



Development of Augmented Reality-Based Solar System Learning Media for Sixth-Grade Elementary School Students

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ABSTRACT

One of the goals of science teaching is to help students gain a deeper scientific understanding of natural phenomena, such as the solar system. However, in reality, students often struggle to understand abstract ideas about the solar system. Difficulty in understanding abstract concepts can cause students to experience misconceptions so they need appropriate learning media. This research aims to create Augmented Reality-based Solar System Learning Media (ARSSMED), so that it will help students in understanding abstract ideas. The ADDIE (Analysis, Design, Development, Implementation, Evaluation) approach is the basis of the research and development which is used in this study. The research instrument used validation sheets for media, material, and language experts to determine product feasibility. Practicality test was also used through student and teacher response questionnaires in the study. The results showed validation by ARSSMED experts included in very valid criteria. This can be seen from the assessment of media experts of 82.5%, material experts of 92.5, and linguists of 97.5%. At the implementation stage, teachers and students also gave positive responses to ARSSMED. Based on students' responses, ARSSMED is included in the very practical criteria. These findings indicate that the ARSSMED developed is feasible to use for learning. This study recommends further testing the effectiveness of ARSSMED.

Keywords: *augmented reality, learning media, solar system*

ABSTRAK

Peningkatan pemahaman siswa terhadap suatu fenomena alam secara ilmiah merupakan salah satu tujuan dari pembelajaran sains, salah satunya pada materi sistem tata surya. Namun pada kenyataannya, siswa sering kali kesulitan untuk memahami ide-ide abstrak tentang tata surya. Kesulitan dalam memahami konsep abstrak dapat menyebabkan siswa mengalami miskonsepsi sehingga memerlukan media pembelajaran yang sesuai dan tepat. Tujuan dari penelitian ini adalah untuk mengembangkan Media Pembelajaran sistem tata surya berbasis Augmented Reality yang akan membantu siswa dalam memahami ide-ide abstrak. Pendekatan ADDIE merupakan dasar dari penelitian dan pengembangan yang digunakan dalam penelitian ini. Instrumen penelitian

menggunakan lembar validasi ahli media, materi, dan bahasa untuk mengetahui kelayakan produk. Uji kepraktisan juga digunakan melalui angket respon siswa dan guru dalam penelitian. Hasil penelitian menunjukkan validasi oleh ahli, ARSSMED termasuk dalam kriteria sangat valid. Hal tersebut terlihat dari penilaian ahli media sebesar 82,5%, ahli materi sebesar 92,5, dan ahli bahasa sebesar 97,5%. Pada tahap implementasi, guru dan siswa juga memberikan respon yang positif terhadap ARSSMED. Berdasarkan respon siswa, ARSSMED termasuk dalam kriteria sangat praktis. Temuan ini menunjukkan bahwa produk ARSSMED yang dikembangkan layak digunakan untuk pembelajaran. Penelitian ini merekomendasikan untuk selanjutnya dilakukan uji efektivitas media pembelajaran berbasis augmented reality dalam pembelajaran sistem tata surya.

Kata Kunci: augmented reality, media pembelajaran, sistem tata surya

INTRODUCTION

A primary objective in the realm of science education is to enhance students' comprehension of natural phenomena from a scientific perspective (OECD, 2019). Elementary education, representing the initial formal educational experience for children, is considered the optimal environment for shaping their cognitive conceptions (Ratnasari et al., 2025). Science learning should facilitate the development of a profound comprehension of the system that connects various scientific concepts, theories, and principles in a logical and systematic manner (Plummer et al., 2015). A crucial component of scientific education for students is an understanding of the solar system.

The integration of the solar system concept into the scientific learning process has been demonstrated to enhance students' comprehension of natural phenomena, such as the position of the planets in the solar system (Prima et al., 2018; Zahara et al., 2020). Science learning on the concept of the solar system is imperative to ensure that students do not encounter misconceptions. Students' understanding, ideas, and opinions that conflict with scientific concepts is referred to as misconceptions (Vosniadou & Skopeliti, 2017).

A significant number of students harbor misconceptions regarding solar system material. As indicated in the research, students encounter difficulties comprehending the concepts of moon phases, seasonal changes, the position of the sun in the sky, shooting stars, comets, star orbits, comets and constellations (Korur, 2015; Serttaş & Türkoğlu, 2020). The inability of students to observe the motion of planets in the solar system has been shown to make knowledge construction abstract and incomprehensible (Chen et al., 2022). The students' misconceptions are corroborated by field data obtained through a preliminary study.

A preliminary study through a survey conducted in seven grade sixth elementary schools in the Banyumas-Cilacap area. The survey was conducted with 133 primary school students as respondents using two-tier diagnostic test and Certainty of Response Index (CRI) instruments. The results showed that 44.55% of students had misconceptions about the solar system material. Students who understood the concept were only 15.42% and as many as 40.98% did not understand the concept. Based on these percentage figures, almost half of all students experience misconceptions. These findings indicate that the level of misconceptions experienced by elementary school students is quite high (Muhabib et al., 2024).

The high level of misconceptions experienced by students can occur due to various factors. They face difficulty in understanding basic concepts, limited direct observation of astronomical phenomena, wrong initial concepts, and limited ability in visualization (Kanli, 2015; Korur, 2015; Serttaş & Türkoğlu, 2020; Vosniadou & Skopeliti, 2017). Teaching factors by teachers

about the material presented can also make students experience misconceptions (Kanli, 2015). The paucity of learning tools in the form of appropriate media is a factor in students experiencing misconceptions about abstract solar system concepts (Kanli, 2015; Vosniadou & Skopeliti, 2017).

Based on the preliminary study, a needs analysis was conducted to determine the specific needs that need to be met to make learning more effective. The needs analysis was conducted through interviews with sixth-grade teachers and school observations. The teacher stated that students were not interested because they only saw pictures in the book, even though the material on the solar system should use interesting visualizations. Teachers stated that interactive media that is visual and easily accessible to students is greatly needed, especially for explaining phenomena that cannot be observed directly. The observation studies indicate that, despite the presence of adequate facilities and infrastructure, including internet networks, projectors, and teaching devices, educators have yet to identify effective learning media to facilitate student comprehension of solar system material.

Previous empirical studies have supported the effectiveness of using augmented reality in science education. For example, Aydin & Ozcan (2022) found that the application of AR significantly improved students' understanding of astronomical concepts and reduced misconceptions among elementary school students. Similar findings were reported by Salazar et al. (2020), who demonstrated that AR helps students visualize the scale and distances between planets more accurately than conventional media. Additionally, Sirakaya & Cakmak (2018) emphasized that AR not only enhances cognitive understanding but also motivates learning through direct interaction with three-dimensional objects. These results provide a strong empirical basis that AR is a relevant alternative medium for addressing misconceptions in solar system material in elementary schools.

One proposed solution to address these misconceptions is the incorporation of augmented reality-based learning media (Arici et al., 2019). Augmented reality has been demonstrated to facilitate the visualization of abstract concepts through interactive three-dimensional rendering (Hamzah et al., 2021; Mansour et al., 2024). Its potential to simulate the scale, distance, and movement of the solar system is a subject of considerable interest, given the challenges often encountered in comprehending these concepts through conventional methods (Hordiienko et al., 2020; Salazar et al., 2020). The employment of augmented reality as a media for learning has been extensively explored, yielding favourable outcomes.

Augmented reality significantly improves students' understanding and retention of solar system concepts (Salazar et al., 2020). Augmented reality helps correct misconceptions about celestial phenomena by providing accurate and real-time visualizations, thus improving students' understanding of planetary sizes and distances (Aydin & Ozcan, 2022; Sirakaya & Cakmak, 2018). Interactive features, such as quizzes and touch-based input, allow students to test understanding and receive immediate feedback, further reinforcing correct concepts (Elmunyah et al., 2019; Salazar et al., 2020).

Research on augmented reality-based learning media has been widely conducted on science learning. Augmented reality is used to eliminate student misconceptions (Sirakaya & Cakmak, 2018). Augmented reality integration in learning as a tool in developing students' scientific concepts (Setiawaty et al., 2024; S. Yoon et al., 2017; H. Y. Chang et al., 2018). The application of augmented reality has been utilized to ascertain students' conceptions of science

learning (Cheng, 2018; Oh et al., 2018). The findings indicated that the implementation of augmented reality has led to a substantial enhancement in students' cognitive engagement (Wen, 2021). The utilization of augmented reality in educational settings has yielded favorable outcomes in learning activities, as evidenced by the findings of recent studies.

Science education should ideally provide a thorough understanding of natural phenomena scientifically. Indeed, a significant number of students continue to encounter misconceptions regarding solar system material. The abstract concepts inherent in the material necessitate the utilization of learning media to facilitate comprehension. The employment of augmented reality-based learning media has emerged as a potential solution to these challenges. The development of augmented reality-based learning media remains underutilized in elementary schools. Most of the research on augmented reality-based learning media has been conducted within the secondary school context. A research study is necessary to explore the potential of augmented reality as a learning media in elementary schools. There is a need for research that discusses augmented reality as a learning medium at the elementary school level so that it can help students understand abstract concepts on solar system material.

In the context of this research, the goal to be achieved is the formulation of augmented reality-based learning media. Augmented Reality-based Solar System Media (ARSSMED) is designed to help students understand abstract astronomy concepts interactively. The development model employs the ADDIE procedure, which is anticipated to serve as a viable learning media for solar system material. It is hypothesized that this research will contribute to enhancing the quality of science education by developing ARSSMED. The objective of this media is to assist students in comprehending the abstract concepts of solar system material.

METHODS

Type and Design

The present study employs research and development methodologies (R&D). Research and development are a research method that involves the production of specific products and subsequent testing of their effectiveness or feasibility (Sugiyono, 2019). The objective of this study is to develop ARSSMED using Assembr EDU for sixth-grade elementary school students on solar system material.

The development model employed is the ADDIE development procedure. The ADDIE model, an acronym for Analyse, Design, Develop, Implement, and Evaluate (Sugiyono, 2019), is a structured approach to instructional design that involves a systematic process of planning, preparation, and implementation of an educational program. The ADDIE model development procedure was selected due to its ability to provide a systematic approach, ensure comprehensive coverage of all aspects of instructional design, and facilitate efficient organization of the development process (Widyastuti & Susiana, 2019).

This study explicitly focuses on two main aspects, namely the validation and feasibility of the developed product. This study does not include an analysis of the cognitive impact on students, as this was not included in the initial research objectives. Therefore, it is recommended that future research examine the effectiveness of the product on cognitive learning outcomes in greater depth, in order to gain a more comprehensive understanding of

the contribution of the developed tools or instruments in improving student learning outcomes.

Data and Data Sources

This research aims to develop ARSSMED to facilitate sixth-grade students' comprehension of abstract solar system concepts. The research was conducted at SD Negeri 5 Salebu in Majenang, Cilacap. The data were collected through various means, including surveys, interviews, expert validation questionnaires, student response questionnaires, and teacher response questionnaires.

The survey was administered using a two-tier test questionnaire to assess students' comprehension. Further, a series of interviews were conducted with teaching professionals in order to ascertain the needs of teachers in relation to learning media tools. Assessing the feasibility of ARSSMED that had been developed, expert validation questionnaires were administered to three validators: media experts, material experts, and linguists. The practicality test was carried out through the assessment of student responses using a student response questionnaire. The questionnaire was administered to 10 respondents from small-scale groups and 36 respondents from large-scale groups. The objective of the teacher response questionnaire was to ascertain the educators' evaluation of the efficacy of ARSSMED.

Data collection technique

The present research data collection was carried out through the implementation of questionnaires, interviews, and documentation. The questionnaire is a data collection method that aims to obtain answers by presenting research subjects with a series of questions or written statements (Sugiyono, 2019). The employment of a questionnaire is predicated on the premise that respondents are required to select responses from a predetermined list, thereby enhancing the efficiency of the data collection process (Riduan & Suryani, 2024). The questionnaires employed in this study encompass a media feasibility questionnaire, a student response questionnaire, and a teacher response questionnaire, designed to assess ARSSMED.

Data analysis

The data obtained through the questionnaire was then subjected to analysis. The expert validation questionnaire and teacher responses used a modified Likert scale with a 1-4 rating system. The student response questionnaire, which is administered to ascertain the practicality of ARSSMED, consists of 10 questions. Testing students' practical skills using a questionnaire with a 1-0 Gutman scale. The feasibility and practicality analysis of ARSSMED uses the following percentage calculations:

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

Information:

P: Percentage score of the feasibility questionnaire

$\sum x$: The maximum score of the assessment item

N: Total average score of assessment items

The following table (Puspasari et al., 2024) presents the criteria for the feasibility and practicality level of ARSSMED.

Table 1. Media Feasibility and Practicality Level Criteria

Feasibility Percentage (%)	Criteria
81 - 100	Very Valid & Very Practical
61 - 80	Valid & Practical
41 - 60	Enough & Less Practical
21 - 40	Invalid & Not Practical
0 - 20	Very Invalid & Very Not Practical

RESULTS AND DISCUSSION

The research that has been carried out is a type of development research, also referred to as research and development. The research procedure employed in this study is the ADDIE model. The ADDIE procedure is an acronym for Analyze, Design, Develop, Implement, and Evaluate (Sugiyono, 2019). The utilization of this procedure is predicated on its systematic nature, which commences with a problem and needs analysis and culminates in the evaluation of product trial results.

Analyze

This stage is subdivided into two phases: (1) need assessment and (2) front-end analysis. The objective of the assessment is to ascertain the learning needs of the participants through observation and interviews. Preliminary findings from the need assessment indicate an absence of prior implementation of ARSSMED.

The results of direct interviews indicate that teachers require learning media to facilitate student comprehension of solar system material. The presence of solar system material in the sixth-grade curriculum has been identified as a factor contributing to students' challenges in conceptualizing abstract concepts. The survey data illuminates the prevalence of students' challenges, as evidenced by the finding that 44.55% of 133 sixth-grade elementary school students exhibited misconceptions.

The front-end analysis stage is designed to develop technology-based learning media. This stage includes audience analysis, technology analysis, task analysis, media analysis, and extended data analysis. The target users are sixth-grade students of SD Negeri 5 Salebu, consisting of 36 respondents. The Assembler EDU platform was selected for the development of ARSSMED through the utilization of various available tools. Access to ARSSMED is facilitated through Quick Response Code and markers.

The curriculum analysis is conducted by identifying the scope of IPAS learning, specifically the topic of the solar system. The selected topic is aligned with the needs of students who require learning media to comprehend abstract concepts. The acquisition of competencies in media development is undertaken to address these exigencies and challenges.

The development of ARSSMED is undertaken with the learning objectives to be achieved in mind. The expected end result is that through the use of ARSSMED, students have the ability to understand the concept of the solar system including the constituent celestial bodies of the solar system, the characteristics of the planets, the classification of inner and outer planets, and the differences between meteors, meteorites, and meteoroids.

Design

The design stage is the process of conceptualizing a product. At this stage, the process of storyboarding is implemented, thereby serving as a comprehensive framework for media content, encompassing template design and the preparation of learning materials. Furthermore, the software necessary to facilitate the media design process has been prepared. The software utilized in this phase encompasses Assemblr EDU, which functions as the primary platform for the development of ARSSMED in 3D and animation, supported by Sketchfab. Beyond the scope of these platforms, Canva is also employed for the creation of various components, including captions in the form of images. The following image depicts the Assemblr EDU platform, which is utilized for the development of ARSSMED.

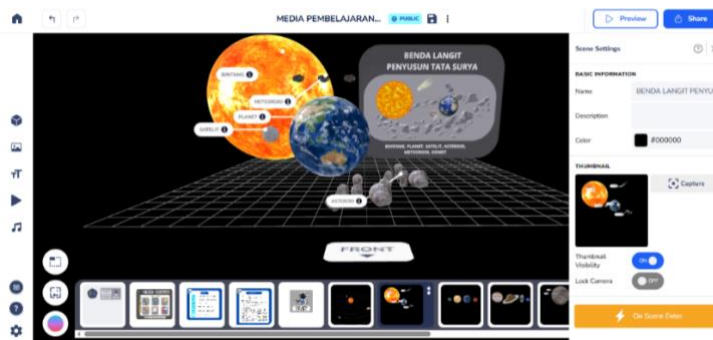


Figure 1. Display of Assemblr EDU Platform

The learning media developed is three-dimensional and includes annotations. Upon clicking the annotation, a description is rendered, providing an explanation of the celestial object in question. The subsequent image illustrates the annotation that is displayed upon clicking, accompanied by an explanation of the object in question.

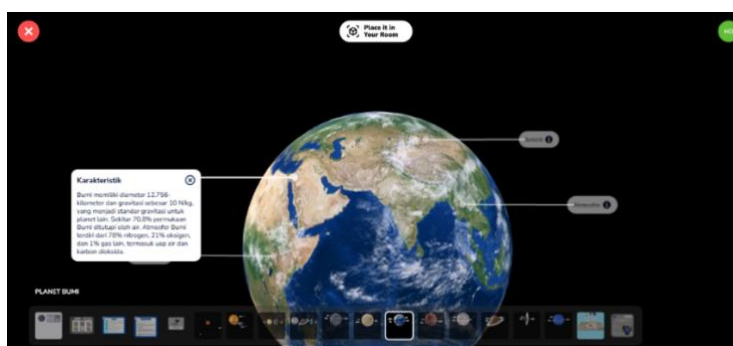


Figure 2. ARSSMED Annotation Display

The learning media developed using Assemblr EDU contains a front cover, main menu, usage guide, material identity, solar system material, evaluation tools, and media maker

profile. The guidebook has been developed to assist users in leveraging ARSSMED. The guidebook contains a preface, specifications of the product developed, material identity, instructions for use, media display, media maker profile, and Quick Response Code.

Development

Researchers developed ARSSMED using Assemblr EDU and assessed its feasibility and validity through expert testing. Validation was conducted by media, content, and language experts using a questionnaire based on specific indicators. Media experts assessed software aspects and visual communication, while content experts evaluated the content and its alignment with learning objectives. Meanwhile, language experts assessed language usage and readability for students. The following section presents the results of the expert validators' assessments.

Table 2. Calculation Results of Media, Material, and Language Expert Validation Assessment

Validator	No	Indicators Assessment	Number of Items	Score Obtained	Percentage	Criteria
Media Experts	1	Software	5	18	82,5%	Very Valid
	2	Visual Communication	5	15		
	Sum of Scores			10	33	
Material Experts	1	Content	5	18	92,5%	Very Valid
	2	Learning	5	19		
	Sum of Scores			10	33	
Language Experts	1	Linguistics	5	20	97,5%	Very Valid
	2	Language suitability with users	5	19		
	Sum of Scores			10	33	

The validation results show that ARSSMED is considered highly valid by experts. The media experts gave a score of 82.5% with suggestions for improvement regarding the background music to make it more cheerful. The material experts gave a score of 92.5% and suggested adding learning objectives and student evaluations. Meanwhile, the language experts gave a score of 97.5% with feedback regarding adjustments to the learning outcome indicators. All feedback has been incorporated, making ARSSMED increasingly suitable for use in education.

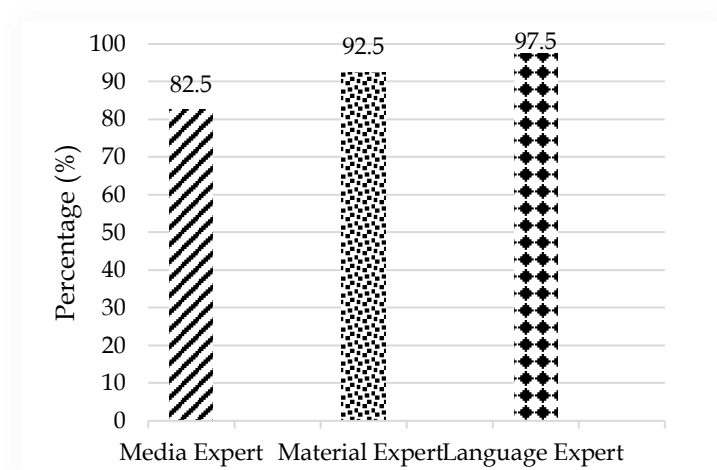


Figure 3. Validation Results by Media Experts, Content Experts, and Language Experts from the Development of ARSSMED

Figure 3 shows the assessment results from the three experts evaluating the ARSSMED product development. Referring to Puspasari et al. (2024) expert assessment criteria, ARSSMED was declared to be highly valid. Therefore, ARSSMED as a development product can proceed to the implementation stage.

Implementation

Small Scale Trial

Subsequent to being evaluated as valid by media, material, and language experts, products in the form of ARSSMED are subjected to testing on a small scale. A series of small-scale trials were conducted at SD Negeri 03 Salebu sixth-grade, with a total of 10 respondents participating in the study. It is evident that the execution of small-scale trials occurred in the absence of the concomitant learning process. This is attributable to the fact that the students had already obtained the prerequisite material. A series of practical tests were conducted to ascertain the readability of products in the form of ARSSMED. The ensuing table presents the results of these tests.

Table 3. Small Scale Trial Results Student Response

No.	Assessment Indicator	Percentage Score (%)	Criteria
1	View	97.5	Very practical
2	Navigation icons	100	Very practical
3	Language	100	Very practical
4	Media attractiveness	100	Very practical
5	Clarity of material	100	Very practical
Average Percentage Score		99.5	Very practical

The differences in the percentage scores obtained by students in response to ARSSMED in the small-scale test can be seen in the following figure.

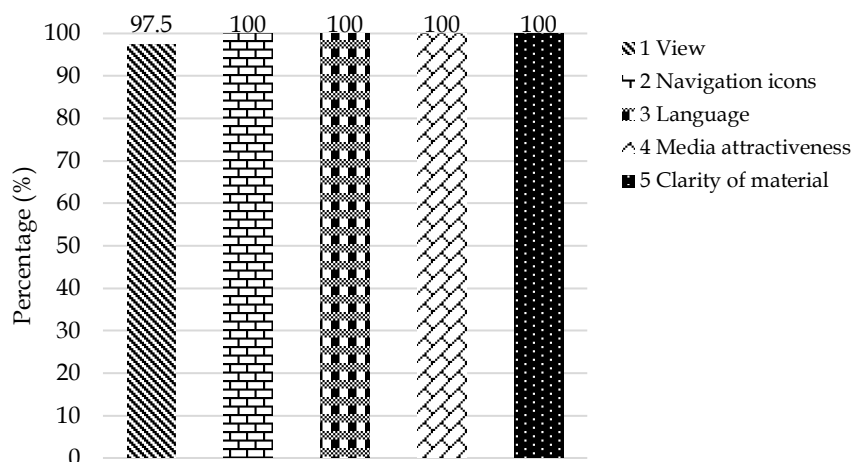


Figure 4. Comparison of ARSSMED Assessment Indicator Scores through Student Responses in Small-Scale Trial

Based on Table 3 and Figure 4, it shows the students' responses during the small-scale test. The percentage of scores obtained on each indicator was very high, reaching an average of 99.5%. Therefore, based on the criteria mentioned by Puspasari et al. (2024), it can be concluded that ARSSMED is classified as very practical.

Large Scale Trial

Student Response to ARSSMED

The large-scale test is designed to assess students' understanding before and after treatment. Nevertheless, a substantial-scale evaluation was likewise executed to ascertain the responses of students to ARSSMED. In accordance with its implementation in the educational context, a series of inquiries were directed at the students, the responses to which are delineated in the subsequent table.

Table 4. Recapitulation of Student Response to ARSSMED

No.	Assessment Indicator	Percentage Score (%)	Criteria
1	View	100	Very practical
2	Navigation icons	100	Very practical
3	Language	100	Very practical
4	Media attractiveness	100	Very practical
5	Clarity of material	94	Very practical
Average Percentage Score		98	Very practical

The scores obtained from the large-scale student response test to determine the percentage of each indicator can be seen in the following figure.

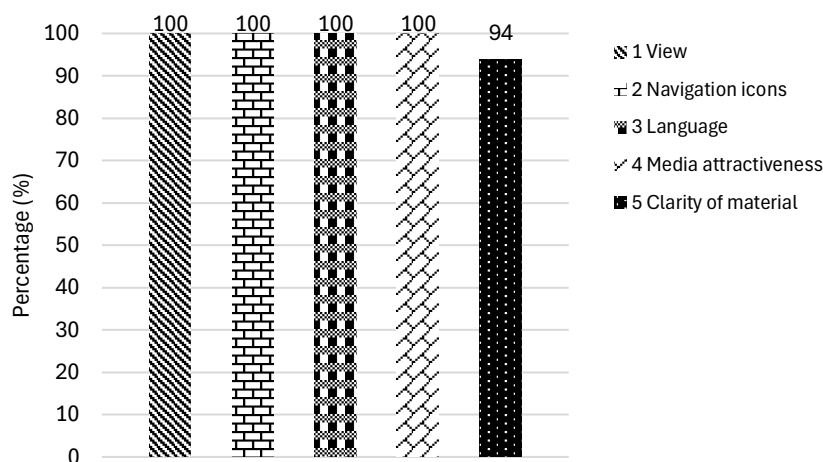


Figure 5. Comparison of ARSSMED Assessment Indicator Scores through Student Responses in Large-Scale Trial

According to the findings presented in Table 4 and Figure 5, the results of the analysis of student responses to the implementation of ARSSMED have been obtained. Based on the criteria mentioned by Puspasari et al. (2024), ARSSMED received an average score of 98%, which is indicative of the Very practical category. The findings indicate that students exhibit a positive response to ARSSMED. Aspects such as visual appearance, ease of navigation, clarity of language, attractiveness, and understanding of the material are very supportive of the learning process.

Teacher Response to ARSSMED

To assess the efficacy of the ARSSMED that has been developed, data collection is conducted through the administration of questionnaires to teachers. Teacher response constitutes a pivotal metric for evaluating the viability, pragmatism, and efficacy of media in facilitating the teaching and learning process. Based on the results of the teacher response questionnaire, responses were obtained that reflected the level of acceptance and potential use of ARSSMED.

Table 5. Recapitulation of Teacher Response to ARSSMED

No.	Assessment Indicator	Number of Item	Percentage Score (%)	Criteria
1	Learning media design	1,2	100	Very good
2	Curriculum alignment	3,4	100	Very good
3	Effectiveness of learning media	5,6	100	Very good
4	Practical to use	7,8	100	Very good
5	Benefits of media	9,10	100	Very good
Average Percentage Score			100	Very good

The results of teachers' responses to ARSSMED development products in large-scale trial can be seen in the following figure.

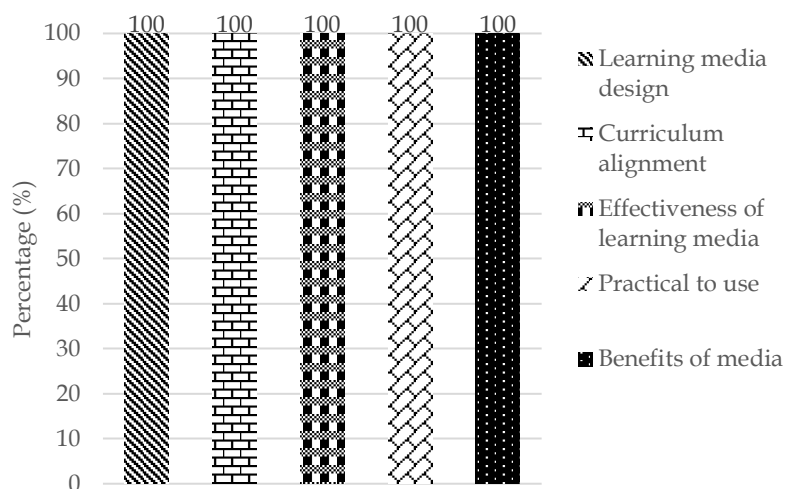


Figure 6. Comparison of Assessment Indicators from Teacher Responses to ARSSMED in Large-Scale Trials

As indicated by the data presented in the Table 5 and Figure 6, the average score assigned by teachers to responses to ARSSMED with a percentage of 100%. The research indicators, encompassing aspects such as learning media design, alignment with the curriculum, efficacy of learning media, practicality of use, and media benefits, attained an average score of 4. Therefore, based on Puspasari et al. (2024) criteria for evaluating teacher responses, ARSSMED is classified in the Very Good category. The results of the study indicate that the ARSSMED developed is rated very well by teachers from various perspectives, including design, material suitability, effectiveness, practicality, and benefits in supporting the learning process.

Evaluate

The evaluation stage is conducted to ascertain the extent to which the learning media has been developed. Consequently, a systematic evaluation is conducted at each stage of the development process. At this stage, an evaluation of the results of the media feasibility assessment is carried out. The evaluation is grounded in the insights of material and media experts, complemented by students' responses to the developed media. The evaluation process serves to ascertain the viability of media for educational purposes. Revisions obtained from expert suggestions and during implementation are carried out to improve the quality of ARSSMED that has been developed.

Final Product Review

The objective of this study is to develop ARSSMED that is both valid and practical, with the aim of enhancing students' conceptual understanding of solar system material. The results of this study offer a comprehensive response to the problem formulation, present significant findings, delineate the rationale behind these findings, and connect the findings to the underlying theory and pertinent research.

Based on the research results, the ARSSMED developed is declared feasible to use. This is supported by the results of media, material, and language expert validation which shows valid to very valid criteria. In addition, based on the practicality test to students and teachers who showed very positive responses to the media.

The findings of this investigation yield notable insights concerning the development of ARSSMED for sixth-grade students in the domain of solar system studies. ARSSMED was rated as highly valid by material experts (92.5%), linguists (97.5%), and media experts (82.5%). The practicality of the media, as evidenced by students' responses, demonstrated an average score of 98%, while the teacher's response attained 100%, both in the "very good" category.

The findings of this study are predicated on the principle that AR-based media has the capacity to transform abstract concepts into concrete and interactive learning experiences. In the context of solar system materials that are classified as difficult to visualize, the use of AR media allows students to see, manipulate, and understand real representations of celestial bodies through digital devices. This pedagogical approach fosters heightened student engagement during the learning process, thereby enhancing conceptual comprehension.

The results of this study indicate that ARSSMED is considered highly valid and practical for teaching the solar system theme in sixth grade elementary school. These findings are consistent with the study by Aydin & Ozcan (2022), which also found that the use of augmented reality-based media significantly increases student engagement. However, unlike Salazar et al. (2020), who emphasized the visualization of three-dimensional objects, ARSSMED combines visual, interactive, and user-friendly aspects through the Assemblr EDU platform. This underscores the uniqueness of ARSSMED as an educational tool that is not only visually appealing but also practical within the context of the IPAS curriculum in elementary schools.

Furthermore, Krüger et al. (2019) explained that AR has the characteristics of contextuality, interactivity, and spatiality. Field findings show that students can actively interact with virtual objects in a realistic context, strengthening engagement in learning. The virtual objects presented in this media are connected to the real space spatially, providing a meaningful three-dimensional learning experience.

In terms of theory, the results of this study corroborate constructivist thinking that learning becomes more effective when students actively construct knowledge through direct experience. Yoon et al. (2017) mentioned that the advantage of AR lies in its ability to combine interaction with the real and virtual worlds simultaneously, encourage active student participation, and help visualize hidden information. This finding confirms that AR not only increases learning motivation but also deepens the understanding of scientific concepts.

Theoretically, this study corroborates extant theories regarding the role of augmented reality in education, while concomitantly extending its application in the context of science learning in elementary schools. Empirical evidence has demonstrated that the implementation of augmented reality has the potential to serve as a conduit between abstract concepts and tangible reality. As a result of this integration, novel theoretical frameworks concerning the incorporation of augmented reality in educational settings are being developed. It has been demonstrated that the ARSSMED developed is feasible, practical, and effective in improving the quality of the teaching-learning process, therefore, its use is recommended. Moreover, it has been demonstrated to facilitate the development of innovative, experience-based educational technology.

However, this study has several limitations. First, most of the practical data was obtained through self-reports from teachers and students, so there is still the possibility of response bias. Second, the trial was limited to the context of sixth grade elementary school students at one

school, so generalizing the results to other schools should be done with caution. Therefore, further research is recommended to use more in-depth observation methods and involve a broader sample to strengthen the findings.

CONCLUSION

The results of the development of augmented reality-based learning media using Assemblr EDU for sixth-grade elementary school students about the solar system are included in the very valid category. This assertion is corroborated by the findings of the assessment conducted by media, material, and language expert validators, who assigned an average score of 90.8%. The efficacy of ARSSMED has been demonstrated through the implementation of small-scale and large-scale trials, which has led to its classification as a highly practical media. The learning media in question was awarded an average score of 98.75% in the results of both the small-scale and large-scale practicality tests. Considering these findings, the utilization of ARSSMED has been demonstrated to facilitate comprehension of abstract solar system material among students.

The use of ARSSMED in elementary school education has significant practical potential, particularly in supporting the understanding of abstract concepts such as the solar system. However, the implementation of Augmented Reality (AR)-based media needs to consider the context and limitations of the existing infrastructure in elementary schools. In schools with limited facilities, ARSSMED can still be used with adaptive strategies, such as the rotational use of students' mobile devices.

The integration of ARSSMED into the lesson plan can be done during the core activity phase, particularly in inquiry-based learning syntax. This media can be utilized to accommodate digital observation activities of objects within the solar system, thereby supporting the achievement of core competencies such as "identifying the positions and movements of celestial bodies within the solar system" in science lessons.

To optimize the use of this media, support is needed in the form of teacher training on the use of the Assemblr EDU platform and the integration of AR technology in learning. Training can be conducted through school workshops, the development of teacher learning communities, or the provision of self-guided tutorial videos tailored to the needs of elementary school teachers. With this approach, ARSSMED is not only an innovative media but also practical and adaptable to various learning conditions in the field.

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