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E-Learning Materials Assisted by Augmented Reality in the Subject of Natural Sciences, Circulatory System Material for Grade V Elementary School

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Abstract: Natural and Social Sciences (IPAS) at the elementary school level still faces a number of challenges that affect the achievement of student learning outcomes. This study was conducted using a research and development (R&D) method based on the Borg and Gall model with the aim of developing and testing the feasibility, practicality and effectiveness of e-learning materials assisted by augmented reality (AR). Researchers collected data using test techniques (pretest-posttest) and non-tests in the form of observations, interview results, surveys and document data. The e-learning materials assisted by AR developed by researchers obtained very feasible criteria results from material, media and language validator experts. E-learning materials assisted by AR have proven effective in improving student learning outcomes, as seen from the increase in the average score between the pretest and posttest achieved by students so that a high N-gain score of 0.76 can be obtained. Based on the results of the questionnaire responses given, very positive responses can be obtained from teachers and students. From these results, it can be concluded that AR-based e-teaching materials are declared feasible and practical to use and effective in improving student learning outcomes in the subject of science with the topic of the circulatory system in class V of SD Negeri Ngaliyan 03.

Keywords: Augmented reality; Circulatory system; E-teaching materials; Science

Introduction

According to the Minister of Education and Culture Regulation Number 47 of 2023 concerning the standards for managing early childhood education, elementary education levels and secondary education levels in Article 7 paragraph (3) it is stated that learning programs are arranged flexibly, clearly, and simply according to the context and characteristics of students. However, in reality in the field there is still learning whose teaching materials have not been designed according to the characteristics of students, plus the existing learning media have not been designed effectively to help understand the material, especially about the human circulatory system. Several previous studies also support this statement. Rogti (2024), stated that the use of media such as interactive multimedia that adapts to the characteristics of students has not been used because teachers do not integrate technology into the learning process. This condition makes grade V students at SD Negeri 1 Banjarejo easily bored and less motivated, especially if the teacher only uses the lecture method without being accompanied by interesting teaching materials (Hollister et al., 2022). This shows that the lack of teacher creativity can cause boredom and boredom in students due to minimal motivation in the learning process. To increase students' learning motivation, teachers' creativity is needed in designing simple and

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easy-to-understand teaching materials, as well as implementing interactive learning methods, such as educational games, discussions, presentations, questions and answers, and other approaches that can encourage motivation as well as improve students' learning outcomes.

Based on the results of interviews, questionnaires, and analysis of the list of grades of fifth-grade students at SDN Ngaliyan 03, SDN Ngaliyan 05, and SDN Tambakaji 04 as sample elementary schools in the Anggrek Cluster, Ngaliyan District, Semarang City. Researchers identified various problems in the learning process, one of which is that teachers use teaching materials that are less appropriate to the characteristics of students. This can be seen from the results of observations of learning assessments, where teachers deliver material using teaching materials that are difficult for students to understand, thus hindering their understanding of the material presented. Based on the results of interviews with teachers and data from questionnaires filled out by fifth-grade students at sample elementary schools in the Anggrek Cluster, the teaching materials used by teachers are diverse, in addition to utilizing teacher books, student books, and LKS, teachers also rely on learning resources from the internet. However, in compiling teaching materials from materials taken from the internet, teachers have not fully adapted the material into a language that is easy for students to understand.

Research by Teplá et al. (2022), supports this, from the results of interviews with teachers showing the lack of teachers in visualizing abstract material on the topic of the circulatory system, which affects the cognitive outcomes of students. Therefore, this material requires teaching materials that can be easily understood by students. In addition, the reality in the field, researchers found that teaching materials regarding the material on the circulatory system were not included in the teacher's book or student's book. In addition, in field observations when teachers carried out teaching and learning activities, they did not provide reaffirmation regarding the material that had been explained through learning videos from the YouTube platform. This can have an impact on student learning outcomes, where there were 12 out of 28 students, or 43%, who did not achieve the KKTP score of 75. In the learning media used by teachers, researchers also found a problem, namely the absence of concrete learning media related to the material on the circulatory system at SD Negeri Ngaliyan 03. This is also supported by the results of a questionnaire filled out by students, which showed that 48% of students stated that teachers only sometimes use learning media. In fact, based on the questionnaire filled out by students, 39% of students considered the use of learning media to be influential in helping to understand the material being studied. This was also reinforced by the results of interviews with teachers where the use of learning media was indeed only for certain materials. Meanwhile, based on the questionnaire filled out by students, the results showed that 26 out of 28 students had smartphones that should be used by teachers to provide more effective teaching materials and learning media, as well as provide clearer visualizations of the material on the human circulatory system.

Parents of students also support the use of smartphones in the learning process at school. This can be seen from the results of the questionnaire in Gugus Anggrek regarding permission to use smartphones at school with teacher supervision. Of the 57 parents, 53 parents agreed with the use of smartphones for learning tools at school with teacher supervision and only 4 parents disagreed. This will certainly have a positive impact on student productivity, compared to only being used for playing games and socializing on media. Based on the results of the questionnaire distributed to fifth grade students at SDN Ngaliyan 03, it was revealed that 14 out of 25 students used their smartphones to play games, 6 people for social media, and 1 person to watch YouTube. of course this is very unfortunate, plus based on the questionnaire that has been filled out by students, it shows that 12 students spend time playing smartphones for around 2-4 hours and 7 students spend more than 4 hours using smartphones.

The main source that supports the learning process is teaching materials (Ribosa & Duran, 2022; Van Dulmen et al., 2023). Without teaching materials, teachers will face challenges in achieving learning objectives. Therefore, it is very important for teachers to prepare teaching materials to ensure the smooth implementation of learning. Teaching materials, or learning materials, include three main elements: knowledge, skills, and attitudes that need to be mastered by students to meet the established competency standards. In more detail, learning materials include knowledge (facts, concepts, principles, procedures, and skills), values, and attitudes (Aisyah et al., 2020), This is in line with the study entitled "Analysis of Teaching Materials" which explains that teaching materials can also be interpreted as all forms of materials that are systematically arranged to facilitate students in learning independently, with a design that is adjusted to the applicable curriculum. (Tong et al., 2022). E-teaching materials are one of the teacher's efforts to provide learning that adapts to the characteristics of students. Digital e-teaching materials are teaching materials that are presented in digital format and designed for use in electronic devices.

E-Materials facilitate student access in carrying out learning activities (Hunaidah et al., 2022). Student learning outcomes increase due to the ease of learning when using e-teaching materials in learning (Arsita & Astawan, 2022; Haryono et al., 2023). E-teaching materials can increase student enthusiasm in learning so that it also increases student interest in learning (Susanti et al., 2022). This is because e-teaching materials contain assistance such as images that make it easier for students to understand abstract material (Haleem et al., 2022). learning contained in learning outcomes is not all listed in the teacher's book or student book that has been made by the Ministry of Education. One of them is the material on the human circulatory system in the subject of science. Therefore, to help provide understanding and enable students to visualize the material well, an educational technology is needed that can present visualization of the material effectively, namely augmented reality. Augmented reality is defined as "physical reality in which participants also see virtual elements." This means that AR is a system that utilizes technology to add virtual elements to physical reality, so that users can see these virtual elements in the context of physical reality.

AR includes not only the use of virtual elements that do not interact with reality, but also virtual elements that can interact with users and the surrounding environment (Rauschnabel et al., 2022; AlGerafi et al., 2023). This reflects the goal of AR as a technology that can enhance the user experience by utilizing relevant and interactive virtual elements in physical reality (Arena et al., 2022). This is in line with the study entitled "Enhancing Elementary School Students' Abstract Reasoning in Science Learning through Augmented Reality-Based Interactive Multimedia" which shows that the use of AR-based interactive multimedia can improve students' abstract reasoning abilities at the elementary school level. Students who use AR-based interactive multimedia show a more significant increase in abstract reasoning abilities compared to students who do not use AR-based interactive multimedia (Kharisma et al., 2023; Festiyed et al., 2023). Augmented reality (AR) is one of the learning media that utilizes three-dimensional animation to present learning materials more interactively.

Science learning media that uses a 3-dimensional animation model will offer several visualizations of science lessons. So that this learning media in science learning in elementary schools can make it easier for students to learn in a fun way (Hendajani et al., 2019; Tiwari et al., 2024). The novelty of the teaching materials that will be developed by researchers is that e-teaching materials will be equipped with the help of augmented reality which will later be used for grade V elementary school students. E-learning materials assisted by augmented reality will contain material on the circulatory system in the form of an e-book by including barcode images to display augmented reality to be scanned and accessed through the assembler edu application which allows students to visualize the heart organ in 3D. In its implementation, students can use an Android device as a barcode scanner, which can be used to access e-learning materials assisted by 3D augmented reality with the ability to zoom, rotate up to 360 degrees, and see details from various sides of the heart organ and the large and small circulatory system in humans.

The use of augmented reality allows objects that are difficult for students to understand to be visualized more easily, so that it can make it easier for teachers to convey material to students (Maulida et al., 2024). Based on the description above, the purpose of the research conducted by the researcher is to provide solutions to several problems found by developing electronic teaching materials with the help of augmented reality technology. The e-learning materials developed were also tested for feasibility, practicality and effectiveness. This is done in order to see how feasible the e-teaching materials developed by researchers are before being given to students and teachers, then how practical the e-teaching materials developed by researchers are when used by students and teachers, and finally to see how effective the e-teaching materials assisted by augmented reality are in improving student learning outcomes.

Method

This study uses the Research and Development (R&D) method. That "Research and development is a research method that aims to produce a particular product and test the effectiveness of the product." The purpose of this study is to create a product in the form of effective e-teaching materials for grade V students at sample elementary schools in Gugus Anggrek, Ngaliyan District, Semarang City regarding the material on the human circulatory system. The researcher carried out the development according to the procedure developed by (Snyder, 2019), This study refers to the Borg & Gall model which consists of 10 steps, but only uses 9 stages, namely: Identification of potential and problems, Data collection, Product design, Design validation, Design revision, Product trial, Product revision, Usage trial, and Product revision. The research scheme can be seen in Figure 1.

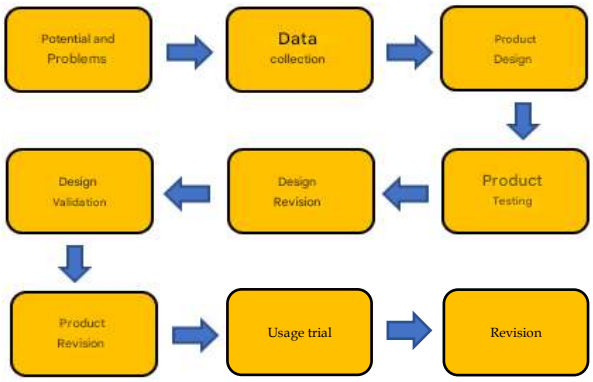

Figure 1. Modified from Borg & Gall Model

In the first stage, the researcher conducted observations to identify potential and problems in the school through observation, interviews, and data collection from grade V elementary school students in Gugus Anggrek. After that, the data was analyzed, and references were sought in order to design a product that would be developed to suit the needs of grade V elementary school students in Gugus Anggrek. After the product was designed, the researcher validated the augmented reality-based e-teaching materials by involving material experts, language experts, and media experts who provided assessments by filling out validation sheets using a Likert scale. The next stage was to revise the product based on input from experienced validators so that the product was ready to be tested. After the revision stage was complete, the product was then tested on a small scale in grade VI of Ngaliyan 03 Elementary School consisting of 15 students using a deliberate sampling technique based on different levels of cognitive ability.

In the small-scale test stage, students were first given the opportunity to use the media, then asked to fill out a response sheet related to their experience in using Augmented Reality-assisted e-teaching materials to determine the level of practicality of the product. Students were then given 50 pretest questions which were then continued with teaching and learning activities using e-teaching materials assisted by Augmented Reality. After the learning was given, students were given posttest questions again. In the small-scale test stage, the researcher aimed to evaluate the level of practicality and effectiveness of the product being developed. In addition, validity and reliability tests were carried out. After the validity test was completed, the researcher conducted a difficulty test to measure the level of difficulty of the questions. This difficulty level test was carried out using SPSS. level of difficulty, and the discrimination power of the questions to ensure the validity and consistency of the questionnaire that will be used in the large-scale test. A summary of the results of the item analysis is presented in table 1.

Table 1. Summary of Item Analysis Results

Analysis Criteria	Analysis Results
Question Validity	30 valid questions with coefficient value > 0.514
Question Reliability	Cronbach's Alpha Coefficient = 0.969
Difficulty Level	6 questions: Easy category
Discrimination Power	19 questions: Medium category
Conclusion	5 questions: Difficult category

A large-scale test was conducted on 25 fifth-grade students of Ngaliyan 03 Elementary School in the 2024/2025 academic year. This test aims to evaluate the effectiveness and practicality of the product developed based on student learning outcomes. The implementation procedure is similar to the small-scale test, but there are differences in the number of pretest and posttest questions used. Product effectiveness was analyzed using pretest and posttest data through normality tests, t-tests, and N-gain tests. The results of this analysis are used to determine the extent to which the product is able to improve student learning outcomes.

Result and Discussion

Potential and Problems

Based on the results of the initial study, several problems were found, namely the teaching materials used by teachers are quite diverse, in addition to teacher books, student books, and LKS, teachers also utilize learning resources from the internet. However, in taking material from the internet where teachers often use the YouTube platform, it has not been adapted into a language that is easy for students to understand. In addition, in field observations, teachers did not provide reaffirmation regarding the material that had been explained through learning videos from the YouTube platform. Furthermore, researchers observed that in the teacher's book and student book published by the Ministry of Education and Culture, material on the circulatory system was not explained specifically. The material was only inserted in the discussion of the human respiratory system and the human digestive system. This can be seen from the learning outcomes of students, where there were 12 out of 28 students or 43% who had not reached the KKM, which was 75.

Initial Data Collection

Researchers collected initial data by distributing questionnaires to teachers and students to find out their needs. Based on the results of data collection, it was found that material on the human circulatory system was not found in the teacher's book or student book. In addition, there is no concrete media that supports learning about the human circulatory system in sample elementary schools in the Anggrek Cluster. This will certainly make it difficult for teachers to convey material to students. The lack of visualization of science material through real and clear learning media can make students feel bored and lose their enthusiasm for learning. Students will certainly be more interested and understand better if they use teaching materials that are new, which will certainly provide something new that is more fun and of course will have more complete material and of course students can visualize the learning material being studied. For this reason, researchers are developing teaching materials that are expected to provide deeper and more effective meaning for students.

Teaching materials will be combined with technology as a learning medium that is not concrete but can visualize an object in the material being studied by students into the real world. This is expected to help students understand the material better and make learning more meaningful. Based on the questionnaire filled out by students, the results showed that 96% of students have smartphones that should be able to be used by teachers to provide learning media that provide more visualization of material that is considered too abstract for students such as the material on the human circulatory system. However, of the 96% of students who have smartphones, 75% still have not optimized their smartphones for learning. This certainly should be optimized by teachers for learning because parents of students also support the use of smartphones in learning at school. This can be seen from the results of a questionnaire in Gugus Anggrek regarding permission to use smartphones in schools with teacher supervision. As many as 93% of parents agree with the use of smartphones for learning facilities at school with teacher supervision and only 7% of parents disagree. Thus, the reality in the field strongly supports the development of e-teaching materials assisted by augmented reality on the material of the circulatory system which is expected to be able to overcome problems that occur in the field.

Product Design

E-teaching materials assisted by augmented reality are designed based on learning achievements and learning objectives to be achieved in grade V. This e-teaching material is made with complete material notes with images and augmented reality where the teaching material has been adjusted to the characteristics of students, so that it is easy to understand and can increase student motivation and learning outcomes. This e-teaching material was created by starting with preparing the material, format and layout to be used, followed by creating a product design using several applications. For the design of the e-teaching material, the researcher used Canva, while for the 3D Augmented Reality object we used the assembler edu application. Furthermore, the researcher combined the results of the 3D augmented reality object that was exported into a QR code into the e-teaching material in Canva. The final product of this e-learning is an e-teaching material which will later be in the form of a QR code where this e-teaching material will be scanned using a smartphone. Where it is also equipped with an augmented reality QR code. This e-teaching material consists of a title page, application instructions, table of contents, concept map, material explanation, conclusion, glossary, bibliography and author profile.

Figure 2. Title Page


KATA PENGANTAR

Puji syukur kami panjatkan ke hadirat Tuhan Yang Maha Esa, karena atas rahmat dan karunia-Nya, penyusunan bahan ajar ini dapat diselesaikan dengan baik. Bahan ajar ini disusun sebagai bahan ajar dalam mata pelajaran Ilmu Pengetahuan Alam (IPA) untuk kelas V Sekolah Dasar (SD), dengan fokus pada sistem pencernaan manusia.

Tujuan dari penyusunan bahan ajar ini adalah untuk membantu siswa memahami proses dan fungsi sistem peredaran darah manusia secara lebih interaktif dan menarik. Dengan adanya gambar, animasi, dan penjelasan yang sederhana, diharapkan siswa dapat lebih mudah memahami materi ini dan dapat meningkatkan minat belajar mereka.

Kami mengucapkan terima kasih kepada semua pihak yang telah membantu dalam penyusunan bahan ajar ini, terutama kepada para guru dan teman-teman yang telah memberikan masukan serta dukungan. Semoga bahan ajar ini dapat bermanfaat bagi para siswa dan menjadi sumber belajar yang menyenangkan serta bermanfaat.

Kami menyadari bahwa bahan ajar ini masih jauh dari sempurna, oleh karena itu, kritik dan saran yang membangun sangat kami harapkan guna penyempurnaan bahan ajar ini di masa mendatang.

Akhir kata, kami berharap bahan ajar ini dapat memberikan kontribusi positif dalam proses pembelajaran siswa. Semoga Tuhan Yang Maha Esa selalu memberikan rahmat dan hidayah-Nya kepada kita semua.

Semarang, 6 Juni 2024

Tri Andika Rahman

Figure 3. Foreword Page

Figure 4. General Information Page

Figure 5. Application Instructions Page

Figure 6. Table of Contents

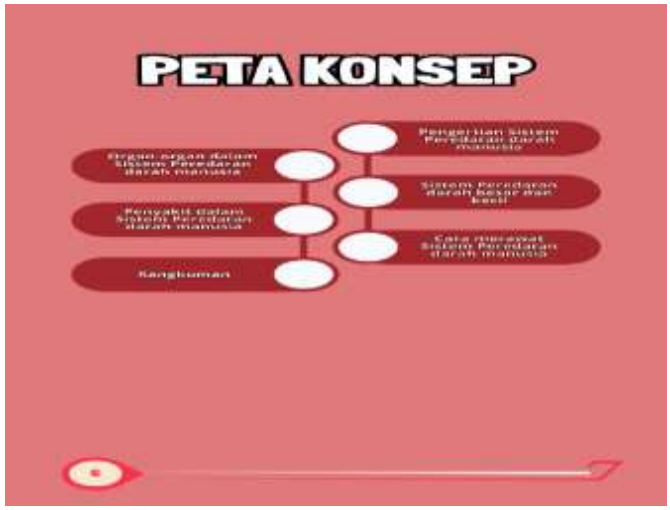

Figure 7. Concept Map

Figure 8. Material Explanation

Figure 9. Summary and Glossary

Figure 10. Bibliography

Figure 11. Author Profile

Product Feasibility

At this stage, researchers will validate the product by involving validators who have expertise in their fields, such as media experts, material experts, and language experts, to evaluate the feasibility of the product before being tested in the field. After being viewed by the validator, there are several inputs for the product being developed. Learning media will enter the criteria that are very feasible if the score is 76%-100%, quite feasible if the score is 51%-75%, quite good if the score is 26%-50% and not feasible if the score is 0%-25%. A summary of the validation results for each assessment component is presented in table 2.

Based on the results of the validator assessment presented in Table 2, e-teaching materials with the help of augmented reality are very feasible in terms of material, language and media. So that e-teaching materials with the help of augmented reality can be tested in the field.

Table 2. Expert Validator Research Results for E-Learning Materials with Augmented Reality Assistance

Section	Media Values	Material Value	Language Values
Total Score	76	71	42
Maximum Score	80	80	52
Presentation	95%	88%	80%
Criteria	Very Worth It	Very Worth It	Very Worth It

Design Revision

After the e-teaching materials are validated by experts, the researcher will revise the product according to the suggestions and input given by the validator experts to improve the quality and suitability of the product to learning needs. In the media expert, there are several additions to the e-teaching materials assisted by augmented reality developed by the researcher. The media expert provides suggestions, namely adding learning outcomes and learning objectives on the home page after the foreword page. Then add suggestions for the font in the right atrium in augmented reality to be changed to a dark color to make it more visible. The material expert provides suggestions for adding material for the characteristics of human blood circulation. The language expert provides suggestions for writing the foreword to be changed to a preface, and fixing the sentences to make them more effective.

Figure 12. General Foreword Page Before Revision

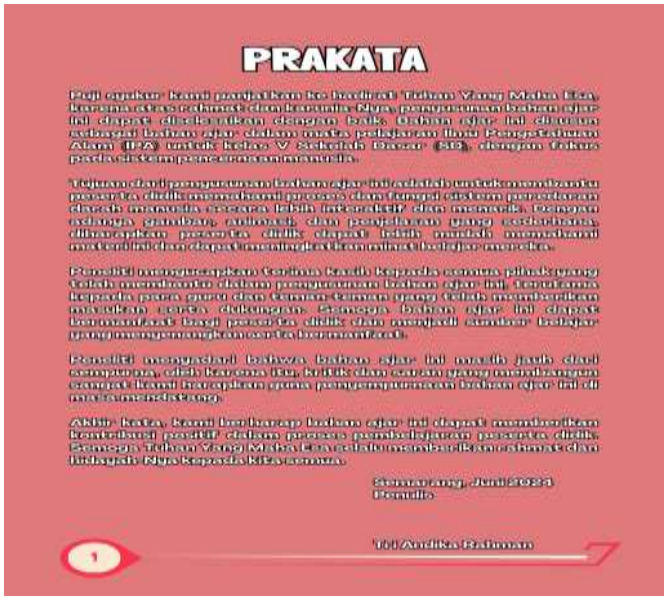

Figure 13. General Foreword Page After Revision

Figure 14. Augmented Reality Page of Heart Organ Before Revision

Figure 15. Heart Organ Augmented Reality Page after Revision

Figure 16. Blood Vessel Characteristics Page Before Revision

Figure 17. Blood Vessel Characteristics Page After Revision

Figure 18. Lung Organ Page Before Revision

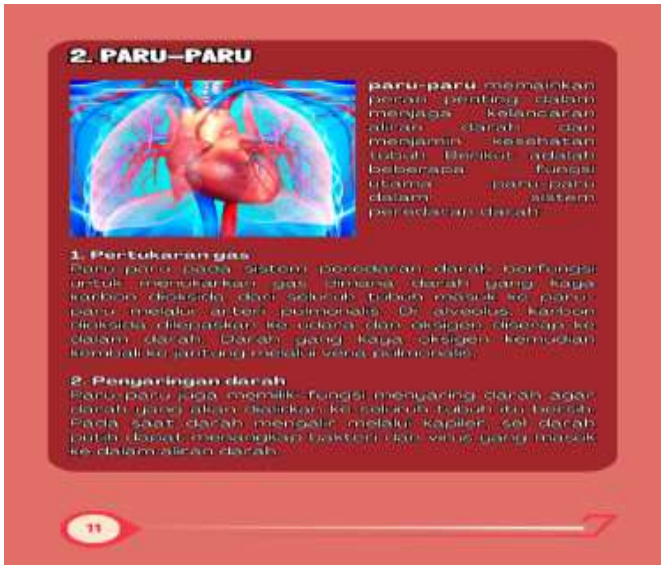

Figure 19. Lung Organ Page After Revision

Practicality of Augmented Reality-Assisted E-Learning Materials

The next step for the researcher was to conduct a small-scale product trial using 15 grade VI students who were selected heterogeneously based on their ability level, namely 4 students with high rankings, 8 students with middle rankings, and 3 students with low rankings. After students and teachers mastered the use of augmented reality-assisted e-learning materials, it was continued by providing response sheets to students and teachers. The response sheet contains three aspects, namely material, media quality and language with a Likert scale that must be filled in based on their experience when using the product provided by the researcher. The results of the response sheet have assessment criteria, namely very positive 76%-100%, positive if 51%-75%, negative if 26%-50%, and very negative if 0-25%.

Table 3. Results of teacher and student responses regarding e-teaching materials assisted by augmented reality in small-scale testing

Section	Teacher	Students (15 students)
Total Score	91	713
Maximum Score	92	780
Presentation	98%	91%
Criteria	Very positive	Very positive

Table 3 shows that the results of teacher and student responses to e-learning materials assisted by augmented reality gave very positive results and there was no input from teachers or students so that e-learning materials assisted by augmented reality can be practically used in teaching and learning activities. Because there were no suggestions and input from teachers and students from the results of the e-learning material response sheet included in the very positive criteria, there was no revision in the small-scale test.

Table 4. Results of Teacher and Student Responses to E-Learning Materials Assisted by Augmented Reality in Large-Scale Testing

Section	Teacher	Students (25 students)
Total Score	92	1185
Maximum Score	92	1300
Presentation	100%	91%
Criteria	Very Positive	Very Positive

Table 4 shows that the results of teacher and student responses to e-learning materials assisted by augmented reality gave very positive results, there was no input from either teachers or students so that e-learning materials assisted by augmented reality can be used practically in learning activities.

Effectiveness of E-Learning Materials Assisted by Augmented Reality Trial Use

A large-scale trial was conducted in class V consisting of 25 students, using e-learning materials assisted by augmented reality in the subject of Natural and Social Sciences with the material of the human circulatory system. This test aims to measure the effectiveness of the product based on student learning outcomes. This study uses an experimental preview design with a pretest-posttest model, namely the measurement of learning outcomes is carried out before (pretest) and after (posttest) the use of e-learning materials.

Table 5. Pretest and Posttest Results on the Use of the Test

Section	Average	Average maturity
Pretest	51.28	
Posttest	88.68	37.40

According to table 5, the average learning outcomes of students in the large-scale trial increased by 37 points. This increase indicates a significant difference in student learning outcomes in the subject of science, especially the material on the human circulatory system, in class V of SDN Ngaliyan 03 before and after the use of e-learning materials assisted by augmented reality. These results are also supported by statistical analysis including normality tests, t-tests, and N-gain tests, which confirm a significant increase in the average pretest and posttest results.

Based on table 6. The significance value of Asymp.Sig (2-tailed) obtained is 0.095, greater than 0.05. Based on the basis of decision making on the Kolmogorov-Smirnov normality test, this result shows

that the data is normally distributed. Therefore, it can be concluded that the assumption or requirement of normality in the regression analysis has been met.

Table 6. Normality Test Results

Tes normalitas			
	Statistics Statistik	Df	Shapiro Wilk Sig
Pretest Score	133	25	0.200
Posttest Score	161	25	0.095

Table 7. t-Test Results

Paired sample test			
	T-statistic	Degree of freedom	Sig. (2-tailed)
Pretest Score	-	-	-
Posttest Score	22.908	49	<.001

Based on table 7. It is known that the Sig. (2-tailed) value is 0.001 <0.05, so H0 is rejected and Ha is accepted. Thus, it can be concluded that there is an average difference between the pretest and posttest learning outcomes, which means that the use of e-teaching materials assisted by augmented reality has an influence on improving the learning outcomes of the science subject, especially the circulatory system material, in grade 5 students of Ngaliyan 03 Elementary School in 2024.

Table 8. N-gain Test Results

Average Distance	N-Gain	Criteria
48.72	0.76	High

According to Table 8. the average result of the large-scale product trial of 48.72 shows that grade V students of SD Negeri Ngaliyan 03 experienced an average increase of 0.76, which is classified as high. This increase indicates that the use of e-learning materials assisted by augmented reality in science learning on the subject of the circulatory system has succeeded in improving student learning outcomes. This finding confirms that e-learning materials assisted by augmented reality are effective and efficient learning media, because they are able to support significant improvements in student learning outcomes. The results of the data analysis show that e-learning materials assisted by augmented reality are appropriate for use in science subjects on the subject of the human circulatory system. This feasibility is further strengthened by several factors.

First, the presence of e-learning materials assisted by augmented reality contributes to increasing student motivation to gain knowledge and experience using technology in 21st-century learning as shown by increasing student learning outcomes. Research that also supports the problem solving in this study is a study entitled "Development of Learning Media Based on Augmented Reality Book Simulation of Animal Reproduction in Science Subjects Case Study of Class VI - SD Negeri 4 Suwug." The results of the study showed that AR has a significant impact on three levels of learning outcomes, namely response, knowledge, and skills, and performance. AR can be used to promote student performance in the best possible authentic situations. AR can also be used to promote positive student responses such as learning motivation. Student learning experiences such as learning about cultural heritage or learning languages can be enhanced by the use of visual, verbal, and interactive virtual objects that are overlaid on the environment or learning materials (Chang et al., 2022; Jaruševičius et al., 2024; Bryant et al., 2025).

The use of augmented reality can increase positive student responses, such as learning motivation and stronger learning experiences, especially in learning activities about the complex circulatory system (Lee et al., 2015; Hite et al., 2024). In the era of information technology transformation, teachers are always trying to integrate new technologies into learning to improve students' learning experiences. Rapid technological developments have brought significant changes to the world of education, especially when technology is applied with strong pedagogical principles. This combination creates new opportunities to improve the quality of teaching and learning. One of the technological innovations that is now widely used is Augmented Reality (AR), which offers a revolutionary approach to education. With the increasing adoption of mobile devices globally, the use of AR on smartphones and tablets is growing rapidly and becoming a growing trend (Al-Ansi et al., 2023; Bottani & Vignali, 2019).

Second, the use of Augmented Reality (AR) technology in learning media can stimulate students' interest and attention in the learning process, so that students' acceptance of the material can be optimized. Augmented Reality (AR) has gained widespread recognition in various fields, including education. The use of AR technology in learning allows students to understand learning materials in a more creative and innovative way, compared to conventional learning methods (Zhang et al., 2020; Byers et al., 2018). Augmented reality can enrich science education by providing opportunities for meaningful learning experiences. This shows that AR produces significant benefits in increasing student engagement and understanding of science concepts (Pandita & Kiran, 2023). The results of the study entitled "Science Learning Media Application for MI Based on Augmented Reality" show that the use of science learning media based on Augmented Reality (AR) can improve students'

understanding of science material more effectively. This application utilizes AR technology to display 3D objects that can interact with students. The results of the study also show that this application is able to function well and support the learning process effectively on the Android platform and can display 3D objects with a distance of 10-15 cm with standard lighting conditions (Krestanova et al., 2021). Third, students will become more integrated regarding the material on the circulatory system and students will be able to become independent in learning the material. Augmented Reality (AR) can be a tool that helps teachers explain concepts of the circulatory system that are difficult to understand or not directly visible. For example, in learning about the circulatory system, teachers can use AR to visualize how the blood circulation pathways in the body, how the structure and function of related organs, and how the overall blood circulation process is. With the help of AR, these concepts can be presented more clearly and realistically (Flavián et al., 2019; Cipresso et al., 2018; Marougkas et al., 2023).

This is in line with another study entitled "Development of Augmented Reality-Based Learning Media Book Simulation of Animal Reproduction in Science Subjects Case Study of Class VI - SD Negeri 4 Suwug" This study aims to develop Augmented Reality (AR)-based learning media in Sciences subjects for class VI of elementary school. The results of the study showed that the AR application developed was proven to be very effective in helping students understand material about animal reproduction (Tene et al., 2024; Patra et al., 2018). Fourth, e-teaching materials assisted by Augmented Reality developed by researchers function as visual learning media, because the media presents interesting images, this can increase students' interest in reading and make them more interested in learning the material being taught (Wusqo et al., 2021). Finally, this e-teaching material is designed with practicality, so that students can easily carry it and use it anytime and anywhere, according to their learning needs (Rahmawati & Tirtayani, 2021; Šorgo et al., 2023).

This research has a positive impact, where the Augmented Reality-assisted e-teaching materials developed can be utilized by educators and students in the teaching and learning process, thus contributing to improving student learning outcomes. In line with several previous studies with adjustments to conditions and problems in the field, researchers developed augmented reality-assisted e-teaching materials for social science subject content for grade V elementary schools. Based on the results of the research and previous discussions explained, augmented reality-assisted e-teaching materials have proven to be practical and effective to be applied in teaching and learning activities.

Conclusion

The results of the data analysis showed that the augmented reality-assisted e-teaching materials received a very decent qualification with an average score of 87% in the product validation assessment. The results of the response questionnaire on the e-teaching materials also gave a very positive category from teachers and students. Data analysis also revealed a significant difference between the pretest and posttest scores, with an average difference of 37 and an N-gain of 0.76 which was included in the high category. This proves that the augmented reality-assisted e-teaching materials have proven to be feasible, practical, and effective in improving student learning outcomes in the subject of science, especially in the material on the human circulatory system in grade V of elementary school.

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Author Contributions

T. A. R., in the implementation of this research as a product developer, data analysis and article writer. N. S., as a supervisor in research activities and writing articles.

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Conflicts of Interest

The author declares that there is no conflict of interest in this research.

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