

Development of an E-Module Assisted by Augmented Reality on Digestive System Material to Improve Elementary Students' Critical Thinking Skills

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Received: April 27, 2026. Accepted: May 14, 2026. Published: July 02, 2026

Abstract: Digital teaching materials, such as e-modules in basic science that utilise technology, have not yet been implemented in learning, resulting in 56% of students having low critical thinking skills. This study aims to describe the development design and to test the feasibility and effectiveness of an Augmented Reality-assisted e-module to improve the critical thinking skills of V-grade students at SDN Pendrikan Lor 03, Semarang City. This type of research is Research & Development (R&D) with the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The research subjects were 25 V-grade students. The data collection technique used non-test methods (observation, interviews, questionnaires, and documentation) and test methods (pretest and posttest). The data analysis technique used normality tests, homogeneity tests, t-tests, and N-Gain tests. The feasibility of the e-module assisted by Augmented Reality is proven by the assessment of the material expert validator of 91% and the media expert validator of 95% in the very feasible category, supported by the results of the teacher response questionnaire analysis of 92.5% and the student response questionnaire of 90.3% in the very feasible category. The effectiveness of the e-module assisted by Augmented Reality is evidenced by an increase in pretest and posttest scores of 20.26, supported by a t-test result of 0.000, and an N-Gain score of 0.5314, which falls within the medium range. The research on the e-module assisted by Augmented Reality for the digestive system material was successfully developed, is very feasible, and is effective in improving the critical thinking skills of V-grade students at SDN Pendrikan Lor 03, Semarang City.

Keywords: Augmented Reality; Critical Thinking Skills; Digestive System; E-Module.

Introduction

Science learning is the interaction among learning components, a process that includes planning, implementation, and assessment of learning outcomes to achieve predetermined competency objectives. Science learning in elementary schools aims to develop students holistically, not only in the cognitive (knowledge) domain but also in the affective (attitude) and psychomotor (skills) domains. Ideal learning not only emphasizes mastery of theory, but also links it to practice through inquiry and experimental activities that actively involve students [1]. Ideal science learning provides students with the opportunity to conduct direct observations, experiments, and explorations of natural phenomena in order to build scientific understanding [2].

The scope of V-grade science learning includes light and sound, balance in ecosystems, magnetism and electricity, the shape of the earth, and living things and their growth processes. Learning that only presents material in the form of writing and pictures does not help students understand abstract concepts, such as the human digestive system [3]. According to Piaget's theory, students at the concrete operational stage learn more easily if assisted by real objects, clear images, or direct experience. This abstract digestive system material requires a teaching module that can make the abstract concept concrete.

Teaching modules are categorized into two categories: printed modules and electronic modules. Printed teaching modules present images and text that are less effective in supporting abstract learning into concrete learning. Electronic modules are systematic, stand-alone teaching materials in electronic format that contain animation, audio, and navigation, making them more interactive for users [4]. An electronic module, or e-module, is a book-style display of information presented electronically and can be read on a computer, laptop, or smartphone. A good learning e-module has several characteristics, including: Self-instructional (able to teach students independently), Self-contained (contains all learning materials), Stand-alone (not dependent on other media), Adaptive (has the power to adapt), and User-friendly (friendly to its users) [5].

Given these issues, a technology-based teaching module is needed to provide various benefits for students and to support their visual and audiovisual learning styles. The increasing use of technology development can be better because it allows the use of teaching modules containing materials, images, videos, quizzes and teaching aids that can be accessed online, which makes lessons more interesting and easier to understand [6].

The use of e-modules for human digestive system material can help elementary school students visualize the structure and function of digestive organs more clearly, so that abstract concepts can be presented in a more concrete

How to Cite:

A. Z. Kamila and A. E. Andriani, "Development of an E-Module Assisted by Augmented Reality on Digestive System Material to Improve Elementary Students' Critical Thinking Skills", *J. Pijar.MIPA*, vol. 21, no. 4, pp. 637–649, Jul. 2026. <https://doi.org/10.29303/jpm.v21i4.11970>

and easily understood form and encourage student involvement and independence in learning [7]. E-modules are designed as teaching materials that help students learn independently, with an attractive appearance and a clear structure. An e-module usually contains main components such as subject objectives, an introduction, learning activities, exercises, summaries, evaluations, and follow-ups, presented in an interesting and independent manner [4].

Based on the results of pre-research conducted at SDN Pendrikan Lor 03, Semarang City through observation, interviews, and questionnaires for science learning conducted with grade V teachers, it was found that teachers have not used technology based teaching materials and only sourced from textbooks from the Ministry of Education and Culture, and the use of technology by teachers is not optimal because it is only limited to videos taken from YouTube, so it has not adjusted the needs of students with learning materials. Student learning outcomes in science subjects remain relatively low, as evidenced by the final summative value, which shows that as many as 56% of students are below the Learning Achievement Criteria (LAC), indicating that this contributes to students' low critical-thinking skills in understanding learning materials. This is because the material on the digestive system is difficult to understand, namely, mechanical and chemical digestion, because it must differentiate where it occurs, and there are many new vocabulary and scientific terms that are still foreign to students' ears. This misconception is that the majority of students do not understand the difference between mechanical and chemical digestion, with a peak percentage of 57.14% [8]. In addition, the digestive system, which is abstract and occurs within the human body, cannot be seen directly with the eye, so it requires concrete visualization to help students understand the material.

This data is supported by the learning outcomes of V-grade students at SDN Pendrikan Lor 03, showing that the science subject has a low average. This is shown by the final summative results: among students with a minimum LAC of 75, 56% (14 students) are still below the LAC, while 44% (11 students) get a score above the LAC. Based on students' final summative learning results, the average ability at the end of the semester is relatively low. The students' low learning outcomes are caused by the-module used not facilitating problem-solving and abstract concepts [9].

Critical thinking skills are the ability to make objective and logical assessments regarding situations and information that lead to drawing conclusions and making the right decisions [10]. Critical thinking skills encompass several important aspects of science learning, such as connecting science concepts to real life and solving problems effectively. Students' thinking skills can be achieved by paying attention to 4 indicators, namely 1) Interpretation, 2) Analysis, 3) Evaluation, 4) Inference. These abilities can be achieved if the learning process is designed actively, contextually, and student-centered so that they are trained to think systematically, critically, and independently [11].

One potential alternative to answer the need is an e-module assisted by Augmented Reality (AR). According to [12] Augmented reality in the teaching and learning process can improve students' critical thinking skills. The use of AR can display 3D visualizations that can help students to understand each abstract object more realistically and clearly. At the same time, AR can support their own learning

process so that teachers can save time that would be used to explain the subject repeatedly [13]. Through AR technology, students can see three-dimensional models of organs and digestive processes, interact visually, and understand the relationship between parts of the human body system more concretely.

Relevant research, development of Interactive Electronic Modules for Problem-Based Learning on Human Senses of Vision and Hearing, was successfully developed with assessments from material experts, 92.5% very feasible criteria, and media experts, 90% very feasible criteria, supported by the results of teacher response questionnaires, 95% with very feasible criteria and 100% student responses [14]. Development of e-modules for science based on augmented reality and discovery learning for plant body parts material. Augmented reality has been proven to be effective in improving critical thinking skills [15].

Based on the problem identification, researchers developed an Augmented Reality (AR)-assisted e-module on the digestive system material by utilizing Assembler Edu as a 3D AR visualization media and a Gizmos Laboratory to support virtual practicums that apply science process skills. The development of this e-module includes the design of learning materials integrated with 2D visuals, AR-based 3D visuals, and audiovisuals in the form of learning videos, equipped with interactive live worksheets and quiz exercises using Google Forms, as well as educational games through Educaplay. This development presents a combination of concept visualization (Augmented Reality), virtual practical activities (laboratory gizmos), as well as worksheets (liveworksheets) and interactive evaluation (Google Forms and educaplay) in one AR-assisted e-module. Augmented Reality (AR)-based e-modules can improve students' scientific literacy aspects through high interactivity, immersive learning experiences, virtual simulations and experiments, and active involvement in the learning process [16]. AR technology allows students not only to understand concepts concretely but also to actively engage in the learning process, thereby encouraging critical thinking skills.

Research Methods

Types of research

This type of research is Research & Development (R&D), aimed at developing products, testing their feasibility, and testing their effectiveness. The development model used in this research is the ADDIE model.

Research Procedures

This research uses the ADDIE development model. The ADDIE development model is an extension of Analysis, Design, Development, Implementation and Evaluation [17]. The research design used in the effectiveness test was a pretest-posttest design, in which students were given tests before and after using the e-module, assisted by Augmented Reality, to assess improvement in critical thinking skills. The Analysis stage is related to activities analyzing environmental situations in the form of analyzing needs, student characteristics, the environment, and potential. The Design stage involves developing a product by designing e-modules, compiling

materials, and developing research instruments. The Development stage is conducting activities to test a product to be developed. This stage involves developing an e-module assisted by an Augmented Reality product, validating it with material and media experts, and making revisions based on their suggestions. The Implementation stage is the activity of using the developed product. The product will be tested with students in both small and large groups. The Evaluation is the final stage. A product assessment will be carried out to determine whether the product is suitable and can be accounted for, based on trial results and data analysis.

Research Subjects

The research subjects were 25 students, comprising 11 boys and 14 girls, in grade V at SDN Pendrikan Lor 03. The research began with a small-group test involving 6 students, selected using purposive sampling, namely, selecting participants based on specific criteria [17]. Purposive sampling was used, considering students' academic ability levels to represent the class's ability range. So the subjects in the small groups were categorized according to their level of understanding: two very proficient, two proficient, and two students who needed guidance, with the aim of obtaining initial input regarding the use of the e-module assisted by Augmented Reality. The large group test involved 19 students.

Research Instruments

The validity of the research instrument was examined through expert assessment. A questionnaire instrument comprising teacher and student responses was used to assess the product's practicality. Reliability analysis was conducted using Cronbach's Alpha, yielding a coefficient of 0.854, indicating good internal consistency. Pretest and posttest questions were used to measure students' critical thinking skills in aspects such as interpretation, analysis, evaluation, and Inference. The pretest and posttest included 20 multiple-choice items aligned with the learning objectives and students' critical-thinking skills, with 1 point awarded for each correct answer.

Data Collection and Analysis Techniques

Data collection techniques were divided into two parts: non-test (observation, interviews, questionnaires, and documentation) and one-group (pretest and posttest) to test one group. Data analysis techniques included normality tests, homogeneity tests, t-tests, and N-Gain tests to assess the effectiveness of the Augmented Reality-assisted e-modules.

Results and Discussion

This research focuses on the development, design, feasibility, and effectiveness of an e-module assisted by Augmented Reality on digestive system material.

E-module Assisted by Augmented Reality Design

The development design of this module uses the ADDIE development model, consisting of five stages:

Analysis

The analysis stage is an analysis activity of the work situation and environment, so that it can be determined what products need to be developed [17]. The aim of the analysis stage is to determine user needs and student characteristics to ensure the developed product is on target. This stage is the initial step in developing a product by identifying obstacles that arise in learning at school.

Researchers carried out pre-research stages, namely observation, interviews, questionnaires and documentation [17]. Location in class V SDN Pendrikan Lor 03 Semarang. Based on pre-research, the problem found in class V SDN Pendrikan Lor 03 is that the teacher has not used teaching materials technology-based learning, which is based on textbooks from the Ministry of Education and Culture, and teachers' use of technology is suboptimal because it is limited to videos taken from YouTube, thus not aligning student needs with the learning materials. Student learning outcomes in science remain relatively low, as evidenced by final summative scores showing that 56% of students are below the learning achievement criteria (LAC), which contributes to low levels of critical thinking.

The potential of SDN Pendrikan Lor 03 to support the learning process lies in the availability of fairly complete facilities. The facilities at SDN Pendrikan Lor 03 have a projector that can be used during the learning process, allowing teachers to deliver material visually and more interestingly. In addition, there are loudspeakers in each classroom to support the audiovisual material delivered by the projector. From these problems, researchers developed an e-module assisted by Augmented Reality to help in education and training with real simulations that approach real conditions [18].

Design

The design stage is the product design stage according to needs [17]. At this stage, researchers designed learning resources in the form of e-modules supported by Augmented Reality using Assembler Edu to enhance students' learning, increase student involvement, and improve independent understanding before entering the product development stage. Researchers compiled an initial framework as a prototype.

Researchers designed products based on the needs of teachers and students, using results from distributed questionnaires. The design process was adjusted to the students' characteristics. The products were designed using the Canva app. Canva makes it easy for someone to create the designs they want or need, such as creating posters, infographics, video templates, and presentations [19]. Researchers developed an e-module assisted by Augmented Reality using Assembler Edu. Assembler Edu is an application designed with an Augmented Reality concept that can construct 3D displays [20]. Therefore, researchers developed an e-module assisted by Augmented Reality, which provides complete facilities starting from the title page, instructions for use, learning instructions, learning outcomes, learning objectives, main material on the digestive system, live worksheets, practice questions, a glossary, a bibliography, and author profiles. Augmented reality makes it easier to visualize abstract objects in concrete forms

relevant to the digestive system topic. The uniqueness of this research lies in its book-like format, as it utilizes the Hyzine Flipbook app and a specially designed e-module assisted by Augmented Reality. Below are some images of the product development results.



Figure 1. Display of the e-module user manual

The e-module is presented in an attractive and easy-to-use digital book format. The page layout is neat and tidy, so students can read the material comfortably. This e-module is user-friendly, has a neat layout, unobtrusive color selection, and easy-to-read font size [21]. In addition, the Augmented Reality-assisted e-module is standalone, allowing students to open each section of the material systematically and independently. The use of navigation buttons or menus is made consistent so that students can easily move from one section to another. The e-module supports digital learning and improves students' learning skills [22]. This way, students become more active in managing their learning process, accustomed to exploring material independently, and are able to optimize the use of technology as an effective learning tool.

The e-modules presented outline the competencies to be achieved and the learning objectives. This is in accordance with the characteristics of the e-module, which are standalone because the e-module can be used independently without having to rely on other media or learning resources [21]. In this case, the module provides students with the opportunity to understand the learning flow independently by reading the learning objectives presented in the e-module. In the e-module, a concept map is displayed to provide an overview of the material to be studied. Through this concept map, students can see the relationship between topics in the learning. The visual media, such as concept maps, help connect concepts and understand the material [23]. This helps students understand the flow of the material before studying more detailed explanations.

The e-module, assisted by Augmented Reality, facilitates critical thinking by aligning learning outcomes and objectives with cognitive levels (C2, C4, and C5). In the e-module, there are components that do not stand alone, but are interconnected and influence each other: objectives, methods, tools, and assessments [24]. By considering these components, the e-module is expected to positively impact critical thinking skills.



Figure 3. Display of digestive system material in the e-module



Figure 2. Learning Objectives 1 and 2 Display

The digestive system material is presented in simple, easy-to-understand language. The material also includes visual elements (2D and 3D images) and audiovisuals (learning videos) to help students understand the functions and processes of each organ. This aims to reduce the excessive verbalism available in printed modules by providing a visual element using video tutorials [25]. With these illustrations, students can more easily understand the concepts being studied. The presentation of interesting and interactive material can increase student interest and understanding in learning [18]. This e-module is self-contained and contains the entire scope of learning materials. The digestive system material includes (definition of organ function, mechanical and chemical digestion, digestive disorders, and how to maintain digestive health).

To support students' critical thinking skills, e-modules assisted by Augmented Reality provide stimuli related to problems in the form of videos and images. Students will analyze the content of the problem and then answer questions based on their knowledge. Learning stimuli in the form of videos or images can encourage students' thinking skills because they contain contextual problems that

can encourage students to understand the problem, then analyze the problem in the form of the cause of the problem arising from the trigger question, then the evaluation by determining whether the action is right or wrong and what the impact is. With the stimulus, students can draw correct conclusions and use all relevant information to the problem [26].



Figure 4. Learning material display

The e-module, assisted by Augmented Reality, contains Lessons 1 and 2. In Lesson 1, there are two materials, namely the function of the digestive system organs and mechanical and chemical digestion. In Lesson 2, there are 2 materials, namely digestive disorders and how to maintain the health of the digestive organs. In the material on the function of digestive organs, researchers use AR assistance for each organ using the Assembler Edu application, which is easy to understand and can make complex and abstract concepts feel more real by presenting them directly in the classroom [27]. This is also in accordance with the characteristics of the e-module, which is standalone and can be used independently by students to obtain learning information.

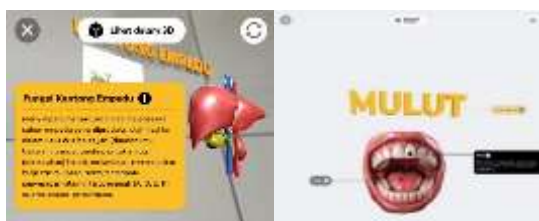


Figure 5. Augmented Reality display in e-module



Figure 6. Student activities using 3D AR in e-modules

In AR, using Assembler Edu, virtual objects representing digestive organs will appear when the camera scans a specific image (marker), accompanied by an

explanation for that organ. Based on observations of media use, students tended to direct the device to parts of the organ they considered not yet understood and to repeat the scanning process to deepen the information obtained. This activity shows that students indirectly regulate their own focus and learning needs. In this process, students not only receive information but also engage in observing, connecting organ parts, and analyzing the functions displayed. This e-module, assisted by Augmented Reality, supports interactive and adaptive characteristics. This means being able to adapt to developments in technology and science [21]. This condition significantly supports the development of critical thinking skills because students are trained to determine what needs to be learned and how to understand the information more deeply.

During the media implementation, it was evident that students were able to use AR without significant reliance on additional explanations from the teacher or other learning resources. Students simply scanned the provided markers to obtain the necessary visualizations and information. From there, students began to demonstrate initiative in exploring the material independently, such as trying to understand the order of the digestive organs or comparing the functions of different organs based on the information presented. Augmented Reality can develop students' critical thinking skills by supporting their ability to imagine and understand images, a skill known as visual literacy. Visual literacy uses skills as a toolbox and is a form of critical thinking that enhances intellectual abilities [28].

This process demonstrates that students are not simply following instructions, but actively constructing their own understanding through direct interaction with AR. Theoretically, this can be explained through a constructivist approach, which positions students as active subjects in constructing knowledge through direct experience. This supports independence in accessing and processing information in accordance with standalone characteristics [21]. Compared with conventional learning, which tends to rely on teacher explanations, the use of AR provides more space for students to engage in independent exploration and reflection on the information they obtain. This condition contributes to critical thinking skills, particularly in interpreting information, constructing understanding, and drawing conclusions from independent exploration.



Figure 7. Augmented Reality view of the small intestine in 3D and place it in the room

The use of AR in e-modules presents integrated learning components, from markers, three-dimensional object visualizations, to accompanying explanations in one complete system. Based on user experience, students have

no difficulty in finding additional information because all the necessary materials are immediately available during the scanning process. The use of AR technology is also able to visualize abstract objects more realistically, making them easier for students to understand [29]. This allows students to focus more on understanding the relationship between the form and function of the digestive organs. In addition, students can connect information across parts and evaluate their understanding through observation. The completeness and integration of this information indicate that the e-module assisted by Augmented Reality has self-contained characteristics. In relation to critical thinking skills, this condition enables students to conduct analysis, compare information, and draw logical conclusions.

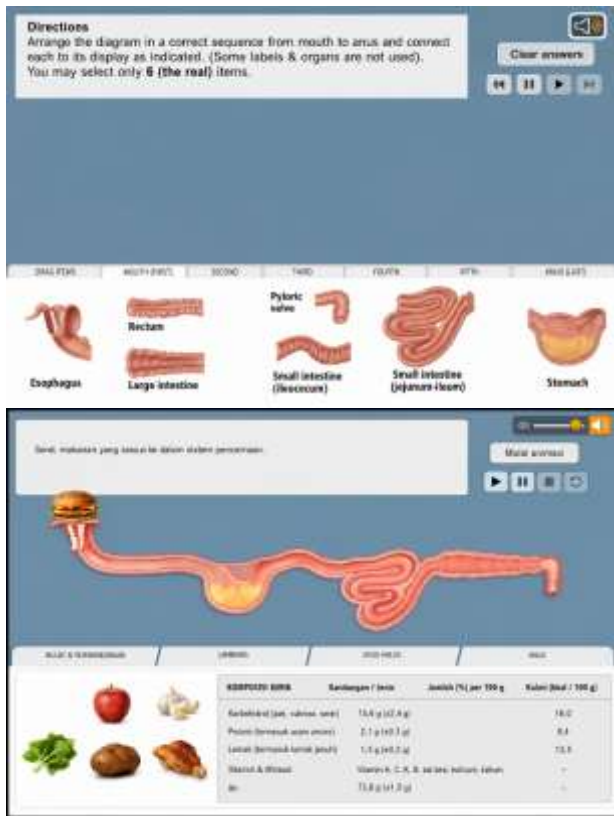


Figure 8. Gizmos Laboratory View

The Gizmos virtual laboratory helps students conduct digital learning simulations. The use of virtual laboratories such as Gizmos can increase student engagement and conceptual understanding through interactive visualizations and simulation-based learning experiences [30]. With this feature, students can observe digestive system processes more interactively. The use of this Gizmos laboratory supports the e-module, which is standalone, meaning students can conduct their own lab work anywhere using technology. The Gizmos Lab in this e-module supports the adaptive concept by utilizing virtual laboratory technology in the learning process. This activity makes learning more engaging and helps students better understand concepts.

Liveworksheets is a digital worksheet platform that students can work on directly. In this activity, students perform several activities such as arranging the digestive organs in order, matching concepts, and answering questions based on the video shown. The worksheet in the e-module is tailored to the existing material to support the e-module's

characteristic of being interactive and self-contained. Liveworksheets supports adaptive worksheet content aligned with current technological developments. An interactive worksheet has been proven to make learning more practical and effective because it provides varied and interesting digital activities [31].



Figure 9. Liveworksheets view in e-module

The e-module contains live worksheets with several features used, namely drag & drop, multiple choice, matching, and fill-in. The use of Liveworksheets in science classes at elementary schools has provided a more interesting learning experience, increased student motivation, and supported the early development of critical thinking skills [32]. This interactive worksheet supports critical thinking skills because it has features that facilitate the ability to understand problems by analyzing problem videos, then conducting evaluations, and drawing conclusions by writing the answer in it.



Figure 10. Google Forms and Educaplay Quiz View

At the end of the e-module, an evaluation quiz is administered via Google Forms and Educaplay. The use of Google Forms as a digital evaluation medium is considered effective for learning assessment because it simplifies

question compilation, improves efficiency, and enables a more interactive evaluation process [33]. This quiz contains several questions designed to assess students' understanding after studying the material. The quiz in this e-module is adaptive because questions that are usually presented only in printed form are updated using technology, namely the Educaplay quiz display. Researchers use the TTS (Crossword) feature, which provides a new experience for students. In addition, the quiz in the e-module supports stand-alone work, as students can work independently and receive corrections and feedback directly from their results.

Development

The development stage is the activity of making and testing the product [17]. This stage is achieved through the collection of materials and resources, which are then developed into an e-module assisted by an augmented reality product. After product development is complete, an initial trial or testing is conducted, *alpha testing*, to see whether the product is in accordance with the learning objectives [34]. The developed e-module, assisted by an Augmented Reality product, underwent a feasibility test through expert validation by media experts and subject matter experts. The validation results were used to refine the product for use or implementation with students. Validation during this development process was conducted twice until the product was declared suitable for use without revision.

Media expert validation is conducted by media experts to assess the feasibility of the developed e-module, particularly its visual and technical usability. Feedback from media experts serves as the basis for improving the product to make it more optimal, attractive, and ready for use in learning. Validation by media experts aims to obtain information, criticism, and suggestions so that the teaching materials developed by researchers become better products based on aspects of design, appearance, and use [35].

Material expert validation is conducted by professionals with a deep understanding of the material's concept and design. The validation stage, by material experts, evaluates the validity of the material aspects of the product being developed [36]. The material experts are tasked with ensuring that the content presented is in accordance with scientific principles, is systematically structured, and is relevant to the basic competencies in the curriculum. This validation process is carried out by experts in their fields, especially in the natural sciences. The results of this assessment are used to improve the product before it is tested in elementary school learning.

Implementation

Researchers carry out implementation, namely the stage where the learning products that have been developed begin to be applied in real learning situations [34]. This stage is carried out after conducting validation tests with media and material experts, meeting the "very worthy" criteria, and completing the revision stage. The implementation stage aims to determine how practical the product is to use, how well the learning is implemented, and how students react to the product. Implementation is carried out in two stages: small-group testing and large-group testing.

In the initial stage, product testing was conducted with a small group of 6 V-grade students at SDN Pendrikan Lor 03 on the use of the Augmented Reality-assisted e-module. Next was a large-group trial involving 19 V-grade students from SDN Pendrikan Lor 03, excluding those who had participated in the small-group trial. In this large group trial, the focus was on collecting data related to student responses seen from the results of the final assessment of the use of an e-module assisted by Augmented Reality with a wider number of students. The results of this trial were used as the basis for final revisions to improve the developed product.

Evaluation

The final stage in product development using the ADDIE model is evaluation. At this stage, the developed product will be measured. Evaluation measures the process as a means of reflection to refine teaching strategies to ensure they remain in line with student goals and needs [37]. Formative evaluation is carried out at each stage of development for the product refinement process, as well as through the distribution of questionnaires to teachers and students. Meanwhile, summative evaluation is conducted at the end of learning activities to determine student learning outcomes and measure critical thinking skills related to the material presented.

Table 1. Pretest and Posttest Results

Action	Average	Improvement
Pretest	60.79	20.26
Posttest	81.05	

Based on the data from the table, the average pretest score was 60.79, and the average posttest score was 81.05, an increase of 20.26. It can be concluded that there is a significant difference between the before and after periods when using the e-module assisted by Augmented Reality.

Feasibility of E-module Assisted by Augmented Reality

The feasibility of the e-module assisted by Augmented Reality is measured from 1) the results of the validity test by media and material experts, 2) the results of the teacher and student response questionnaire.

Table 2.Expert Validation Results

Expert	Percentage	Criteria
Material Expert	91%	Very Feasible
Media Expert	95%	Very Feasible

Based on Table 2, the validation results for the material expert are 91%, in the very feasible category, while those for the media expert are 95%, also in the very feasible category. The material expert validation questionnaire contains 4 assessment indicators, namely 1) Content feasibility, 2) Language, 3) Presentation, 4) Critical thinking skills with a total of 25 aspects, from 25 aspects the researcher obtained a content feasibility score of 95.8%, language of 83.3%, presentation of 96.8%, and critical thinking skills of 85% so that the average score gets a value of 91% and obtains the criteria of very feasible.

The media expert validation questionnaire contains 5 indicators, namely 1) Design appearance, 2) Ease of use, 3) Product consistency, 4) Product graphics, 5) Usefulness with a total of 25 aspects, the researcher obtained a design appearance score of 91.6%, ease of use 100%, product consistency 100%, product graphics 100%, critical thinking ability 85%, so that the average score gets a value of 95% and obtains the criteria of very feasible.

Table 3. Teacher and Student Response Results

Response	Percentage	Criteria
Teacher	92.5%	Very Feasible
Student	90.3%	Very Feasible

Based on Table 3, the teacher response questionnaire has a score of 92.5% with very feasible criteria, and the student response questionnaire has a score of 90.33% with very feasible criteria. Therefore, the e-module assisted by Augmented Reality is highly feasible for use in science learning about the digestive system for class V at SDN Pendrikan Lor 03 Semarang. This finding is supported by research on the e-module product: the module expert obtained a feasibility score of 97.5%, and the material expert obtained 86%. [38]. The results of other studies show that the e-module is very valid (the validity of the e-module is 94.2% and the validity of the material is 93.3%) and is very practical (teacher questionnaire 95.7% and student questionnaire 94%) [15].

Effectiveness of E-module Assisted by Augmented Reality

The effectiveness of the e-module assisted by Augmented Reality is measured using the results of the normality test, homogeneity test, paired-samples t-test, and N-gain test.

Table 4. Normality Test Results

Action	Sig	Criteria
Pretest	0.368	Normal
Posttest	0.423	Normal

Based on Table 4, the Shapiro-Wilk normality test with a decision criterion of Sig > 0.05 indicates that the data are normally distributed [39]. The significance assessment yielded 0.368 > 0.05 based on the Shapiro-Wilk normality test in the table, indicating that the pretest data met the normality assumption. Furthermore, the posttest data were normally distributed, with 0.423 > 0.05.

Table 5. Homogeneity Test Results

Data	Levene Statistic	df1	df2	Sig	Criteria
Based on Mean	0.998	1	36	0.324	Homogen

Based on Table 5 and the results of the homogeneity test for the large-group pre-test and post-test, the significance value for the mean is 0.324 > 0.05, indicating that the data variances are homogeneous. The homogeneity test is important in research because measuring the similarity of variance (homogeneity) is one of the important assumptions

that must be met before carrying out further analysis, such as the t-test or analysis of variance (ANOVA) [40].

Table 6. Paired Sample t Test Results

Action	Average	Improvement	Sig
Pretest	60.79	20.26	0.000
Posttest	81.05		

Based on information from Table 6, the results of the Paired Sample t Test show that the average pre-test score of the large group test is 60.79 and the average post-test score is 81.05, indicating an increase of 20.26. So there is a significant difference before and after using the e-module assisted by augmented reality. As the p-value is 0.000 < 0.05, H0 is rejected, and Ha is accepted. So there is a significant difference between before and after the use of the e-module assisted by Augmented Reality among grade V students at SDN Pendrikan Lor 03, Semarang City.

Table 7. N-Gain Results

Data	Score	Criteria
Average N-Gain	0.531	Medium

Based on Table 7, the N-Gain test result of 0.531 falls within the medium criteria. This indicates that the improvement between the pre-test and post-test falls within the medium criteria. This category indicates that the improvement in conceptual understanding is quite effective, meaning that learning using Augmented Reality-assisted e-modules significantly improves students' critical thinking skills, although it has not yet reached the high category. Previous research has shown that the use of innovative e-modules can improve elementary school students' understanding of critical thinking skills. The results of this study showed an N-Gain value of 0.531 after treatment, indicating a significant increase in conceptual understanding [41].

Critical Thinking Skills

Critical thinking skills are measured using critical thinking skills indicators (Interpretation, analysis, evaluation, and Inference) contained in the pretest and posttest questions, with the following results:

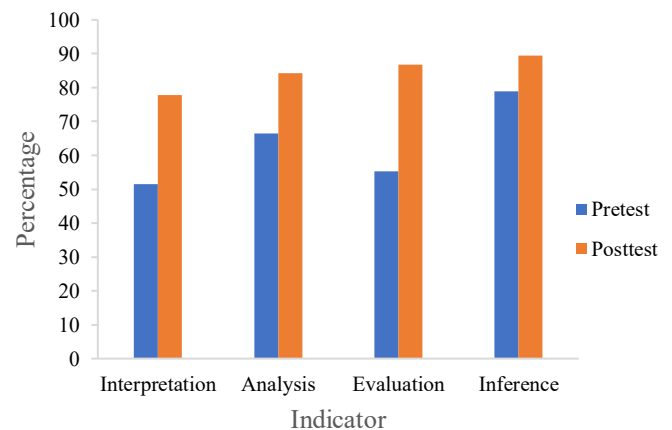


Figure 11. Pretest and Posttest Results Diagram

Figure 11 compares student results on four indicators of critical thinking skills between the Pretest and Posttest. According to Facione in [42] in solving problems, there are several aspects of critical thinking skills that must be achieved, namely interpretation, analysis, evaluation, and inference, by listing the percentage increase or decrease in scores for each indicator. In general, the study showed a significant difference in students' critical thinking skills after using an e-module assisted by Augmented Reality (AR). This is indicated by an increase in the average score from 60.79% in the Pretest stage to 81.05% in the Posttest stage, a 20.26% increase. These findings indicate that AR integration increases cognitive engagement and fosters students' higher-order thinking skills. This is in line with [43] who found that Project-Based Learning (PBL)-based e-modules were effective in improving the critical thinking skills of V-grade students. Both places students as active subjects in learning, which is key to the emergence of critical thinking processes. The difference is that this study highlights the role of concrete visualization through AR in helping students understand concepts more deeply, so that critical thinking processes are not only formed through activities, but also through strengthening conceptual understanding. This increase indicates that the use of e-module assisted by Augmented Reality has a positive contribution to the development of students' critical thinking skills.

The first indicator of interpretation, namely, questions that present information in the form of images, charts, or graphs, will train students to understand the meaning of the question and change it into a form that is easier to understand [44]. For this indicator, there was an increase from 51.5% on the pre-test to 77.8% on the post-test, representing a 26.3% rise, indicating that students are becoming better at identifying and understanding problems. Students with low critical thinking skills tend to be less able to meet the indicator of interpreting problems because they can only identify the facts provided in the question [45]. This can be overcome by presenting material in an interactive visual format through AR technology, which can make abstract concepts easier for students to understand. Theoretically, this aligns with constructivism, which views learning as an active process of constructing knowledge through experience [46]. Students do not simply receive information, but relate new knowledge to knowledge they already possess. In the e-module, Augmented Reality explains each digestive organ and its function in a more realistic and complete way. In this ability, the questions given are related to the digestive organs and their functions, as well as the stimulus given in each question that is linked to each digestive organ.

The second indicator of analysis is that students are able to describe information and connect relevant concepts [42]. This indicator increased from 66.4% in the pretest to 84.2% in the posttest, a significant increase of 17.8%. This is supported by an e-module assisted by Augmented Reality, which contains video stimuli with trigger questions related to human digestive disorders. In the e-module assisted by Augmented Reality, the material is presented with engaging visuals and audiovisuals. Furthermore, the use of liveworksheets train students' analytical skills, one of which is by using laboratory gizmos to conduct virtual experiments to arrange organ functions and simulate when food enters the body until it leaves the body, then students reassemble the

organs in sequence and independently by using the drag and drop feature in liveworksheets.

The third evaluation indicator shows the students' ability to evaluate information, assess accuracy, and consider various alternatives [42]. This indicator increased significantly from 55.3% in the pretest to 86.8% in the posttest, a 31.5% increase. This improvement in ability is inseparable from students' use of an e-module assisted by Augmented Reality, which allows for a more concrete and interactive understanding of the material. Furthermore, the use of live worksheets, Educaplay games and Google Forms as quizzes provide students with opportunities for independent practice and immediate feedback. The largest increase in this indicator suggests that AR-based learning not only supports conceptual understanding but also effectively fosters students' ability to critically evaluate information. This shows that direct interaction with visual representations and simulations allows students to compare, test, and validate the information they obtain, so that the evaluation process is not passive but is shaped by meaningful learning experiences. This finding is in line with research showing that Augmented Reality-based learning provides opportunities for students to be actively involved in analyzing information, evaluating various sources, and drawing conclusions independently as part of the critical thinking process [47].

The fourth indicator of Inference is presenting information and asking students to identify its relationship to inductively draw conclusions from the answer options [48]. This indicator increased from 78.9% in the pretest to 89.5% in the posttest, with a relatively lower increase of 10.6% compared to other indicators. However, this still shows that students are increasingly skilled at drawing conclusions from observations and analyses. The use of Augmented Reality can measure the extent to which students analyze information, develop opinions, and draw conclusions [49]. Further learning that supports students in achieving this ability is drawing conclusions in live worksheets. In the first lesson, students complete the mission. After they have completed their understanding, analysis, and evaluation, in mission 4 they formulate conclusions in their own words to answer several questions. In the second lesson, students also complete several stages, including four videos on digestive disorders that test their problem-solving, analysis, and evaluation skills. Students are then asked to draw conclusions from the videos and apply solutions.

The process and results of students' critical thinking skills are influenced by two main factors, namely internal factors and external factors, influenced by learning readiness [50]. Basically, learning readiness has a positive effect on students' abilities [51]. In addition, differences in learning styles influence student learning outcomes [52]. Meanwhile, the measured ability also has an effect: critical thinking through question evaluation. Critical thinking skills are high-level thinking skills that require reasoning and analytical processes in solving problems [53]. Therefore, although there is an increase from pretest to posttest, the results remain in the medium category. Thus, it can be concluded that the development of an Augmented Reality-assisted e-module on digestive system material is effective in improving the critical thinking skills of class V students at SDN Pendrikan Lor 03, Semarang City.

The results of this study indicate that an e-module assisted by Augmented Reality is effective in improving students' critical thinking skills, especially in the aspects of problem understanding, analysis, and drawing conclusions. Learning by implementing an Augmented Reality-based science e-module helps students to understand concepts and learning materials, so that they can have a big influence on improving critical thinking skills [15].

Conclusion

The results of the study indicate that the development of an e-module assisted by Augmented Reality on the digestive system material has been in accordance with learning needs, with an emphasis on the use of AR as a key feature that helps students visualize organs and digestive processes more concretely and interactively through links or barcode scanning. This e-module is also supported by interactive media such as Gizmos, Liveworksheets, Google Forms, and Educaplay, which increase student engagement and independence. The e-module, assisted by Augmented Reality, received a very decent assessment from material experts (91%) and media experts (95%), as well as from teachers (92.5%) and students (90.3%), placing it in the very decent category and indicating excellent product quality that can be used in learning. The trial results also showed a significant increase from pre-test to post-test scores, with the average score rising from 60.79 to 81.05 (20.26 points), and an N-Gain of 0.531 in the medium category, indicating that the e-module is effective in improving students' critical thinking skills. The implications of this study indicate that an e-module assisted by Augmented Reality can be used by teachers as an interactive and student-centered learning innovation, and can serve as a reference in the development of digital teaching materials in schools. However, this study has limitations: a small number of subjects, a single school, and reliance on a virtual gizmos laboratory that provides free simulations for only 5 minutes per day, thus limiting students' time to optimally conduct practicums. Therefore, further research is recommended to involve a wider range of subjects, test other materials, and use a virtual laboratory with more complete features and more flexible time. The conclusion of the research on an e-module assisted by Augmented Reality on digestive system material was successfully developed, very feasible, and effective in improving the critical thinking skills of V-grade students at SDN Pendrikan Lor 03, Semarang City.

Author Contribution

A. Z. Kamila: contributed to product development, data analysis, and is the primary author of this article. A. E. Andriani: contributed to compiling and revising the research results.

Acknowledgments

The researcher would like to express her gratitude and appreciation to the Elementary School Teacher Education Study Program, Faculty of Education and Psychology, Semarang State University, for the academic support provided. The author would also like to express her gratitude to Mrs. Aldina Eka Andriani, S. Pd., M. Pd., as her supervisor who has provided direction, advice, and motivation throughout the research process. The researcher

would like to express her gratitude to the parents for their prayers, attention, and support. Thank you to the principal, teachers, educational staff, and all students of SDN Pendrikan Lor 03 for the opportunity, assistance, and cooperation that ensured the successful completion of this research.

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