



Development of Augmented Reality-Assisted Teaching Materials in Science Subjects: Solar System Topic

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Received: January 22, 2024

Revised: April 23, 2024

Accepted: May 25, 2024

Published: May 31, 2024

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DOI: [10.29303/jppipa.v10i5.7027](https://doi.org/10.29303/jppipa.v10i5.7027)

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Abstract: The minimal use of learning resources and the underutilization of technology in learning materials used in science education have an impact on students' learning outcomes. This study aims to develop and test the feasibility, practicality, and effectiveness of augmented reality-assisted teaching materials in the science subject, specifically on the topic of the solar system. This research falls under the category of Research and Development (R&D) following the Brog and Gall model. The population in this study consisted of 46 students, with a small-scale trial group comprising 12 sixth-grade students and a large-scale trial group comprising 34 fifth-grade students from SD Negeri 3 Bebengan. Data collection techniques included test techniques such as pretest-posttest and non-test techniques such as observation, interviews, questionnaires, and document analysis. The validation results of augmented reality-assisted teaching materials by media, content, and language experts indicated that the materials met the validity criteria. Based on the pretest-posttest results, it was found that augmented reality-assisted teaching materials were effective in improving students' learning outcomes, as evidenced by the increase in the average pretest-posttest score by 39.53, from an average pretest score of 40.68 to 80.21 in the posttest, with an N-gain score of 0.7 indicating moderate effectiveness. The response from teachers and students through distributed questionnaires was very positive. From these results, it can be concluded that augmented reality-assisted teaching materials are effective in improving science learning outcomes and are suitable and practical for use in science education in elementary school grade five.

Keywords: Augmented Reality; Elementary School; Science; Teaching Materials

Introduction

Learning is the process of interaction between students, teachers, and learning resources in a learning environment. To ensure that the learning process runs effectively and efficiently, the government has regulated in Minister of Education and Culture Regulation Number 16 of 2022 Article 2, where process standards are used as guidelines for implementing effective and efficient learning to develop the potential, initiative, abilities, and independence of students optimally. Process standards include learning planning, learning implementation, and learning process assessment. To conduct learning in accordance with process standards, learning implementation needs to be carried out in an

interactive, enjoyable, challenging, motivating environment that encourages active participation and provides sufficient space for students. Such learning is expected to enhance the achievement of graduate competencies. To achieve graduate competencies, content standards are required, which are minimum criteria covering the scope of material at specific educational levels, pathways, and types. One of the learning contents included in the independent curriculum is Natural and Social Sciences (IPAS).

In the independent curriculum, Natural Sciences and Social Sciences are combined into Natural and Social Sciences (IPAS), which is the science that examines human life as both individuals and social beings interacting with their environment. This aims to enable

How to Cite:

Amirahma, S., & Setyasto, N. (2024). Development of Augmented Reality-Assisted Teaching Materials in Science Subjects: Solar System Topic. *Jurnal Penelitian Pendidikan IPA*, 10(5), 2346-2355. <https://doi.org/10.29303/jppipa.v10i5.7027>

students to integrate their natural and social environments into a unity (Hasanuddin et al., 2023).

The government has regulated content standards to achieve graduate competencies. These content standards are regulated in the decision of the head of the standardization, curriculum, and assessment agency of the Ministry of Education, Culture, Research, and Technology Number 033/H/KR/2022 concerning learning outcomes in early childhood education, basic education, and secondary education in the independent curriculum. In primary education institutions, one of the study materials taught is included in the learning outcomes (CP) phase C of fifth-grade students in the understanding element of IPAS, where students demonstrate how the solar system works and its relation to the rotation and revolution of the earth.

To support learning outcomes (CP), teachers must be able to facilitate students in developing their competencies. As stipulated in Minister of Education and Culture Regulation Number 16 of 2022 Article 9, learning implementation is carried out by educators by providing exemplary behavior, mentoring, and facilities. Thus, teachers must be creative and innovative to realize meaningful learning for students and develop their competencies. However, in reality, there are still problems at the primary school level, as evidenced by research conducted by (Putri et al., 2022) that there is a lack of interest among students in science subjects. Many students complain that they do not understand science subjects well because the learning materials are abstract. Other studies also state that learning is still teacher-centered, with suboptimal methods used and inadequate classroom facilities, resulting in a passive classroom environment and student boredom (Cansiz & Mustafa, 2022; Hota, 2023; Tiago & Luís, 2023). Additionally, there are issues with learning implementation in optimizing learning resources, resulting in suboptimal learning processes (Raqzitya & Agung, 2022; Sinta et al., 2021). This impacts students' learning outcomes, low learning motivation, and their lack of critical thinking skills.

In the implementation of science education (IPAS), learning would be more meaningful if the teaching materials or learning resources used were more innovative and could make science subjects clear and less abstract for students. This can be achieved through the utilization of available technology. However, in reality, the learning process often underutilizes technology, especially in the use of technology in learning resources (Dewi & Sunasih, 2023; Wiguna et al., 2022). The IPAS learning process is not yet optimal, mainly due to the limitations of learning resources for both teachers and students. These limitations affect the quality of learning and the depth of knowledge

acquired, as they rely solely on one book without exploring the material further from other sources.

Based on interview results, questionnaires, and class grade data from class 5 at SD Negeri 3 Bebengan, researchers identified various issues. One issue is that teachers still dominate the learning process, leading to student passivity and resulting in less meaningful learning and a lack of understanding of the taught material. Another issue is the lack of variety in learning resources, relying solely on government books such as teacher and student books. Although these books contain some illustrations, they are limited, and not all material can be visualized by students, especially difficult-to-find material like the solar system. In teaching the solar system, teachers struggle to visualize planetary shapes and movements that cannot be directly observed from Earth. Additionally, the learning resources used by teachers do not utilize information technology such as Wi-Fi and mobile phones. Although the school has Wi-Fi network access, it is underutilized for classroom learning. According to questionnaire results, 31 out of 34 students (91%) have mobile phones that can access the internet, and most can operate them proficiently. The use of technology-assisted learning resources can make learning more engaging, varied, and meaningful by visualizing the material being taught. The underutilization of technology-assisted learning resources hinders students from exploring the material extensively and visualizing abstract concepts, impacting their learning outcomes. Consequently, some students' grades fall below the Minimum Competency Criteria (KKM) set for IPAS learning. From a data summary of student grades at SD Negeri 3 Bebengan, out of 34 students, 24 students (70.6%) have not met the KKM, while 10 students (29.4%) have, with the KKM set at 70.

Interactive and enjoyable learning can be supported by learning resources. Learning resources come in various forms, one of which is teaching materials. Effective teaching materials can motivate students to learn and clarify learning material. The use of teaching materials in learning is crucial. (Suyahman, 2021) explains that teaching materials serve as guidelines for students to master competencies, guide teachers in directing learning activities, and serve as learning evaluation tools, facilitating both teachers and students in learning and teaching material. This is consistent with research by (Rahmani et al., 2021) that teaching material can simplify science learning for both teachers and students while remaining meaningful.

Teaching materials that can support abstract topics to be well-received by students, such as the solar system, are not ordinary teaching materials but those that support students in understanding and visualizing the content. These materials can utilize technology like Augmented Reality (AR) to create engaging, enjoyable,

and meaningful learning experiences that visualize the content and enhance learning. With the advancement of information technology, educators always seek to adopt new technologies into education to enhance students' learning experiences. Augmented Reality is one such emerging technology with significant pedagogical potential and is increasingly recognized by educational researchers. By merging virtual objects into the real world, AR creates new possibilities for improving teaching quality and learning activities.

Augmented Reality (AR) is a technology that integrates virtual 2D or 3D objects into the real world and projects them into reality (Ariani et al., 2023). Some advantages of Augmented Reality include making the taught material more engaging, increasing student engagement in learning, providing more information than written text alone, and offering visual representations that are easier for students to remember than reading text (Ariani et al., 2023). By integrating virtual objects into the real world, AR makes learning enjoyable, clear, and meaningful, allowing the material to be well-visualized. This aligns with previous research indicating that the application of Augmented Reality technology in learning can help improve students' understanding of the material and increase their motivation to learn, thus improving students' learning achievement (Chang et al., 2023; Fidan & Tuncel, 2019; Yasin & Utomo, 2023).

Previous studies also state that the use of interactive multimedia based on Augmented Reality can improve elementary school students' abstract reasoning skills (Syawaludin et al., 2019). Other findings indicate an improvement in student achievement and student satisfaction when using modules with Augmented Reality technology (Sahin & Yilmaz, 2020). The use of teaching materials equipped with 3D Augmented Reality can improve students' success in science subjects, correct students' misunderstandings of a topic, and increase students' interest in science learning (Durukan et al., 2023). Based on this background, researchers conducted a study to develop Augmented Reality-assisted teaching materials for IPAS on the solar system topic for grade V at SD Negeri 3 Bebengan, Kendal Regency. The purpose of this research and development was to assess the feasibility, practicality, and effectiveness of the developed product. Developing Augmented Reality-assisted teaching materials can facilitate students' learning of the solar system because they include 3D Augmented Reality barcodes that can visualize celestial objects within the solar system. These teaching materials contain content from various sources and include 3D Augmented Reality barcodes that can move and depict the actual celestial bodies that cannot be directly observed from Earth.

Method

This study is a Research and Development (R&D) study. Research and Development is a research method used to produce a specific product and test its effectiveness (Sugiyono, 2017). This study will produce Augmented Reality-assisted teaching materials for IPAS on the solar system topic for grade V at SD Negeri 3 Bebengan. This research uses the Borg and Gall development model. The steps of the development model according to Borg and Gall consist of 10 steps: (1) potential and problems; (2) data collection; (3) product design; (4) design validation; (5) design revision; (6) product trials; (7) product revision; (8) usage trials; (9) product revision; (10) mass production (Sugiyono, 2017). However, in this research and development of Augmented Reality-assisted teaching materials, the researcher limits the application only up to step 8, which is usage trials, due to time and cost constraints. Therefore, the steps in this study are (1) potential and problems; (2) data collection; (3) product design; (4) design validation; (5) design revision; (6) product trials; (7) product revision; (8) usage trials. The research schema can be seen in Figure 1.

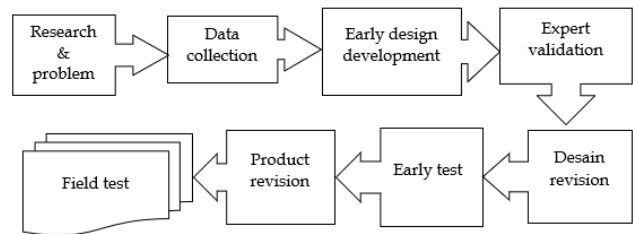


Figure 1. Modified from the Borg & Gall Model

The potential and problem stage is conducted to identify the potential and issues existing in the school by conducting observations, interviews, and document data such as the learning outcomes of grade V students at SD Negeri 3 Bebengan. The next stage is to collect data and information to plan the product that will be developed to address the identified problems by distributing questionnaires on the needs of students and teachers. After analyzing the data through the needs questionnaire, the researcher undertakes several product design activities in terms of design, content, and language. The product design is aligned with the learning outcomes and targets, specifically the solar system topic in the IPAS subject, Phase C of grade V, focusing on the comprehension element of IPAS with the learning outcome (LO): students demonstrate how the solar system works and its relationship with the Earth's rotation and revolution. After designing the product, design validation is conducted by competent expert validators, including media, content, and language

experts, who evaluate the product by filling out validation sheets prepared by the researcher in the form of a Likert scale.

The next stage is design revision. After the product is evaluated by expert validators, it is revised based on the feedback provided, making it ready for testing. Subsequently, the product is tested on a small scale with 12 grade VI students using purposive sampling based on different levels of cognitive ability. In the product testing phase, learning is conducted using Augmented Reality-assisted teaching materials on the solar system, and after the lesson, teachers and students fill out response questionnaires regarding the use of Augmented Reality-assisted teaching materials on the solar system. The responses from both teachers and students are then analyzed, and any feedback is used as input for revising the tested product. The final stage is usage trials. The developed product is tested on a larger scale, with the researcher conducting usage trials in grade V at SD Negeri 3 Bebengan for the academic year 2023/2024, involving 34 students. These usage trials are conducted to determine the effectiveness of the product based on the learning outcomes achieved by the students.

The data used in this study are primary data obtained directly during the research, comprising both qualitative and quantitative data. Qualitative data are obtained from observations, questionnaires, and interviews with teachers conducted at SD Negeri 3 Bebengan. Quantitative data are obtained from the learning outcomes of grade V students at SD Negeri 3 Bebengan in the IPAS subject, as well as the results of pretests and posttests.

The research design used is a pre-experimental design with a one-group pretest-posttest design model, involving a pretest before the treatment and a posttest after the treatment. This is aimed at obtaining more accurate treatment results by comparing the conditions before and after the treatment (Sugiyono, 2017). Data collection techniques in this study include both test and non-test techniques. The test technique comprises 30 multiple-choice questions, while the non-test technique includes observation, interviews, questionnaires, and document data. To assess the feasibility of the developed product, data analysis involves evaluation by expert validators in media, content, and language using a Likert scale. To assess the practicality of the product, questionnaires on student and teacher responses are used with a Likert scale after implementing the product in teaching. Finally, to determine the effectiveness of the product, data analysis involves N-gain testing based on the pretest and posttest scores of students in both small and large-scale trials.

Results and Discussion

Potential and Problems

Based on the pre-research results, several issues were identified, including learning still being dominated by teachers, resulting in students' lack of participation. Additionally, the learning resources used are limited in variation, as teachers rely solely on government-issued books. Teachers also do not utilize information technology resources such as Wi-Fi and smartphones. Furthermore, many grade V students have not met the Minimum Mastery Criteria (KKM) for Science. Out of 34 students, 24 (70.6%) have not met the KKM, while 10 (29.4%) have, with a KKM threshold of 70.

Initial Data Collection

The initial data collection involved distributing questionnaires to students and teachers regarding their needs for learning resources. Based on the initial data collection, it was found that the content of government-issued books, both teacher and student editions, is insufficient to meet the material needs. Teachers require additional teaching materials to broaden students' understanding of abstract topics such as the solar system. They also need teaching materials that facilitate students' understanding of the shapes and movements of planets in the solar system. There is a need for the development of engaging learning tools with visuals to aid students' comprehension of the material. Teachers require teaching materials that utilize technology to merge the virtual world with reality, presenting material not readily observable in their surroundings. Teachers agree that using Augmented Reality-assisted teaching materials, supported by smartphones during lessons, would be beneficial. Students need engaging learning tools to facilitate their understanding of the material. They enjoy using smartphones as learning aids and agree to use them during lessons. The teaching materials are supplemented with 3D images that students can interact with to enhance their understanding and make the material meaningful to them.

Product Design

Augmented Reality-assisted teaching materials are designed in line with the intended learning outcomes (LO). These materials are developed in the form of printed books containing Augmented Reality barcodes. Scanning these barcodes using the Assemblr Edu app reveals interactive 3D images of planets, aiding students in visualizing the material. The creation of Augmented Reality-assisted teaching materials begins with preparing the content and designing 3D images of planets using the Assemblr Edu app, resulting in draft content and Augmented Reality barcodes. Once the draft content and Augmented Reality barcodes are

ready, the teaching materials are designed using the Canva app, incorporating the draft content and Augmented Reality barcodes into the design. The final product is a printed book containing Augmented Reality barcodes that can be scanned using the Assemblr Edu app or website. The Augmented Reality-assisted teaching materials consist of the following components:



Figure 2. Cover



Figure 3. Foreword



Figure 4. Instructions Figure use



Figure 5. Table of Content



Figure 6. CP and Learning Objective



Figure 7. Concept Map



Figure 8. Evaluation



Figure 9. Scan results AR barcodes



Figure 10. Evaluation



Figure 11. Glossary



Figure 12. Reference



Figure 13. Author Profile

The steps in product design include (1) material preparation; (2) creating 3D images using Assemblr edu; and (3) making teaching materials and applying Augmented Reality barcodes in teaching materials.

Validation of Product Design for Teaching Materials Assisted by Augmented Reality

At this stage, the researcher will validate the product with media expert validators, material experts, and language experts to test the suitability of the

product. Researchers carried out product validation with media expert validators, namely lecturers in learning media courses in elementary school teacher education study programs, material experts, namely lecturers in science courses in elementary school teacher education study programs, and language experts, namely lecturers in language, Indonesian literature, and regional education study programs. The assessment criteria for this validation are said to be very feasible if the value is 81%-100%, the criteria are feasible if the value is 61%-80%, the criteria are quite feasible if the value is 41%-60%, the criteria are not feasible if the value is 21%-40%, and the criteria are not very feasible if the value is less than 21%. A recapitulation of product validation results for media expert validators, material experts and language experts are presented in table 1.

Table 1. Results of Expert Validator Assessment of Augmented Reality-assisted Teaching Materials.

Feasibility Aspect	Validation Index (%)	Description
Page	94.5	Valid
Content	92.9	Valid
Language	75	Valid

Based on the results of the validator assessment presented in Table 1, Augmented Reality-assisted teaching materials are declared valid as a whole, including appearance or media, content or materials, and language. The assessment of the appropriateness of the display by media experts received a score with a percentage of 94.5% which is included in the very appropriate criteria, and the assessment of the appropriateness of the content presentation by material experts received a score a percentage of 92.9% which is included in the very appropriate criteria, and the assessment of the appropriateness of the language by language experts get a score with a percentage of 75% which is included in the appropriate criteria. Augmented Reality-assisted teaching materials are declared valid in their entirety in terms of appearance, content, and language and are ready to be tested. This is following research that has been conducted which explains that the results of the development of teaching materials assisted by Augmented Reality show high expert validation results with a decent category because they obtained a score above 75% (Fitriyah et al., 2022; Hasibuan & Chairad, 2023; Lim & Kamin, 2023).

Design Revision

Researchers revised the design with suggestions and input from media experts, material experts, and language experts. Suggestions given by the media validator include a complete cover with the identity of the supervisor, a more varied image layout, and

embedding it in the writing so that it is interesting and not monotonous, and an introductory sentence needs to be added before going into the material. The advice given by the material expert validator is improving learning objectives. The advice given by the linguist validator is consistency in word use, that is, if you use the word "you" as a greeting to the reader, from beginning to end you must also use the word "you", apart from that, improving the writing of words according to enhanced spelling (EYD), and improving the type of bibliography writing, namely using the APA (American Psychological Association) model.

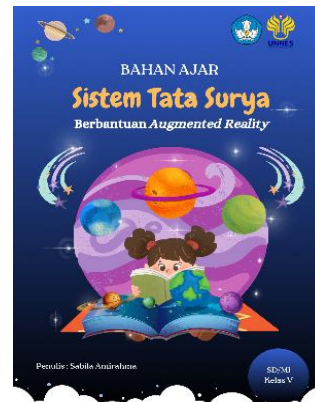


Figure 14. Cover Before revision



Figure 15. Cover after revision



Figure 16. Layout before revision, And there is no introduction yet



Figure 17. Layout after revision and there is already introduction



Figure 18. Goals learning Before revision



Figure 19. Goals learning after revision



Figure 20. Word consistency And correcting the spelling "Hello" Before revision



Figure 21. Word consistency and correcting the spelling Hello" after revision



Figure 22. Bibliography before revision



Figure 23. Bibliography after revision

Practicality of Augmented Reality-Assisted Teaching Materials (Product Trial)

In this trial, there were 12 class VI students with heterogeneous selection based on the cognitive level of the students, namely 4 students with high scores, 4 students with medium scores, and 4 students with low scores. After students and teachers carry out learning using Augmented Reality teaching materials, students and teachers are given a response sheet containing 17 questions with a Likert scale that must be filled in based on their experience using Augmented Reality-assisted teaching materials that have been developed by researchers. The assessment criteria in this questionnaire are very positive if the value is 81%-100%, positive criteria if the value is 61%-80%, moderately positive criteria if the value is 41%-60%, negative criteria if the value is 21%-40%, and criteria very negative if the value is less than 21%. The calculation to measure the percentage of teacher and student response questionnaire answers is as follows (Formula 1).

$$NP = \frac{R}{SM} \times 100\% \quad (1)$$

To test the practicality of Augmented Reality-assisted teaching materials, teacher and student

response questionnaires were distributed which had 3 aspects, namely media quality, content or material, and language which were then divided into 7 indicators, namely appearance, accuracy, suitability, completeness, practicality, usefulness, and use of the product language being developed.

Table 2. Results of Teacher and Student Responses to Teaching Materials assisted by Augmented Reality

Respondent	Evaluation	Description
Teacher	100%	Very positive
Student	94.6%	Very positive

Table 2 shows that the results of the responses from teachers and students on a small scale were very positive towards teaching materials assisted by Augmented Reality because they obtained a score above 81%. Augmented Reality-assisted teaching materials were declared very positive and practical based on 17 questions on a Likert scale, where each question had a maximum value of 4. Because almost all questions received a score of 4, it shows that Augmented Reality-assisted teaching materials received a very positive response. Thus, teaching materials assisted by Augmented Reality can be used practically in learning activities.

Table 3. Results of Teacher and Student Responses to Teaching Materials Assisted by Augmented Reality

Respondent	Evaluation	Description
Teacher	97%	Very positive
Student	96.2%	Very positive

Table 3 shows that the results of the teacher and student responses were very positive towards teaching materials assisted by Augmented Reality because they obtained a score above 81%. Augmented Reality-assisted teaching materials were declared very positive based on 17 questions on a Likert scale where each question had a maximum score of 4. Because almost all questions received a score of 4, it shows that Augmented Reality-assisted teaching materials received a very positive response. This is in line with research that has been conducted which explains that student and teacher response questionnaires to Augmented Reality-assisted teaching materials show very positive results because they get scores above 80% (Hasibuan & Chairad, 2023; Nurcahyani & Sudarmilah, 2023; Rahmadani & Sunarmi, 2023).

Effectiveness of Trial Use of Augmented Reality-Assisted Teaching Material Products

At this stage, a large-scale trial was carried out in class V using Augmented Reality-assisted teaching materials in science and science learning on the solar

system material to determine the effectiveness of the product based on student learning outcomes. The research design used was a pre-experimental design with a one-group pretest-posttest design model, namely a pretest before treatment and a posttest after treatment.

Table 4. Pretest and Posttest Results of Students in Trial Use

Test Type	Average	Average Difference
Pretest	40.68	39.53
Posttest	80.21	

Based on Table 4, it is known that there is an average increase in student learning outcomes of 39.53 in large-scale product trials. These data show that there are differences in student learning outcomes before and after using Augmented Reality-assisted teaching materials in the science and sciences subject on the solar system in class V at SD Negeri 3 Bebengan. To determine the criteria for increasing the average pretest and posttest, analysis was carried out using the N-gain formula.

Table 5. N-gain Test Results

Average Difference	N-gain	Criteria
39.53	0.7	Medium

Based on Table 5, from the analysis of N-gain, it is known that the average difference in large-scale product trials is 39.53 and the N-gain score is 0.7. This shows that the grades of class V students at SD Negeri 3 Bebengan have increased by an average of 0.7 and are included in the medium criteria. This average increase shows that the use of Augmented Reality-assisted teaching materials in science and science learning on solar system material in class V of SD Negeri 3 Bebengan has succeeded in improving student learning outcomes. This is in line with research that has been conducted that the use of teaching materials by applying Augmented Reality can increase students' success in science subjects and contribute to the process of correcting students' misunderstandings and increasing students' interest in science learning (Durukan et al., 2023; Safitri et al., 2023). Other similar research also found that the use of Augmented Reality-assisted teaching materials can significantly improve students' high-level cognitive abilities (Chien et al., 2019). The use of Augmented Reality-assisted learning media contributes positively to the learning process and fosters students' motivation and interest in learning (Chang et al., 2020; Nurhayati, Rusdi, Isfaeni, 2022; Sabbah et al., 2023). Other research also states that using Augmented Reality learning media can visualize abstract concepts for students' understanding (Frasnyaigu et al., 2023). Thus,

Augmented Reality teaching materials are suitable and effective for application in learning because they can increase students' success and also foster students' motivation and interest in learning, and help students visualize abstract material.

Conclusion

Based on the results of the research that has been carried out, it can be concluded that teaching materials assisted by Augmented Reality can improve the learning outcomes of class V students at SD Negeri 3 Bebengan in the science and sciences subject on the solar system. This is proven by the results of data analysis of students' pretest and posttest scores which experienced an increase with an average difference of 39.53 and an N-gain score of 0.7 which is included in the medium criteria. Apart from that, the results of the validation assessment of teaching material products assisted by Augmented Reality by expert validators obtained an average percentage of 87.47% with a very feasible category. Based on the results of the response questionnaire distributed, a very positive response was obtained from teachers and students. This proves that teaching materials assisted by Augmented Reality are feasible, practical, and effective for improving the learning outcomes of fifth-grade elementary school students in the science and science subject on the solar system as well as helping students visualize abstract material such as the solar system.

Acknowledgment

Thank you to the thesis supervisor who has guided the research and writing process of this article to completion. Thank you to SD Negeri 3 Bebengan for helping and allowing the research process. Thank you to the University of Mataram for facilitating the creation of this article and the editors who have reviewed and studied this article. Thank you to yourself, parents, siblings, and friends for your prayers and support.

Author Contributions

Sabila Amirahma contributed to the research, product development, data analysis, and article writing. Novi Setyasto as a supervisor in research activities to article writing.

Funding

This research is research funded by the researcher's funds and does not receive funding from outside parties.

Conflict of Interest

Researchers declare there is no conflict of interest.

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