this article. The authors affirm that the data and content of this article are free from plagiarism.

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