JSER

Journal of Science Education Research
Journal homepage: https://journal.uny.ac.id/index.php/jser/index

ISSN: 2597-9701

Development of Augmented Reality-Based Learning Media on Earth's Rotation and Revolution Material for Sixth Grade Elementary Students

Lidya Choirun Nisa[1*], Subuh Anggoro[2], Masanori Fukui[3]
[1]*Primary School Teacher Education, Faculty of Teacher Training and Education, Muhammadiyah University Purwokerto*
[2]*Master of Primary Education, Faculty of Teacher Training and Education, Muhammadiyah University of Purwokerto, Indonesia*
[3]*Department of Information Engineering, Mie University, Japan*
[*]*Corresponding Author. Email: lidyachoirunnisa1205@gmail.com*

Keywords
Learning media, augmented reality, Assemblr EDU, Earth rotation and revolution, Elementary school students

Phone: * +62 823-2761-7771

Abstract

The study aimed to develop augmented reality-based learning media using the Assemblr EDU platform to help sixth-grade elementary school students understand the material on the rotation and revolution of the Earth. This research was conducted based on the background of high levels of misconceptions and misunderstandings among students, as well as the limited availability of learning media capable of visualizing abstract concepts in the material on Earth's rotation and revolution. The method used a Research and Development (R&D) with the Four-D development model (Define, Design, Develop, and Disseminate). The subjects of the study were 1 subject matter expert, 1 media expert, 1 language expert, and 37 sixth-grade students and sixth-grade teachers at SDN 2 Sokaraja Kulon. Data collection techniques were surveys, direct interviews, validation questionnaires, and questionnaires of students' and teachers' response. The developed product was an interactive learning media with 3D visualization and simulation animations, accompanied by a guidebook and markers. The media was validated and revised based on experts' input. Then, it tested on a small and large scale. The finding showed that the media was highly suitable and practical for use based on validity and practicality tests, with expert subject matter validation scores of 85%, expert media validation scores of 92.5%, expert language validation scores of 95%, students' response score of 99.63%, and teachers' response score of 98.75%. The media has proven capable of facilitating students' conceptual understanding of the material on Earth's rotation and revolution, while also increasing the participation, interest, and enthusiasm of students.

History
Received:
March 6, 2025.
Revised:
Agust 18, 2025
Accepted:
September 5, 2025

How to cite:
Nisa, L. C; Anggoro. S; & Fukui, M. 2025. Development of Augmented Reality-Based Learning Media on Earth's Rotation and Revolution Material for Sixth Grade Elementary Students. *Journal of Science Education Research,* 9(2), 94-105. doi: https://doi.org/10.21831/jser.v9.i2. 86901

INTRODUCTION

Science education is a subject, consisting of science learning in elementary schools. Specifically, science education includes many discussions about the interrelationships between various phenomena in everyday human life that require an understanding of scientific concepts. The reason is, because science education includes complex concepts, which needs to understand the processes behind phenomena and the cause-and-effect relationships of natural phenomena (Widyaningrum *et al*., 2022). Students learn science that is closest to their surroundings through observation and natural experiences in their lives in elementary school. So, learning at the elementary school level needs to be designed to help students in understand scientific concepts from phenomena commonly observed in daily life more easily (Başpınar *et al*., 2024). Based on this background, technology-integrated science learning aims to help students see the connection between everyday phenomena and actual scientific concepts, which builds students' interest and curiosity (Blanco-Chamborro *et al*., 2023).

One of the essential topics in science education at the elementary level is the rotation and revolution of the Earth. This topic is a fundamental astronomical concept that is important to study. Moreover, it is closely related to phenomena that directly impact human daily life (Cardinot & Fairfield, 2021). Earth's rotation creates the basis for understanding the Earth's rotation on its axis every 24 hours, which causes the alternation of day and night (Vosniadou & Skopeliti, 2017; Galano *et al*., 2018; Slater *et al*., 2018; Gaudreau *et al*., 2020; Colantonio *et al*., 2021). Meanwhile, the Earth's revolution explains the movement of the Earth

around the Sun, which causes seasonal changes in various parts of the world (Dankenbring & Capobianco, 2016; Sung & Oh, 2018; Colantonio *et al*., 2021).

The material on Earth's rotation and revolution not only builds understanding of everyday phenomena but also broadens insights into Earth's interaction with the Sun and its various impacts (Felicita, 2020). Through a deep understanding of the Earth's rotation and revolution, students' thinking skills can develop comprehensively and structurally because students will strive to connect scientific theories and direct observations on around them (Başpınar *et al*., 2024).

In reality, students often struggle to construct an understanding of the Earth's rotation and revolution, leading to misunderstandings and misconceptions due to a mismatch between students' understanding based on personal observations and correct concept. Moreover, this concept is too complex and abstract from the perspective of elementary school students (Astuti *et al*., 2023).

Difficulties in understanding the material on Earth's rotation and revolution are often caused by several factors. First, the abstract nature of the material, which is full of three-dimensional, dynamic, and complex concepts, requires students to use their own visual imagination, making it difficult to understand (Serttaş & Türkoğlu, 2020). Second, the learning media often limited to static 2D images or simple demonstrations, which do not adequately support visual representation in helping students understand these concepts (Suparmi *et al*., 2024). Third, many students still have misconceptions about phenomena related to Earth's rotation and revolution, such as the belief that the day-night phenomenon occurs due to the movement of the sun rotating around the Earth or, conversely, the Earth rotating around the sun (Kanli, 2015; Bekaert *et al*., 2022). Also, seasonal changes occur because the Earth's distance from the sun changes, being closer during summer and farther during winter (Testa *et al*., 2015; Felicita, 2020; Bekaert *et al*., 2020; Cardinot & Fairfield, 2021), and the direction of the Earth's rotation from east to west or clockwise (Plummer *et al*., 2016) (Gaudreau *et al*., 2020).

A preliminary study conducted using a survey method with a Two-Tier Diagnostic Test, supplemented by a Certainty Response Index (CRI) on 133 sixth-grade students in the Banyumas and Cilacap regions showed that 43.61% of students had misconceptions. Meanwhile, 40.98% of students did not understand the concept and only 15.42% of students understood the concepts of Earth's rotation and revolution. The survey results indicate that most students have misconceptions and a high level of misunderstanding of the concepts of Earth's rotation and revolution. This data should be a concern for teachers to present the material on Earth's rotation and revolution so that it is easier to understand and adapts to the conditions and students' needs. One of the most common misconceptions is the belief that the change between day and night is caused by the Earth's movement around the sun.

The limitation of illustrations that support three-dimensional visualization during learning is a challenge in teaching the material on Earth's rotation and revolution. Illustrations with spatial visualization help students understand abstract concepts, such as Earth's rotation and revolution. Moreover, it helps students to imagine objects from various perspectives in a realistic way (Lestari & Naila, 2021). The use of 3D illustrations is also important in facilitating students' understanding of scientific concepts. Therefore, there is an urgent need to provide learning media to visualize an abstract object so students can more easily understand the material.

The urgency of the need for learning media is supported by the results of interviews with sixth-grade teachers. The interview shows that teachers feel the need for learning media to provide visualizations of the Earth's rotation and revolution to make it easier for students to understand the material. Although learning tools - such as LCD projectors and internet access are available- their use is still limited to playing videos from YouTube. In fact, teachers have also implemented demonstration learning methods by providing the objects to illustrate the movements of the Earth, Sun, and Moon; however, this approach is not sufficient to provide realistic visualizations. The shortcomings of the approach lead students to experience difficulties in understanding the material on Earth's rotation and revolution. Teachers need a more innovative and interactive learning media, especially in presenting visualizations of abstract concepts to help students understand the material better and more comprehensively. Based on the observations , the school has learning devices that support technology-based learning activities, including LCD projectors, internet connection and access, and Chromebooks. Then, innovative, interesting, interactive, and technology-based learning media are needed in view of the existing problems and needs, supported by the available resources in the school.

Augmented reality (AR) using the Assemblr EDU application can be a relevant alternative in addressing this issue. It is a variation of virtual reality (Virtual Environment/VE) that allows users

to see the real world through the combination of virtual objects and the real world. As the output, users can see virtual objects and real objects in one space in three dimensions, causing real-time interaction (Azuma, 2009). Assemblr EDU is a mobile-based educational application designed to enable users to create three-dimensional works in the form of augmented reality by combining various available virtual elements. Moreover, Assemblr EDU was chosen as the basis for the media development application because it has features for interactive 3D visualization, easy to operate for both teachers and students in elementary school, and supporting the integration of technology in learning (Lissa'adah & Widiyatmoko, 2023). Research indicates that AR improve learning quality since it enables the combination of situational learning and spatial cognition, which supports the acquisition of spatial thinking skills and improves students' conceptual understanding (Huerta-Cancino & Alé-Silva, 2024). The visual presentation of augmented reality offers a specific 3D representation of abstract astronomical phenomena, enabling students to explore objects from various perspectives in greater depth (Astuti *et al*., 2023). The implementation of AR in learning greatly supports and provides opportunities for students to directly observe simulations of phenomena in a more realistic manner, which helps students analyze the connection between scientific theories and observations of everyday phenomena more effectively (Ferrari *et al*., 2024).

Other studies on augmented reality mention that the use of engaging learning media will increase students' engagement, interest, motivation, and curiosity about learning activities related to a subject matter compared to using traditional learning strategies (Afnan *et al*., 2021; Chang *et al*., 2022). Augmented reality interventions greatly support astronomy learning through representative spatial visualization. Not only does it improve spatial thinking skills as a key element in understanding abstract material, but it also develops students' reasoning abilities (Chang *et al*., 2022).

The use of augmented reality in education is effective. However, research specifically developing augmented reality-based educational media on the topics of Earth's rotation and revolution at the elementary school level, particularly those using the Assemblr EDU application, remains limited. Research on augmented reality has primarily focused on astronomy education at the secondary school and university levels (Astalini *et al*., 2024). However, research on augmented reality is more commonly conducted for other disciplines, such as chemistry, engineering, physics, and mathematics (Amir *et al*., 2020; Chang *et al*., 2022; Astalini *et al*., 2024). The gap between the phenomenon and previous research highlights the need for the development of innovative media, specifically designed for elementary school levels to help students better understand concepts. The development of augmented reality-based learning media can be a strategic step to support the science learning process in elementary schools through the integration of technology that provides interactive visualization.

Based on the previous phenomena and research, the main issue raised in this study is the high level of misconceptions and misunderstandings among sixth-grade elementary school students on the material of the rotation and revolution of the Earth. This difficulty is mainly caused by the abstract nature of the material and the limitations of learning media in supporting effective visualization of reality. Therefore, the research problems are formulated as follows: (1) how the development process of augmented reality-based learning media is conducted to assist students' understanding of the Earth's rotation and revolution, and (2) how the feasibility and practicality of the developed learning media are assessed based on expert evaluations and responses of students and teachers.

In line with the research questions, this study aimed to develop augmented reality-based learning media using the Assemblr EDU platform to help students understand abstract astronomical concepts more easily. This research on the development of augmented reality-based media is expected to provide a more concrete, interactive, fun, and immersive learning experience. It makes the students to understand phenomena, such as day and night, the apparent daily motion of the sun, time zone differences, and seasonal changes. The significance of this research lies in the augmented reality-based learning media to facilitate students' conceptual understanding through interactive visualization, thereby creating a more immersive and fun learning experience. This research is expected to contribute to more innovative learning by providing contextual and engaging media alternatives for students and teachers.

RESEARCH METHOD

The study used the research and development (R&D) method, which is a scientific process for researching, designing, developing, producing, and testing the validity and practicality of a product (Sugiyono, 2019: 30). The R&D method is in line with the research objective, which is to produce a product in the form of augmented reality (AR)-based learning media.

The development model used the Four-D model from (Thiagarajan *et al*., 1976: 5) with the stages of Define, Design, Develop, and

Disseminate. The Four-D development model was chosen because of its structured approach, which ensures a more comprehensive development process with an emphasis on validation and iterative refinement. This model ensures that educational tools are well-designed, complete tested, and tailored to students' learning needs. In detail, the stages of the Four-D development model are illustrated in a flowchart in Figure 1.

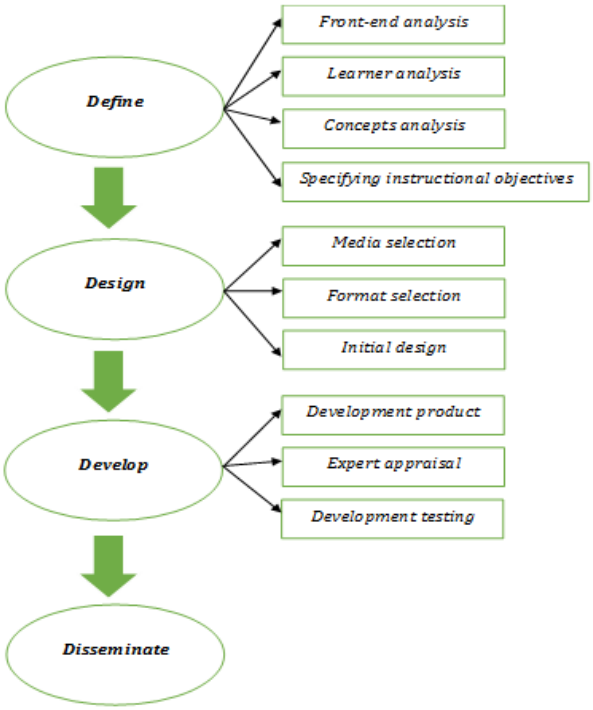

Figure 1. Stages of Four-D Development Model

Based on Figure 1, the development of augmented reality learning media using the Four-D model involves several stages. First, the define stage is carried out by conducting several analyses, which aimed to identify problems and product requirements (front-end analysis), student conditions (learner analysis), concepts material of the learning media (concepts analysis), and the formulation of learning objectives (specifying instructional objectives). This stage involves a review, conducted by the researcher based on preliminary studies and interview results, as well as information obtained from learning books in accordance with the applicable curriculum.

Second, the design stage involves designing the product into a prototype with the preparation of a media storyboard, the selection of media and the collection of media formats. Third, the development stage is carried out by developing the product based on the initial design. Then, it tested for validity by experts and piloted on a small scale to identify initial issues in the media. Also, it tests the reliability of the product before it is used on a larger scale. Moreover, it determines the readability response of the developed learning media before the product is tested on a large scale. After that, the media product tested for practicality in a large-scale trial with students and teachers. At this stage, the product must undergo several revision processes. Finally, the dissemination stage was carried out by distributing augmented reality-based learning media products to several elementary schools after the media had obtained a feasible and practical.

The research focused on two main aspects; the feasibility and practicality of the augmented reality-based learning media. Feasibility testing (validity) is an assessment conducted by experts to evaluate aspects of the media, such as content, presentation, graphics, and language. Meanwhile, practicality testing aims to assess the ease of use and benefits of the media for students and teachers.

The feasibility of the media is determined based on a validity test involving three experts. They are one subject matter expert, one media expert, and one language expert. The research subjects for testing the product consisted of subjects for small-scale trial and large-scale trial. The small-scale trial involved ten students of sixth-grade and a teacher of sixth-grade in SD Negeri 1 Sokaraja Wetan. Meanwhile, the large-scale trial or practicality test used 37 students of sixth-grade and 2 teachers of sixth-grade from SD Negeri 2 Sokaraja Kulon as research samples.

The subjects were selected using purposive sampling technique, in which samples were selected based on several considerations, including the relevance of the material and curriculum used, the readiness of the school infrastructure, and students' characteristics. Grade VI was selected because the material on the rotation and revolution of the Earth is part of the science material for grade VI in the Merdeka curriculum. SDN 2 Sokaraja Kulon were selected as the schools had granted permission for the research and have the necessary facilities to support the use of AR media, such as projectors, internet connections, and mobile devices (laptops or Chromebook). The students - selected as research samples – have the ability in following instructions, paying attention during learning, and demonstrating adequate interest in learning. Also, this selection considered the efficiency of conducting the media trial and the representativeness of the students in relation to the general context of sixth-grade elementary school students.

Data collection techniques used surveys, direct interviews, and questionnaires. The data collection instruments consisted of validation sheets and response questionnaires. The validation sheet is used to assess the suitability of the augmented reality-based learning media using Assemblr EDU based on evaluations by subject matter experts, media experts, and language experts. The response questionnaire is used to assess the practicality of the product through students' and teachers' responses

to the augmented reality learning media using Assemblr EDU on the developed material about Earth's rotation and revolution.

The assessment in the expert validation questionnaire and teachers' response questionnaire uses a modified Likert scale with four levels: "Strongly Agree" with a score of 4, "Agree" with a score of 3, "Disagree" with a score of 2, and "Strongly Disagree" with a score of 1. Meanwhile, the students' response questionnaire is measured using a Guttman scale with 1 for 'Yes' and 0 for "No." The evaluation of the questionnaires is filled out by validators, students, and teachers. It created based on specific aspects related to the content of the material, the visual and technical aspects of the media, language, benefits, and ease of use of the media.

After the data was obtained through the questionnaire, then, it continues to data analysis, which was performed using descriptive statistics through percentage calculations using the following formula.

$$P = \frac{\sum x}{N} \times 100\%$$

Keterangan:
P = Score percentage
$\sum x$ = Total score
N = Maximum score

Then, the data is determined based on percentage intervals. These assessment criteria are useful for categorizing the analyzed data, including expert feasibility assessments, students' readability responses, or teachers' responses. Table 1 shows the validity and practicality assessment criteria in this developmental study.

Table 1. Feasibility Assessment of Criteria and Response

Interval	Feasibility Category	Response Category
81% - 100%	Highly Feasible and Highly Valid	Very Good
61% - 80%	Feasible and Valid	Good
41% - 60%	Somewhat Feasible and Somewhat Valid	Fairly Good
21% - 40%	Not Eligible and Not Valid	Poor
0% - 20%	Very Not Eligible and Very Not Valid	Very Poor

(Puspasari *et al*., 2024)

RESULT AND DISCUSSION

The particular study produced a learning media product based on augmented reality using the Assemblr EDU platform, which was developed to visualize concepts in the material on the rotation and revolution of the Earth in sixth-grade science lessons. The process of media development was carried out by following the stages of the Four-D development model (Define, Design, Develop, and Disseminate). In the define stage, a preliminary study was conducted through a survey to 133 students of sixth-grade elementary school in the Banyumas-Cilacap area and direct interviews with sixth-grade teachers at SDN 2 Sokaraja Kulon. The survey showed that 43.61% of the 133 students of sixth-grade had misconceptions and 40.98% of the students did not understand the material on Earth's rotation and revolution. The problem analysis was supported by the results of direct interviews with teachers. They stated the need for learning media to help students understand the material on the Earth's rotation and revolution because of the abstract concepts in the material. It becomes the basis for the need to develop learning media that could explain abstract concepts in a concrete and visual manner.

The design phase was carried out by selecting the media development platform, Assemblr EDU, as this platform supports the visual presentation of various 3D objects, animations, 2D images, and descriptions in the form of text annotations. The media format consists of 3D objects in GLB format, animations, and supporting images/illustrations using the Sketchfab and Canva websites to collect the media formats.

The media design includes several layers, such as the initial display, introduction to the AR exploration companion, and content. In this media, the character "Nonot" is introduced as an AR exploration companion who provides explanations on each layer. The augmented reality-based learning media on rotation and revolution are accompanied by a guidebook containing media specifications, usage instructions, and access methods.

After the initial design was completed, the media was further developed by adding 3D objects, annotations, and text to each layer. This initial design development entered the development phase, where the media was developed on the Assemblr EDU platform. After that, it validated by subject matter experts, media experts, and language experts. The results of the media validation are shown in the Table 2.

Table 2. Summary of Validity Test Results by Experts

Validator	Score (%)	Category	Improvements	
			Aspect	**Suggestions**
Subject matter expert	85%	Highly feasible and highly valid	Alignment with curriculum and learning objectives	• The learning objectives to be achieved need to be adjusted and further developed • The guidebook needs an introduction, a summary of the materials, and a bibliography
			Interactivity and students' engagement	• An introduction and menu options are needed • Add worksheets to support student learning activities • Include the name of the media developer and the identity of the study program and university
			Ease of understanding	There should be evaluations such as quizzes to measure students' understanding
			Student learning experience	There should be a connection between material and the students' real-life experience
Media expert	92,5%	Highly feasible and highly valid	Visuals and design	• Replace the back-sound music with a happier alternative • Change some background layers with brighter colours
Language expert	95%	Highly feasible and highly valid	Language accuracy	• Improve the grammar and punctuation used in the guidebook • Consistency in the use of terms in the media and guidebook

Based on the validation, the media underwent initial revisions. Suggestions for improvement from experts in the subject matter, media, and language were followed up with revisions to the learning media and guidebook in accordance with the validators' instructions. Revisions to the guidebook began with changing the Operational Verbs in the learning objectives to achievement levels for upper-grade students, so that they were in the C3 and C4 domains. Students Worksheets aims to support student learning activities, introductions, material summaries. Also, bibliographies were added to the guidebook. In terms of language accuracy, revisions were made by improving the grammar and punctuation in content and correcting and standardizing the use of terminology to ensure consistency across the media and guidebook.

In the augmented reality-based learning media, revisions were implemented by adding an introduction and menu options at the beginning of the media. After that, it adds layers showing the transition between day and night through interactive animation to connect the material with students' real-life experiences. And, replacing the background sound with music that feels more joyful and cheerful to help students feel more enthusiastic about learning when using the augmented reality-based learning media on the topic of Earth's rotation and revolution. In addition, the background colors of some layers were changed to be brighter. Additional features include a quiz as an evaluation tool to measure students' understanding and the developer's profile placed at the end of the layer.

The augmented reality-based learning media, which had validity testing by experts and revisions, then pilot-tested on a small scale with 10 students and a teacher of sixth-grade at SDN 1 Sokaraja Wetan. The students' responses to the media showed an average score of 98.9%, while the teacher gave a score of 92.5%. The responses from both students and teachers in the small-scale trial fell into the "Very Good" category. Based on this trial, revisions were made to the readability and language usage aspects, including increasing the text size for easier reading and improving some explanations for better understanding.

After the small-scale product test and revisions, the media was tested on a large scale at SDN 2 Sokaraja Kulon with 37 students and 2 teachers of sixth-grade. This large-scale trial is referred as a practicality test, in which students and

teachers tried to operate the media to determine how practical augmented reality-based learning media in the learning process. The results of the practicality test are presented in the Table 3.

Table 3. Practicality Test Result at SDN 2 Sokaraja Kulon

Respondents	Aspect	Percentage	Category	
Students	Readability		99,10%	Very Good
	Clarity of communication		98,65%	Very Good
	Synchronization of visuals and captions		100%	Very Good
	Cognitive		100%	Very Good
	Media ease		100%	Very Good
	Interest appeal		100%	Very Good
Average			**99,63%**	**Very Good**
Teacher	Visual media		100%	Very Good
	Content relevance		100%	Very Good
	Language usage		100%	Very Good
	Ease of use		93,75%	Very Good
	Media benefits		100%	Very Good
Average			**98,75%**	**Very Good**

The results of large-scale trials or practicality tests showed a very positive response from students and teachers. It indicates the active involvement and participation of students as a positive response to the use of augmented reality-based learning media. During the practical testing of the media, students were enthusiastic to the learning process, actively exploring 3D objects, and engaging in small group discussions to understand simulations of Earth's rotational and revolutionary movements. The presence of the character "Nonot" as an AR exploration companion further enhanced the learning experience, making it more engaging and enjoyable. Thus, it encourages students to focus more and be more active. These results reinforce that the developed media not only provides visual and cognitive benefits but also successfully creates an interactive learning environment and stimulates students' curiosity.

After the practicality test, final revisions were made to the readability and clarity of communication by changing the annotation colours, which aims to make the text clearer and sharper, and adjusting some sentences in the explanations. Thus, the augmented reality-based learning media on the rotation and revolution of the Earth has reached its final product. The final product consists of several layers: cover, menu options, navigation instructions, learning objectives, material selection, introduction, introduction to the AR exploration companion, material content, quiz, farewell to the AR exploration companion, and developer profile.

The final product of the augmented reality-based educational media on the Earth's rotation and revolution, which has undergone validity testing, small-scale product testing, practicality testing, and several revisions is presented in the following figure.

Figure 2. Cover

Figure 3. Menu Options

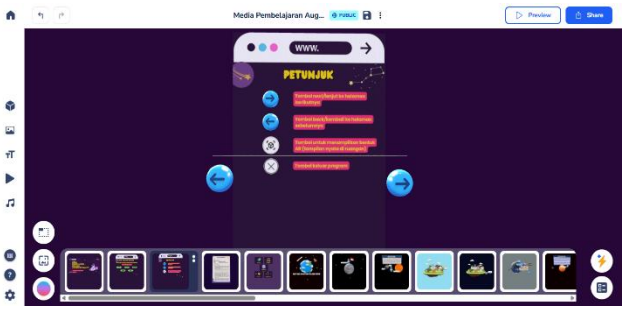

Figure 4. Navigation

Figure 5. Learning Objectives

Figure 6. Material Options

Figure 7. Material Introduction

Figure 8. Introduction to AR Exploration Companion

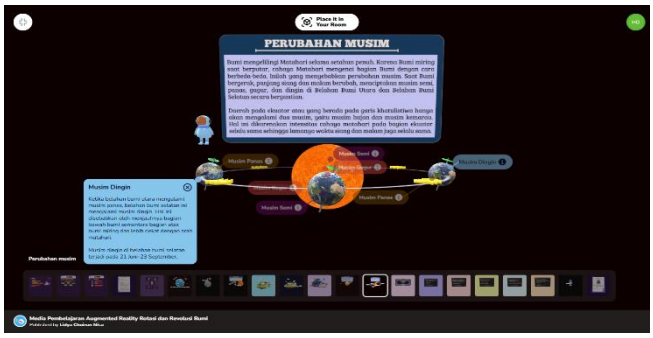

Figure 9. Material Content

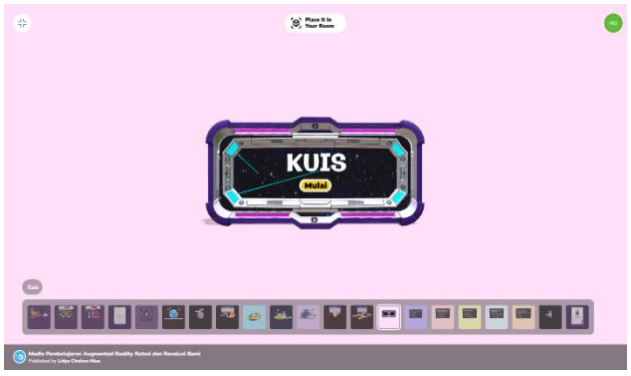

Figure 10. Quiz

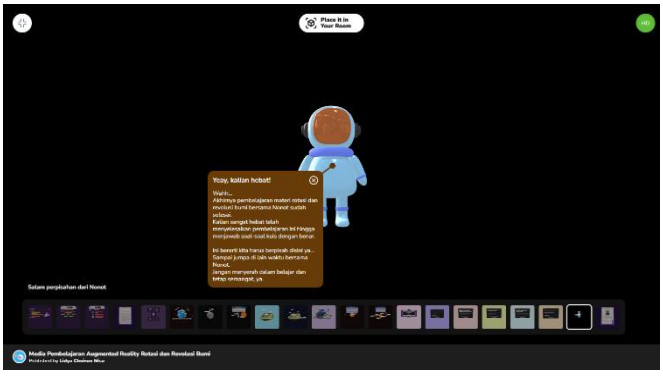

Figure 11. Farewell to AR Exploration Companion

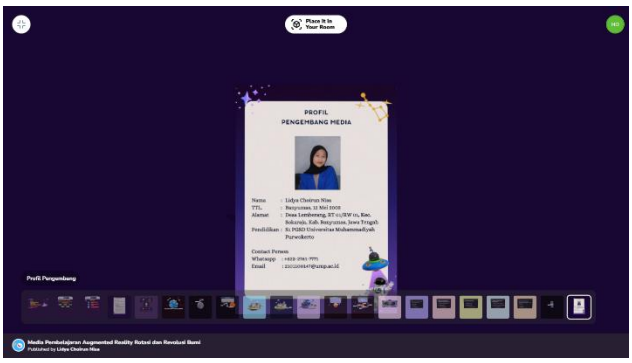

Figure 12. Developer Profile

The final product of augmented reality-based learning media is ready for dissemination. The dissemination stage was carried out on a limited location to four elementary schools; SDN 2 Sokaraja Kulon, SDN 2 Tamansari, SDN 1 Pliken, and SDN 2 Pliken. Time and cost constraints that make the augmented reality-based learning media dissemination could only be distributed to four elementary schools. The dissemination process received positive responses and feedback from both teachers and school officials. Teachers strongly supported the research and development outcomes, expressing willingness to adopt the augmented reality-based educational media for the Earth's rotation and revolution topics in the IPAS (Science) subject for sixth-grade elementary school in the

next academic year. The dissemination was conducted through a presentation of the final product, accompanied by a guidebook, and markers as access tools for the educational media.

Based on the results of the validity and practicality tests of the augmented reality-based learning media, it was found that the developed media is not only suitable in terms of content, visuals, and language, but also practical to use and received very positive responses from both students and teachers. This finding addresses the research problem of high levels of misconceptions and a lack of understanding among students regarding the abstract concepts of Earth's rotation and revolution, as well as the limitations of learning media in helping students understand the material more easily. The developed augmented reality-based learning media presents 3D objects interactively, thereby helping students understand the phenomena of Earth's rotation and revolution in a visually realistic manner and connecting them to students' daily life experiences, such as the alternation of day and night, the apparent daily motion of the sun, time zone differences, and seasonal changes.

The study proved that students' engagement increases during learning using interactive elements with concrete visualizations. Through media that presents concrete visualizations and direct learning experiences, students can easily understand the material. This finding is in line with the Cognitive Theory of Multimedia Learning by Mayer (2002), which states that knowledge transfer in the learning process will be more effective when information is conveyed through visuals accompanied by verbal explanations, rather than words or pictures alone. In addition, Piaget's constructivist learning theory (in Ulya, 2024) states that optimal learning occurs through direct experience and concrete visualization in accordance with the developmental stages of elementary school students who are still in the concrete operational stage.

Practicality test show that nearly all students responded very positive, with an average score of 99.63% across all aspects of the media. Additionally, students demonstrated active participation, enthusiasm, and increased curiosity during the learning process. These findings follow the research results of Chang *et al*. (2022), which noted that augmented reality has a positive effect on various levels of learning outcomes, including student responses, spatial skills, and emotional engagement.

Furthermore, Perifanou *et al*. (2023) emphasize that AR has a great potential in creating a more engaging, motivating, and student-centred learning experience. The visualization of abstract concepts and direct interaction between students and virtual objects -in Perifanou's research - aligns with this study as the presence of the character "Nonot" and the exploration of interactive objects that facilitate deep understanding.

Moreover, the findings support the urgency of using a visual and spatial-based approach, as stated by Bekaert *et al*. (2020), that conceptual misunderstandings can be reduced through learning that provides concrete visual experiences. Thus, the results of this study not only successfully developed a feasible and practical learning media but also integrated visual technology to help students understand previously difficult material. The use of augmented reality has the potential to become a relevant pedagogical strategy for improving the quality of science education, particularly in the context of astronomy education in elementary schools.

The development of augmented reality-based learning media on the subject of Earth's rotation and revolution has limitations, which the trial was only conducted in one elementary school. So, the generalization of the findings is still limited and cannot represent a wider population. The final product of the research has also not undergone widespread dissemination. Then, its effectiveness in different contexts still needs to be further tested. Additionally, access to the Assemblr EDU platform requires a good network connection to be used effectively. Despite these limitations, the main findings of the study already represent the research objectives of the development. First, the implementation of augmented reality-based educational media development has met all stages. And, the results of validity and practicality tests of the media show very good category.

The study has important implications for teacher and professional development. The developed augmented reality-based learning media can be an innovative training resource in workshops, MGMP, and PPG training to strengthen teachers' competence in integrating technology into science learning. The use of this media can also enrich learning strategies that require concrete and visual approaches to understand scientific phenomena containing abstract concepts.

CONCLUSION

The study produced augmented reality-based learning media using Assemblr EDU that is feasible and practical for use for sixth-grade elementary school on the topic of rotation and revolution of the Earth. Validation and test show that this media helps students understand abstract concepts through interactive three-dimensional visualization. At the same time, it increases emotional engagement, active participation, and curiosity during the learning process.

This media is relevant and consistent with previous findings on the effectiveness of augmented reality in creating hands-on learning to build students' learning experiences with realistic visualizations, thereby facilitating students' understanding of the Earth's rotation and revolution. The study is expected to serve as a reference for academics in using technology to create innovative and meaningful learning experiences tailored to students' needs.

Moreover, it recommends further research to test the effectiveness of the learning media in learning implementation to conduct follow-up research, which aims to determine the impact of the media on improving students' conceptual understanding, reducing misconceptions, and its influence on long-term learning outcomes.

REFERENCES

Afnan, Muhammad, K., Khan, N., Lee, M. Y., Imran, A. S., & Sajjad, M. (2021). School of the future: A comprehensive study on the effectiveness of augmented reality as a tool for primary school children's education. *Applied Sciences (Switzerland)*, *11*(11). https://doi.org/10.3390/app11115277

Amir, M. F., Fediyanto, N., Rudyanto, H. E., Nur Afifah, D. S., & Tortop, H. S. (2020). Elementary students' perceptions of 3Dmetric: A cross-sectional study. *Heliyon*, *6*(6). https://doi.org/10.1016/j.heliyon.2020.e04052

Astalini, Darmaji, Kurniawan, D. A., & Octavia, S. W. (2024). Assembler Edu E-Modules: Improving Argumentation Skills, Perseverance, and Curiosity in Physics Learning. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *8*(2), 550–562. https://doi.org/10.22437/jiituj.v8i2.37238

Astuti, I. A. D., Nursatyo, K. I., & Hanafi, I. (2023). Penggunaan Teknologi Digital dalam Pembelajaran IPA: Study Literature Review. *Navigation Physics : Journal of Physics Education*, *5*(1), 34–43. https://www.journal.unindra.ac.id/index.php/jpeu/article/view/1859

Azuma, R. T. (2009). A Survey of Augmented Reality. *Hughes Research Laboratories*, *6*(4), 355–385. https://doi.org/10.1016/j.chaos.2009.03.056

Başpınar, P., Çakıroğlu, J., & Karahan, E. (2024). The Effect of Engineering Design-Based Science Instruction on 6th-Grade Students ' Astronomy Understandings. *Science Insights Education Frontiers*, *24*(1), 3835–3857. https://doi.org/10.15354/sief.24.or628

Bekaert, H., Van Winckel, H., Van Dooren, W., Steegen, A., & De Cock, M. (2020). Design and validation of an instrument to test students' understanding of the apparent motion of the Sun and stars. *Physical Review Physics Education Research*, *16*(2), 20135. https://doi.org/10.1103/PhysRevPhysEducRes.16.020135

Bekaert, H., Van Winckel, H., Van Dooren, W., Steegen, A., & De Cock, M. (2022). Identifying students' mental models of the apparent motion of the Sun and stars. *Physical Review Physics Education Research*, *18*(1), 10130. https://doi.org/10.1103/PhysRevPhysEducRes.18.010130

Blanco-Chamborro, M. S., Varela-Losada, M., Lorenzo-Rial, M., & Pérez-Rodríguez, U. (2023). Review of Educational Research in Astronomy in Early Childhood and Primary Education from 2009 to 2019. *Acta Scientiae*, *25*(6), 118–156. https://doi.org/10.17648/acta.scientiae.6814

Cardinot, A., & Fairfield, J. A. (2021). Alternative Conceptions of Astronomy: How Irish Secondary Students Understand Gravity, Seasons, and the Big Bang. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(3), 1–24. https://doi.org/10.29333/EJMSTE/10780

Chang, H. Y., Binali, T., Liang, J. C., Chiou, G. L., Cheng, K. H., Lee, S. W. Y., & Tsai, C. C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers and Education*, *191*(August). https://doi.org/10.1016/j.compedu.2022.104641

Colantonio, A., Marzoli, I., Puddu, E., Bardelli, S., Fulco, M. T., Galano, S., Terranegra, L., & Testa, I. (2021). Describing astronomy identity of upper primary and middle school students through structural equation modeling. *Physical Review Physics Education Research*, *17*(1), 10139. https://doi.org/10.1103/PhysRevPhysEducRes.17.010139

Dankenbring, C., & Capobianco, B. M. (2016). Examining Elementary School Students' Mental Models of Sun-Earth Relationships as a Result of Engaging in Engineering Design. *International Journal of Science and Mathematics Education*, *14*(5), 825–845. https://doi.org/10.1007/s10763-015-9626-5

Felicita, G. A. (2020). Alternative Conceptions of Elementary Scholl Students in Astronomy. *EPRA International Journal of Multidisciplinary Research (IJMR)-Peer*

Reviewed Journal, *2*, 198–210. https://doi.org/10.36713/epra2013

Ferrari, E., Teijón, P. H., & Ruiz, C. (2024). Unlocking the cosmos: evaluating the efficacy of augmented reality in secondary education astronomy instruction. *Journal of New Approaches in Educational Research*, *13*(8). https://doi.org/10.1007/S44322-024-00007-8

Galano, S., Colantonio, A., Leccia, S., Marzoli, I., Puddu, E., & Testa, I. (2018). Developing the use of visual representations to explain basic astronomy phenomena. *Physical Review Physics Education Research*, *14*(1), 10145. https://doi.org/10.1103/PhysRevPhysEducRes.14.010145

Gaudreau, C. M., Anggoro, F. K., & Jee, B. D. (2020). Children's Spontaneous Gestures Reflect Verbal Understanding of the Day/Night Cycle. *Frontiers in Psychology*, *11*(June), 1–7. https://doi.org/10.3389/fpsyg.2020.01123

Huerta-Cancino, L., & Alé-Silva, J. (2024). Augmented Astronomy for Science Teaching and Learning. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 14737 LNCS* (Issue June). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-60458-4_16

Kanli, U. (2015). Using a Two-tier Test to Analyse Students' and Teachers' Alternative Concepts in Astronomy. *Science Education International*, *26*(2), 148–165.

Lestari, P. D. D., & Naila, I. (2021). Profil kemampuan spasial siswa sekolah dasar dalam pemecahan masalah geometri: Sebuah studi literatur. *Jurnal Fundadikdas (Fundamental Pendidikan Dasar)*, *4*(1), 9–20.

Lissa'adah, L., & Widiyatmoko, A. (2023). The Effectiveness of Augmented Reality Based On Assemblr Edu To Increase Learning Interest and Student Learning Outcomes. *Journal of Environmental and Science Education*, *3*(2), 79–85. https://journal.unnes.ac.id/sju/jese/article/view/61000%0Ahttps://journal.unnes.ac.id/sju/jese/article/download/61000/26100

Mayer, R. E. (2002). Multimedia Learning. *THE PSYCHOLOGY OF LEARNING AND MOTIVATION*, *41*, 85–139. https://doi.org/10.1057/9780230800601_4

Perifanou, M., Economides, A. A., & Nikou, S. A. (2023). Teachers' Views on Integrating Augmented Reality in Education: Needs, Opportunities, Challenges and Recommendations. *Future Internet*, *15*(1). https://doi.org/10.3390/fi15010020

Plummer, J. D., Bower, C. A., & Liben, L. S. (2016). The role of perspective taking in how children connect reference frames when explaining astronomical phenomena. *International Journal of Science Education*, *38*(3), 345–365. https://doi.org/10.1080/09500693.2016.1140921

Puspasari, A. D., Afiani, K. D. A., & Setiawan, F. (2024). PENGEMBANGAN MEDIA FRACTION AR (AUGMENTED REALITY) BERBASIS ASSEMBLR EDUPADA PEMBELAJARAN MATEMATIKA MATERI PECAHAN SEDERHANA KELAS II SD. *Pendas : Jurnal Ilmiah Pendidikan Dasar*, *09*(03), 1888–1904.

Serttaş, S., & Türkoğlu, A. Y. (2020). Diagnosing students' misconceptions of astronomy through concept cartoons. *Participatory Educational Research*, *7*(2), 164–182. https://doi.org/10.17275/PER.20.27.7.2

Slater, E. V., Morris, J. E., & McKinnon, D. (2018). Astronomy alternative conceptions in pre-adolescent students in Western Australia. *International Journal of Science Education*, *40*(17), 2158–2180. https://doi.org/10.1080/09500693.2018.1522014

Sugiyono. (2019). Metode Penelitian & Pengembangan (Research and Development/R&D). In *Penerbit Alfabeta*.

Sung, J. Y., & Oh, P. S. (2018). Sixth Grade Students' Content-Specific Competencies and Challenges in Learning the Seasons Through Modeling. *Research in Science Education*, *48*(4), 839–864. https://doi.org/10.1007/s11165-016-9589-8

Suparmi, N. W., Dinatha, N. M., & Kua, M. Y. (2024). Pengaruh Media Pembelajaran Berbasis Unity 3D Pada Materi Tata Surya. *Didaktika: Jurnal Kependidikan*, *13*(3), 3193–3200. https://www.ssed.or.id/contents/article/view/676%0Ahttps://www.ssed.or.id/contents/article/download/676/544

Testa, I., Galano, S., Leccia, S., & Puddu, E. (2015). Development and validation of a learning progression for change of seasons, solar and lunar eclipses, and moon phases. *Physical Review Special Topics - Physics Education Research*, *11*(2), 1–22. https://doi.org/10.1103/PhysRevSTPER.11.020102

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1976). Instructional development for training teachers of exceptional children: A sourcebook. *Indiana University Bloomington*,

14(1), 75. https://doi.org/10.1016/0022-4405(76)90066-2

Ulya, Z. (2024). Penerapan Teori Konstruktivisme Menurut Jean Piaget dan Teori Neuroscience dalam Pendidikan. *Al-Mudarris: Journal of Education*, *7*(1), 12–23. https://doi.org/10.32478/vg1nnv56

Vosniadou, S., & Skopeliti, I. (2017). Is it the Earth that turns or the Sun that goes behind the mountains? students' misconceptions about the day/night cycle after reading a science text. *International Journal of Science Education*, *39*(15), 2027–2051. https://doi.org/10.1080/09500693.2017.1361557

Widyaningrum, F. A., Maryani, I., & Vehachart, R. (2022). Literature Study on Science Learning Media in Elementary School. *International Journal of Learning Reformation in Elementary Education*, *1*(01), 1–11. https://doi.org/10.56741/ijlree.v1i01.51