Development of E-Learning Materials Assisted by Augmented Reality on the Material of the Form of Matter and its Changes to Improve Learning Outcomes of Elementary School Students

Fatza Hermayanti[1*], Novi Setyasto[1]

[1] Pendidikan Guru Sekolah Dasar, Fakultas Ilmu Pendidikan dan Psikologi, Universitas Negeri Semarang, Semarang, Indonesia.

Abstract: This study aims to develop, test the feasibility of effectiveness, and practicality of E-learning materials assisted by Augmented Reality to improve cognitive learning outcomes of fourth grade students of Kemijen 02 Elementary School, Semarang City. This type of research is development research (R&D) using the ADDIE model. The subjects of the study were 52 fourth grade students of Elementary School. Data collection techniques include non-test and test. Data analysis techniques use t-test, and N-Gain test. The results of the study indicate that the development of E-learning materials assisted by Augmented Reality (AR) includes covers, instructions for use, concept maps, learning competencies, materials, videos, Augmented Reality (AR). From the results of the feasibility test, the percentage of assessment was obtained, namely the validator of language experts 94.40%, media experts 91.18%, and material experts 91.40% with the category "very feasible". The effectiveness of E-learning materials assisted by Augmented Reality is proven through a t-test which shows a significance value of 0.000 (<0.05) with an N-gain value of 0.62 in the moderate category. Practicality is shown from the very positive response from teachers 98.40% and students 97.02% with the criteria of "very positive". This study concludes that the development of E-learning materials assisted by Augmented Reality (AR) has been successfully developed with the category of very feasible, effective, and practical to improve the learning outcomes of science for grade IV students of Kemijen 02 Elementary School, Semarang City.

Keywords: Augmented Reality; E-teaching materials; IPAS; Learning outcomes

Introduction

In the Decree of the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia Number 16 of 2022, the government has established the Independent Curriculum as a guideline for the standard learning process in Indonesia. This curriculum is designed to provide freedom and flexibility to educational units in compiling relevant and contextual learning. The essence of this curriculum is optimizing the use of resources available in the educational unit environment and/or the surrounding community, including the integration of information and communication technology devices. In addition, the implementation of learning is focused on creating a pleasant learning atmosphere, so that students can experience learning experiences that trigger positive emotions, increase involvement, and maximize their potential. Natural and Social Sciences (IPAS) Education has a very important role in the school curriculum. This subject not only aims to provide basic knowledge about nature and the social environment to students, but also

to form their critical and analytical thinking patterns through IPAS learning, students are taught to observe, identify, and understand various natural and social phenomena around them (Zuschaiya et al., 2024).

However, these expectations have not been fully achieved. In implementing learning, teachers tend to only use learning resources provided by the government without adjusting them to the conditions of students (Kristiantari et al., 2022). Several previous studies have highlighted that conventional media currently used in many schools in Indonesia are not effective enough in helping students understand concepts (Imron et al., 2025), such as Powerpoint presentations that contain too much text without clear visualizations related to the material being taught; Difficulty in providing interactive learning media that is appropriate to students' needs is a challenge in itself (Qorimah & Sutama, 2022). The use of internet networks in learning has not been carried out optimally, so that the learning process has not been able to be integrated with technology. Supported by research of Masruroh et al. (2020) which shows that learning activities carried out by teachers are less innovative and creative; The approach applied is still conventional and does not take into account the active role of students in the learning process. This shows that the current learning process is not running optimally. Similar problems were also found in learning Natural Sciences (IPA) at the elementary school level. Based on data from the Program for International Student Assessment (PISA) in 2018, Indonesia ranked 71st out of 79 participating countries, with an average score of 389 in the science category. This score is far below the international average of 500, reflecting significant challenges in improving the quality of science learning in Indonesia (Sajidah & Wulandari, 2024).

Similar problems were also found by researchers at SD Negeri Kemijen 02, Semarang City. Based on the results of interviews with class teachers and analysis of questionnaires filled out by students, it can be seen that the average score, especially in the subject of social studies, is still below the KKTP, which is 56, with the KKTP set at 75. This is in contrast to the results of the questionnaire which showed high interest of students in social studies learning. Of the 52 students who filled out the questionnaire, 39 students (78%) stated that they enjoyed the subject of social studies. Interviews with grade IV teachers revealed several factors that support this problem. First, the models, methods, strategies, and learning media used are still not varied enough. The teaching materials used by teachers tend to rely on student books and teacher guide books from the government without any modifications that are adjusted to the needs of students. In fact, based on the criteria for selecting effective teaching materials, teaching materials should pay attention to the characteristics of students, the material presented, and the relevance to the students' learning environment (Astiti et al., 2021); the available teaching materials are still dominated by reading texts without clear visualizations related to the material; In addition, the teaching materials used have not utilized the technology available in schools optimally. Second, the learning media used by teachers are still limited, generally only in the form of Powerpoint presentations with monotonous content. Third, the teaching materials used by teachers are still less diverse, often only focusing on LKS books. This causes a lack of variation in delivering material to students. Fourth, although the WiFi network infrastructure in schools is adequate, the use of information technology in learning is still not optimal. Based on the results of the questionnaire, out of 52 parents, 50 who filled out the questionnaire, 77.78% of parents agreed to allow their children to bring cellphones to school if needed in learning activities under teacher supervision. However, this potential has not been utilized optimally to support technology-based learning. As many as 71% of students are known to be proficient in operating cellphones in everyday life. Of that number, 52% use cellphones to play games, while the rest use them to access social media. However, students have not utilized their cellphones optimally for educational and productive activities.

E-teaching materials, which in English consist of the terms "e" (electronic) and "teaching materials" (module), are electronic teaching materials that contain materials, limitations, methods, and evaluation guides (Kosasih, 2021). These teaching materials are arranged systematically and attractively to facilitate the achievement of competencies according to the expected level of complexity (Mulyasari et al., 2023). Furthermore, important aspects such as displays that support learning needs and presentations that facilitate the achievement of learning objectives determine the practicality of e-teaching materials. In its preparation, e-teaching materials are designed by considering the specific needs of teachers and students in the relevant schools. In addition, the materials in e-teaching materials are arranged systematically and adjusted to the applicable curriculum, making it easier for teachers to use them as effective teaching materials. This makes e-teaching materials one of the important innovations in supporting the success of learning in the digital era.

Technology-based learning media provides a more interesting, interactive and innovative way of learning, so that students are enthusiastic in learning the material. The role of interactive learning media is important in increasing students' learning motivation to help visualize and simplify the material. The use of learning media in subjects related to science can provide more

beneficial achievements in obtaining more comprehensive and in-depth knowledge. This is because science has many complicated procedures and intuitive processes that are difficult to imagine and understand abstractly (Diab et al., 2024). Therefore, complementary elements are needed with the addition of technological tools to extract intuitive and abstract learning content so that it can be understood properly. Therefore, researchers developed E-teaching materials assisted by Augmented Reality. According to Anggraini et al. (2024) e-teaching materials offer flexibility that is not found in printed teaching materials, where each student can set their own learning rhythm, adjust the speed of understanding to individual capacity, and determine how often they need to repeat the material to achieve optimal understanding.

E-teaching materials are equipped with Augmented Reality (AR) features. Augmented Reality is a technology that integrates virtual information into the real world (Faria, 2024). Augmented Reality has a series of intrinsic characteristics that support its use in the field of Education (Nikou et al., 2024). This technology is known as an interesting, fun, dynamic, and versatile teaching aid, so it can increase the effectiveness of learning (Faria, 2024; Latifa et al., 2020; Nurdyansyah & Mutala'liah, 2018; Nursdiansyah et al., 2024; Rosyid & Setyasto, 2024). In the context of education, the use of Augmented Reality as a learning medium has been proven to improve students' learning experiences, especially in science subjects (Glasby et al., 2023; Roshandel et al., 2023). AR also plays a role in balancing student learning outcomes with 21st-century skills that are increasingly relevant in the modern world of education (Chen et al., 2019). With the use of Augmented Reality that visualizes abstract concepts into real concepts for students, it triggers an interesting and enjoyable learning atmosphere (Anuar et al., 2021).

The use of augmented reality-based learning media has been proven effective in research to Improve Students' Knowledge Competence (Faiza et al., 2022). This study shows that the use of augmented reality (AR)-based media in social studies learning. The results of the study revealed that after using AR-based learning media, there was a significant increase in students' knowledge competence. At the pretest stage, only 33% of students achieved completion, while at the posttest stage, 100% of students succeeded in achieving completion. The purpose of this study is to produce AR-based learning media that supports the learning process by offering more interesting, interactive, and innovative methods. By utilizing AR technology, students are expected to be more enthusiastic in learning materials such as state of matter and its changes. This technology allows the visualization of abstract concepts to be more concrete and easier to understand, thereby increasing student understanding and engagement.

The novelty of this study compared to previous studies lies in the use of non-print media assisted by AR technology. This e-teaching material is intended for grade IV Elementary School with the material of Forms of Matter and Their Changes. The e-teaching material developed allows students to scan markers in the form of QR codes that are connected to AR-based visualizations. This study aims to develop e-teaching materials integrated with AR technology, which are designed to be accessible anytime and anywhere via digital devices such as smartphones or tablets. This makes it easier for students to learn independently and more flexibly. Through AR-based e-teaching materials, students can scan QR codes related to 3D images in e-teaching materials to obtain AR visualizations. For example, the evaporation event which is usually only a 2D image and description in student books, in this e-teaching material is visualized with Augmented Reality in a more concrete 3D form with the addition of steam animations produced from boiling water vapor related to everyday life. This approach not only makes learning more interesting and interactive, but also provides a deeper and more comprehensive learning experience.

Based on the background that has been described, the researcher conducted a research related to the development of E-teaching materials assisted by augmented reality (AR) to improve the learning outcomes of grade IV students in the subject of science, especially in the material of the Form of Substance and Its Changes. The purpose of this research and development is to test the feasibility, practicality, and effectiveness of the resulting product. It is expected that the teaching materials developed can make it easier for students to understand the concepts in the material of the Form of Substance and Its Changes, so as to improve the cognitive learning outcomes of science in grade IV elementary school.

Metode

This research is a type of Research and Development (R&D) that adopts an instructional design approach. The process includes the stages of needs analysis, content design, development, implementation, and evaluation to ensure that the development of AR-assisted E-learning media is carried out optimally, using quantitative methods (Sugiyono, 2019). Development research is a process that aims to develop educational products and validate them through evaluation by experts, with the aim of producing new products and improving existing products (Haryati, 2013). According to Sugiyono (2019), Research and Development (R&D) is

a research method that aims to test, develop, and create certain products. The R&D process begins with the research stage which is then continued with development. This method includes a series of steps, starting from the analysis of previous findings or research that are relevant to the product to be developed, followed by the development process, testing, and revision to improve the resulting product.

The steps in developing learning media are carried out cyclically based on the Research and Development (R&D) approach (Okpatrioka, 2023). This cycle process includes several stages, starting from identification and analysis of the product to be developed, followed by product development based on initial findings obtained from both scientific studies and implementation in the field. After that, revisions are made to correct weaknesses or deficiencies identified at the field trial stage (Haryati, 2013).

In this study, the ADDIE development model was used, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation (Muruganantham, 2015). The ADDIE model was chosen because this approach is continuously evaluative at each phase, ensuring that the development process is not only systematic, but also continuously improved at each stage (Nadiyah & Faaizah, 2015). In addition, this model also allows evaluation of the integration between stages to ensure consistency and coherence in product development. The stages in the ADDIE model are explained in more detail in the illustration in Figure 1.
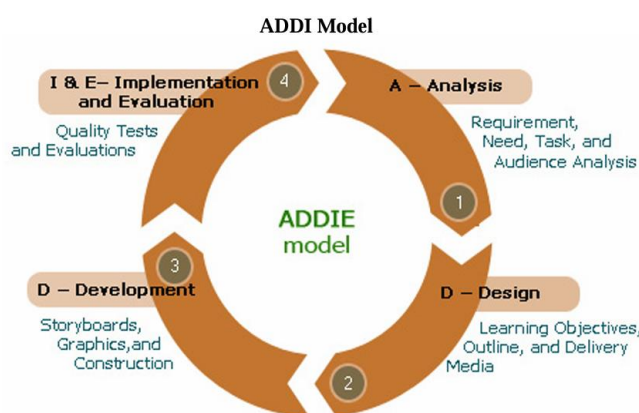

Figure 1. ADDIE development stages (Muruganantham, 2015)

The development of the ADDIE model consists of five main stages that are carried out systematically and gradually. The first stage, analysis, includes identifying problems, student characteristics, teacher needs for learning media, and studying teaching materials. This stage is carried out through observation, interviews, and documentation at SD Negeri Kemijen 02. The results of the analysis show that there are obstacles in making interactive teaching materials and utilizing digital

media, which causes students to have difficulty understanding the concept. Low understanding of science concepts is often associated with learning activities that are still oriented towards memorization (retention), including the concept of reduce, reuse, recycle (3R) which is not yet widely known. Therefore, AR-assisted E-teaching materials based on concrete examples were developed to support learning.

In the design stage, E-teaching materials were designed using the Canva platform combined with Assemblr.Edu for Augmented Reality (AR). This design process was based on interviews and questionnaires that identified teachers' needs for the creation of interactive teaching materials and interactive learning media in grade IV in science learning. The components designed include cover pages, user guides, concept maps, YouTube video integration, learning materials, and Augmented Reality (AR) features.

The development stage involves the creation of a product in the form of E-Learning Materials assisted by Augmented Reality that can be accessed via smartphone devices. At this stage, the data from the questionnaire on teacher and student needs that have been analyzed become the basis for product development. In the design process, researchers began to design the product from the aspects of language, material content, and media design. The design of this product is adjusted to the Learning Outcomes (CP) and Learning Objectives (TP) that are relevant to the material on the Form of Matter and Its Changes in the subject of Science for grade IV Elementary School Phase B. By focusing on Learning Outcomes (CP), this product is designed to help students learn concepts and phenomena related to the form of matter and its changes in everyday life. After the product design stage is complete, the next process is validation. This product is then validated by material experts, language experts and media experts, including lecturers and teachers, to ensure quality and suitability to learning needs.

The implementation stage was carried out by involving a population with a total of 52 fourth grade students of Kemijen 02 Elementary School and Kemijen 03 Elementary School. As a trial subject to measure the effectiveness of the product with a small group trial of 15 students of Kemijen 03 Elementary School and 26 students at Kemijen 02 Elementary School. Data collection was carried out through pretest and posttest, which aimed to assess the impact of media use on student learning outcomes. In the application of E-teaching materials assisted by Augmented Reality, the author used the Problem-Based Learning (PBL) method as a learning approach. PBL is one of the effective approaches to overcome problems that arise in technology-based learning. PBL offers a student-

centered learning experience, involves solving real problems, and increases active student involvement (Kristiantari et al., 2022).

In the context of technology learning, PBL provides opportunities for students to use technology creatively and critically in solving complex and relevant problems. The positive impacts of implementing PBL include increasing students' ability to identify problems, investigate, and apply fact-based knowledge. In addition, PBL also encourages mastery of scientific literacy and the development of in-depth critical thinking skills (Alreshidi & Lally, 2024).

The final stage, evaluation, focuses on assessing the effectiveness of Augmented Reality-based E-Learning Materials in improving students' understanding of the material. Evaluation is carried out through analysis of pretest and posttest results as well as student and teacher responses to the use of the product in learning. This process aims to provide input for further product development and ensure its usefulness in the context of basic education.

The instruments used for data collection in this study include tests (pretest and posttest) consisting of 30 multiple-choice questions and non-tests consisting of interviews, observations, questionnaires, and documentation. The results of the analysis show that the pretest and posttest questions have been evaluated based on four main aspects, namely validity, reliability, level of difficulty, and discrimination. All 30 questions tested showed performance that met the criteria for use in the study. Details of the analysis results are presented in the following table.

Table 1. Details of the Results of the Analysis of Validity, Reliability, Level of Difficulty, and Discrimination Power of the Questions

Analysis Aspects	Result
Validity of Questions	All 30 questions were declared valid with a correlation coefficient > 0.514
Question Reliability	Cronbach's Alpha coefficient is 1.05 (very high)
Difficulty Level	27 questions in the medium category; 3 questions in the difficult category
Differential Power of Questions	2 questions in the very good category; 17 questions in the good category; 11 questions in the sufficient category
Conclusion	The pretest and posttest questions meet the criteria of validity, reliability, level of difficulty, and discrimination power for use in research

The data analysis techniques applied include product feasibility evaluation through validation by material experts, media experts and language experts. Validation is carried out by experts or validators to obtain evaluation and input on important aspects of the product being developed, in order to assess its suitability and feasibility in use. The assessment is carried out using a Likert scale with a range of 1 to 4.

In addition, the responses of teachers and students to the use of E-teaching materials assisted by Augmented Reality (AR) during the learning process were analyzed using a dichotomous scale. This scale is designed to identify the level of acceptance and response to the effectiveness and practicality of the product in supporting the learning process.

The analysis of product effectiveness was conducted by processing the pretest and posttest data. The analysis process began with a normality test using the Shapiro-Wilk method through SPSS software. Furthermore, an analysis was conducted using the Paired Samples Test (t-test) to test for significant differences between the pretest and posttest results. As a complement, the N-Gain test was used to measure the level of score increase from pretest to posttest, in order to quantitatively evaluate the effectiveness of the product (Adnan et al., 2020).

Result and Discussion

Augmented Reality-assisted e-learning materials were developed using Canva software for material design, which was then collaborated with Assemblr.EDU in creating Augmented Reality elements. This development went through systematic stages that included analysis, design, and development.

Design of E-Learning Material Development Assisted by Augmented Reality
Analysis Stage

An interview with Herlina Dewi Rahmawati S.Pd., a fourth grade teacher at Kemijen 02 Elementary School, revealed several aspects that need to be evaluated: the limited use of digital media in learning, a learning approach that is still centered on the teacher, the lack of continuous development in the development of teaching materials that can be integrated comprehensively in fourth grade, and the low learning outcomes of the IPAS subject in fourth grade.

Observation results at SD Negeri Kemijen 02 Semarang City show that this school has supporting learning facilities, such as computers, LCDs, and policies that allow students to bring mobile phones to school. Based on the availability of these facilities, learning

media in the form of E-teaching materials assisted by Augmented Reality are considered applicable to improve students' IPAS learning outcomes. This media is designed to present more effective and interesting learning materials. Therefore, it was decided to develop E-teaching materials assisted by Augmented Reality as an effort to improve students' learning outcomes in the IPAS subject.

Design and Development Phase

After determining the solution to overcome the existing problems, the next step is to design the research stages by creating an e-teaching material design assisted by Augmented Reality in the subject of Science, the material of the Form of Matter and Its Changes, essential for the independent curriculum for grade IV of Kemijen 02 Elementary School. The requirements for creating e-teaching materials assisted by Augmented Reality (AR) include: ease of use anywhere, attractive design, ease of operation, and relevance to needs. The presentation of this learning media is designed on several pages with an aesthetic layout to attract students' attention and increase their interest in learning. This format includes various components, including an opening page designed to attract students' attention with an attractive and creative appearance, so that students become more interested and do not feel bored during the learning process. The author combines two solutions, namely e-teaching materials and Augmented Reality, in an innovative teaching material design for e-teaching materials integrated with Augmented Reality. With this e-teaching material, students can learn independently anytime and anywhere via their smartphones (Riyanti et al., 2022). Augmented Reality (AR) is an innovative concept that combines digital information such as images, videos, audio, and text into a physical environment and displays it in real-time. AR technology uses objects as markers to display digital content such as images, videos, audio, text, and 3D visuals (Qorimah & Sutama, 2022). Thus, AR can present tools and practical materials virtually in 3D (Çöltekin et al., 2019). This capability makes a major contribution to the development of learning media, making it more interactive and interesting for students (Tasrif et al., 2020). Research that supports the solution to the problem in this study is a study by Qorimah et al. (2022). In their research, which reviewed 21 literature studies, it was proven that Augmented Reality provides space for students to imagine, so that it can improve cognitive learning outcomes. Students can scan the QR code marker that has been inserted in the e-learning materials to obtain visualization of the form of matter and its changes as well as the phenomenon of changes in matter that are often encountered in everyday life through

Augmented Reality (AR) technology. The author provides two options for using Augmented Reality (AR) technology. First, students can access it directly through e-learning materials, second, students can scan AR through the QR code in the learning materials. By providing two options using AR, the author hopes that students can easily use the available Augmented Reality.

It provides an interactive and immersive learning experience, allowing students to see abstract concepts in real 3D. Thus, learning becomes more interesting and effective, so that it can motivate students to continue exploring and understanding the material in more depth. The design of the e-teaching materials developed includes several components, namely covers, instructions for use, concept maps, learning competencies, materials, videos, and Augmented Reality (AR) features as follows.
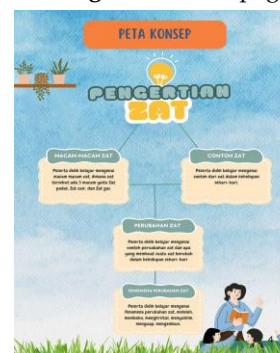

Figure 2. Cover page

Figure 3. Learning objectives

Figure 4. Material concept map

Figure 5. Example of a material page

Figure 6. Example of augmented reality using QR

Figure 7. Example of augmented reality

Figure 8. Example of augmented reality sublimation

Figure 9. Example of augmented reality condensing

Implementation and Evaluation Stage

The implementation stage was carried out through a trial in small groups consisting of 15 grade IV students, held on November 21 and 22, 2024. At this stage, students were given an understanding of the use of E-teaching materials assisted by Augmented Reality after carrying out a pretest. After that, students operated E-teaching materials assisted by Augmented Reality and learned to use Augmented Reality which could be scanned with a QR code on the E-teaching materials. The small group trial showed very good post-test results without requiring revision, so that it could be continued to the effectiveness test on a large group consisting of 26 grade IV students of Kemijen 02.

The last stage is evaluation. This evaluation aims to determine the effectiveness of E-learning materials assisted by Augmented Reality. To collect data, a response questionnaire was given to all students and teachers of grade IV. The questionnaire consisted of 10 student questions and 24 teacher questions, where respondents were asked to give a mark (√) on the right choice.

Feasibility of Augmented Reality-assisted E-learning materials

The feasibility of the developed product will be determined based on the evaluation results of the language, material and media validators, supported by feedback from students and teachers (Balqis & Andriani, 2024). Expert validation was carried out by lecturers at Semarang State University, with the aim of obtaining assessments and input for improvements related to the products being developed. Amalina et al. (2024) said that the purpose of the development stage is to produce and validate the products being developed. The aspects assessed in the development of Augmented Reality-assisted E-teaching materials include several main components to ensure the quality and effectiveness of learning media. In terms of language, material, and media, they are arranged using simple language that is easy for children to understand, making it easier for them to understand the learning content.

Assessment by material experts includes evaluation of the suitability of the material content, learning steps, and assessment of learning outcomes. In this stage, E-learning materials assisted by Augmented Reality receive various suggestions from experts, such as adjusting the question grid and questions to suit the cognitive aspects of students, syntactic alignment with the material delivered through the media, and summarizing the conclusion section to be more concise but informative.

The assessment by media experts includes evaluation of the visual appearance and communication of learning media, attractive and interactive media design, benefits resulting from the use of media, and technical aspects of the software. All of these aspects aim to ensure that E-learning materials are not only effective in delivering material but also attractive to users, easy to operate, and in accordance with the learning needs of students.

The validation results from media and material experts are presented in Table 2.

Table 2. Results of Validation of the Feasibility of E-teaching Materials Assisted by Augmented Reality (AR)

Validator	Category Indicator	Percentage (%)	Feasibility criteria
Linguist	The language used is appropriate to the level of thinking of the students; The language used is in accordance with Indonesian grammar rules.	94.40	Very feasible
Material Expert	Display and visual communication of learning media; Learning media design; Benefits of learning media; Soft serve.	91.18	Very feasible
Media Member	Material suitability; Learning steps; Evaluation	91.25	Very feasible

Based on the validator results in Table 2, the development of e-teaching materials assisted by Augmented Reality can be said to be very feasible to be applied to grade IV students of Kemijen 02 Elementary School.

Figure 10. Before revision

Figure 11. After revision

Figure 12. Learning objectives before revision

Figure 13. Learning objectives after revision

Figure 14. Material before revision

Figure 15. Material after revision

Furthermore, to find out the responses of students and teachers of grade IV after using E-teaching materials

assisted by Augmented Reality on the material of the Form of Matter and its Changes for the learning process in learning Science can be seen through a questionnaire of student and teacher responses to the use of E-teaching materials assisted by Augmented Reality. Suryawan et al. (2020) Also revealed that seeing appropriate and effective media in the learning process can be seen from direct feedback from users "teachers and students". with Tables 3 and 4.

The researcher revised the product design based on suggestions and input from the language expert validator, material expert validator, and media expert validator. Suggestions from the material expert validator included adjusting the learning objectives, rearranging the order of the learning materials, and refining the discussion on the form of matter and its changes. Meanwhile, the language expert validator provided input to avoid using sentences that were difficult for students to understand and to improve the grammar in the material explanation section. Suggestions from the media expert validator included changing the font type to make it easier to read and replacing the font that previously resembled a comic with a more formal font type.

Practicality of E-learning Materials Assisted by Augmented Reality (Product Trial)

Based on Table 3, regarding the response results, students and teachers of grade IV showed responses with very positive criteria. The product trial was conducted on a small scale involving 15 students of grade IV of SD Kemijen 03 in the 2024/2025 academic year. The selection of students was carried out heterogeneously based on their ability level, consisting of 5 students with the highest ranking, 5 students with medium rankings, and 5 students with the lowest rankings.

Table 3. Results of Small-scale Student and Teacher Response Questionnaires

Validator	Percentage (%)	Feasibility criteria
Class IV Teacher	90.20	Very positive
Student	92.30	Very positive

After the learning using augmented reality-based e-learning materials was completed, a questionnaire was given to teachers and students. The questionnaire covered three main aspects, namely material quality, language quality, and media quality. The assessment used a Likert scale of 1–4, where respondents provided an evaluation based on their experience in using the developed product. The results of the questionnaire responses were classified based on the level of feasibility as follows: very feasible if it obtained a score of 82–100%, feasible if it obtained a score of 63–81%, quite feasible if

it obtained a score of 44–62%, less feasible if it obtained a score of 25–43%, and very unfeasible if it obtained a score of less than 25%. The results of this trial will be used as a basis for evaluating and improving the augmented reality-based e-learning material product.

This is also reinforced by the findings of previous research by Ginanjar et al. (2024) also stated that the use of e-teaching materials assisted by Augmented Reality in developing learning media for the learning process is very positive for use in learning. It is further explained by the development of media e-teaching materials learning assisted by Augmented Reality by integrating Smartphones received a positive response to the responses of teachers and students (Dewi & Suniasih, 2023).

Based on the data presented in Table 4, the responses of teachers and students in the small-scale trial showed a very positive response to the use of e-learning materials assisted by augmented reality, with scores reaching more than 98.40%.

Table 4. Results of Large-scale Student and Teacher Response Questionnaires

Validator	Percentage (%)	Feasibility criteria
Class IV Teacher	98.40	Very positive
Student	97.02	Very positive

Furthermore, the results of the large-scale trial responses also showed that e-learning materials assisted by augmented reality were stated to be very positive and practical with a score of 98.40%. This assessment was based on 20 questions contained in the questionnaire using a Likert scale of 1–4. Thus, e-learning materials assisted by augmented reality can be stated to be practical and feasible for use in learning activities.

Effectiveness of Augmented Reality-Assisted E-Learning Materials to Improve Student Learning Outcomes

Evaluation by experts shows that the learning media was tested on a sample of fourth-grade students of Kemijen 02 Elementary School through testing on all students. The main purpose of this test is to evaluate the suitability and feasibility of the developed learning media. The assessment was carried out by measuring learning outcomes using Augmented Reality-assisted E-learning materials before and after science learning. In addition, a questionnaire was given to teachers to find out their responses regarding the use of Augmented Reality-assisted E-learning materials. The teacher response score showed that 98.40% agreed that Augmented Reality-assisted E-learning materials were able to improve student learning outcomes.

Data analysis was conducted using paired sample t-test to evaluate changes in IPAS learning outcomes. Before the main analysis, a normality test was conducted

to assess whether the data were normally distributed. Decisions were based on significance values: if the significance value < 0.05, the data were not normally distributed; if the significance value > 0.05, the data were normally distributed. The results of this normality test are summarized in Table 5 (Usmadi, 2020).

Table 5. Results of Data Normality Test

	Shapiro-Wilk		
	Statistics	Df	Sig.
Pretest score	.930	26	.079
Posttest score	.952	26	.260

Based on the analysis results in Table 5, the data shows that the distribution is normal because the significance value is > 0.05. The next test conducted is the Paired Sample Test. Decision making in this t-test is based on the significance value (2-tailed). If the significance value is < 0.05, then there is a significant difference in the average learning outcomes of grade IV students between the pretest and posttest scores. Conversely, if the significance value is > 0.05, then there is no significant difference in the average learning outcomes of grade IV students between the pretest and posttest scores. The results of the Paired Sample Test analysis are shown in Table 6.

Table 6. Results of Paired Sample Tests

	T-statistics	Degree of freedom	Sig. (2-tailed)
Pretest–Posttest score	10.99	26	.000

The data in the table above shows a significance value (2-tailed) of 0.000 < 0.05, so it can be concluded that there is a significant difference between the pretest and posttest with the use of E-learning materials assisted by Augmented Reality. In addition, this is also proven through the average increase test (N-gain) by comparing the increase in pretest and posttest results calculated using the n-gain index analysis in Table 7.

Table 7. N-Gain Test Results

	Average	N-Gain	Category
Pretest	46.53	0.62	Medium
Posttest	80.19		

Based on the results of the N-gain test, it was obtained at 0.62, which is in the range of $0.3 \leq g \leq 0.7$, indicating a moderate category or there is an increase in student learning outcomes from the pretest and posttest. This is supported by Manggala et al. (2023) showing that the use of Augmented Reality-assisted E-learning material development is feasible and can be used to improve learning outcomes. In line with Nistrina (2021) revealed that the development of Augmented Reality-

assisted e-learning materials is effective in improving student learning outcomes.

The feasibility test shows that E-learning materials assisted by Augmented Reality are very effective in the learning process, with very positive responses from both students and teachers. N-Gain is in the medium category.

Augmented Reality (AR)-assisted e-learning materials have proven to be suitable for use in science learning for grade IV elementary school. The use of AR which is able to visualize abstract concepts to be more real creates an interesting and enjoyable learning atmosphere, in addition, this media can also increase students' interest in learning, which ultimately has an impact on improving learning outcomes. With the active involvement of students in learning, their enthusiasm for learning is increasingly triggered. In addition, research results from Nistrina (2021), Nursdiansyah et al. (2024), Perifanou et al. (2023), and Riyanti et al. (2022) show that AR is able to provide a more in-depth and interactive learning experience. The use of AR-based e-learning materials is also very practical because it only requires a smartphone in its implementation. The 3D visualization presented makes it easier to understand, strengthens memory, and increases students' active involvement in the learning process. Therefore, AR-assisted e-learning materials are very effective in supporting science learning activities in elementary schools.

In addition, AR-based e-learning materials offer flexibility that printed learning materials do not have. This media can be used anytime and anywhere, allowing students to learn independently at a pace that suits their needs. This is very helpful for students who are slow to understand the material in class, while also supporting overall learning. An attractive design, equipped with 3D images, clarifies the learning material, thereby increasing students' interest in learning and curiosity. This AR technology also develops critical thinking skills, visual-spatial skills, and supports collaborative work during the learning process.

This study shows that AR-assisted E-teaching materials not only make it easier for teachers to deliver materials, but also effectively improve student learning outcomes. By adjusting to the needs and challenges in the field, these e-teaching materials have proven to be feasible, effective and practical to use in IPAS learning in grade IV of elementary school.

Conclusion

The conclusion of this study shows that the design of the development of E-teaching materials assisted by Augmented Reality, which includes components of cover, instructions for use, concept maps, learning competencies, materials, videos, Augmented Reality, is declared feasible, effective, and practical to use. This is proven through the results of the validation feasibility test by language experts, media experts, and material experts. The percentage of scores from each validator is 94.40% for language experts, 91.25% for media experts, and 91.18% for material experts. Practicality is shown by the very positive response from teachers 98.40% and students 97.02% with the criteria very positive. The effectiveness of E-teaching materials assisted by Augmented Reality in science learning is also declared effective based on the results of the pretest and posttest values which show a significant increase. The results of the paired sample test produce a significance value of 0.000 (< 0.05) with an n-gain value of 0.62. Thus, the development of E-learning materials assisted by Augmented Reality is declared feasible, practical, and effective in improving learning outcomes in the material of Forms of Substances and Their Changes. This study provides a positive contribution to science learning for grade IV students of Kemijen 02 Elementary School, Semarang City. This shows that E-learning materials assisted by Augmented Reality can be an innovative solution in supporting technology-based learning processes.

Author Contributions
All authors in this article contributed to the process of completing the research. Fatza Hermayanti collecting initial research data, processing data, and writing draft of article. Mr. Novi Setyasto directing research flow, validating data collection instruments, methodology, and reviewing article.

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