Al-Bidayah : jurnal pendidikan dasar Islam
Volume 16 Number 2, December 2024
ISSN: 2549-3388 (online)
Available online at https://ejournal.uin-suka.ac.id/tarbiyah/albidayah
Submitted: September 25, 2024, Accepted: December 30, 2024

Empowering Education with Augmented Reality: Planetarium Virtual Laboratory Development Society 5.0 Era

Rofiatun Nisa'[1], Ahmad Isroil[2]

Universitas Billfath, Indonesia[1,2]
E-mail: fyanisa1214@gmail.com[1], ahmad.isroil@gmail.com[2]

DOI: 10.14421/al-bidayah.v16i2.9729

Abstract

Elementary school students in the Society 5.0 era have become accustomed to advanced technology. Therefore, teachers must make smart efforts to ensure the success of quality education. This research aims to analyze product practicality and product feasibility according to experts to support quality education for elementary school students in the Society 5.0 era. This study's Research and Development (RnD) method follows the ADDIE model. The research was conducted with sixth-grade elementary school students in Lamongan Regency, with 166 participants. Data analysis utilized interview and questionnaire techniques. The research results are as follows: The first stage involved analyzing the needs of teachers and students in IPAS learning that could support quality education relevant to the current era. The next stage was designing the learning media. After the design process, the learning media was developed and validated by two expert media validators, two science subject matter validators, and ten education practitioners in the very good category. The implementation results with sixth-grade students at Madrasah Ibtidaiyah in Lamongan showed that 90% of the students rated the media in the outstanding category. Thus, it can be concluded that this virtual planetarium laboratory media is effectively applied to sixth-grade students in science learning to support quality education in the Society 5.0 era.

Keywords: augmented reality; digital learning; quality education; society 5.0 era; virtual planetarium laboratory

Introduction

A shift towards deeper technology integration in all aspects of life, including education, characterizes the Society 5.0 era (Mohamed Hashim et al., 2024). This Society 5.0 era presents challenges in education (Ponraj et al., 2023) due to technological advancements such as artificial intelligence, the internet, and social media, which are already commonly used by elementary school students today (Mourtzis et al., 2023). Elementary school students in the Society 5.0 era enjoy freedom in learning, have a penchant for discovering new things, and feel comfortable in environments connected to the internet. Therefore, teachers need to make intelligent efforts to ensure quality education that aligns with the current era (Abigial, 2022), one of which is developing technology-based learning media with the help of augmented reality (Chen et al., 2019).

However, Many teachers have difficulties integrating augmented reality-based learning media into teaching and learning activities, especially for planetary and solar-

system materials (Dash et al., 2024). Most teachers do not have sufficient experience and knowledge to implement augmented reality effectively and tend to feel more comfortable with the hands-on practicum method in the classroom (Liao et al., 2024). However, they stated that school laboratories equipped with modern and sophisticated equipment that can accurately describe various planets are needed to provide students with a deep understanding. Unfortunately, the availability of these tools is limited in many schools, so learning is not optimal (Wu et al., 2024). Therefore, the development of augmented reality-based Virtual Laboratory Planetarium media is an important solution to bridge this limitation, allowing students to explore the concepts of the solar system in an interactive and immersive way without the need for expensive and hard-to-access physical equipment at school.

Based on the results of a needs survey conducted for teachers and students, it was found that there is a high interest and urgent need for innovative learning media that can support the understanding of astronomical materials, especially related to the concept of planetariums and space (Jhuang et al., 2024). Most teachers stated that conventional learning methods in this topic are often not optimal in arousing students' interest in learning due to the limitations of visualization and interactivity (Gunčaga & Záhorec, 2024). Meanwhile, students revealed that their understanding of the concept of the solar system and the universe will be better if supported by interesting and interactive visual media (Vashisht, 2024). Based on these findings, the Augmented Reality-based Planetarium Virtual Laboratory product was developed to increase student engagement and enrich the learning experience visually and immersively. This product is expected to meet the need for quality learning in the Society 5.0 era, where digital technology is increasingly becoming an integral part of education.

Previous research has applied planetarium media (Abdurrahman, 2019). Applying augmented reality learning media has also been carried out, but only research qualitatively without a clear percentage (Huang et al., 2019) (Lai et al., 2019). Other research also applies augmented reality learning media only as a quiz without any material supporting self-regulated learning (Winarni & Purwandari, 2019). Another study (Sahari & Wahyudi, 2020) found that students' visualization perspectives were still limited due to the use of images.

Subsequent research (Imronah et al., 2022) developed digital-based planetarium media. This study utilized the SAC App. However, the developed media consisted only of 2D images that could not present a more engaging and realistic 3D portrayal. Research (Latif et al., 2023) (Frincu & Frincu, 2023) has also advanced augmented reality-based learning media, but it only reached the design stage. Another study examined the use of augmented reality as a science learning medium, but the sample size used in the study was insufficient, with only 21 respondents (Setiawan et al., 2023). Furthermore, a systematic literature review that analyzed only 23 articles, this relatively small sample size may not sufficiently represent the diverse research on augmented reality as a learning medium (Pahmi et al., 2023).

Therefore, the current study will implement a virtual laboratory learning media in the form of an augmented reality-based planetarium that can provide visualizations of simulated images that appear realistic with a 3D display viewable from various angles. The virtual planetarium can emerge on the user's table or floor and react to the user's movements or interactions, making it seem as if it exists in the real world that no other study has ever done. This aims to support the SDGs related to quality education and the digital economy in education. Therefore, this research aims to analyze product practicality and product feasibility according to experts to support quality education for elementary school students in the Society 5.0 era.

Research Methods

This research is designed using the Research and Development (RnD) method (Saputro, 2021) with stages from ADDIE (Runco, 2023). This model consists of five main stages, namely: analysis of the needs of teachers and students needed for the media development process, design begins with making a detailed plan of the media to be developed, development of learning products according to the design that has been planned, implementation in schools, and the last stage namely a thorough evaluation is carried out after implementation (Putera et al., 2024). This approach is employed to produce a new product in the form of learning media developed based on the needs of elementary school students in the era of Society 5.0. The developed media will be analyzed for its feasibility, effectiveness, and appeal.

This study will be conducted from July to September 2024, with the research trial subjects being sixth-grade students of Madrasah Ibtidaiyah in the Maduran, Sekaran, Laren, and Karanggeneng Subdistrict in Lamongan Regency. The selection of research locations includes 10 Madrasah Ibtidaiyah in Lamongan Regency that have implemented blended learning and have adopted technology-assisted learning media. The number of students as research subjects is 166, serving as the experimental class.

The research stages are depicted in the following image:

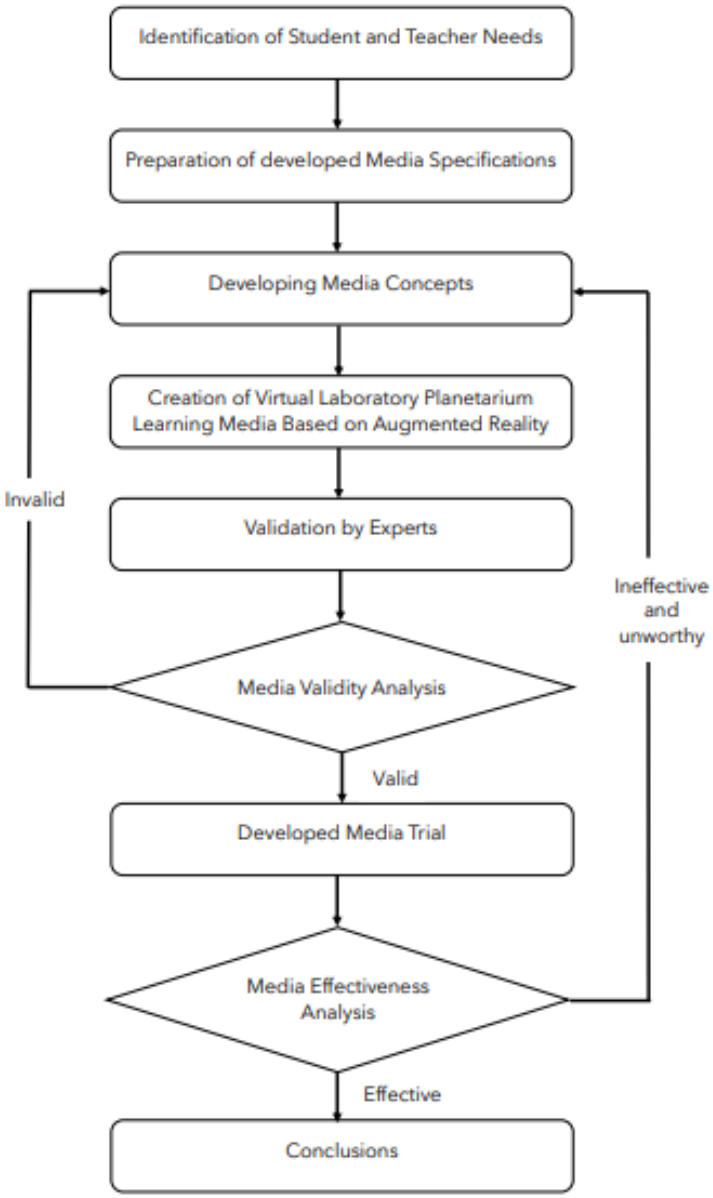


Figure 1
Research Flow Chart
Source: Personal Document

The data collection technique in this study used interviews and questionnaires. Interview activities were carried out to obtain data on the analysis of teacher and student needs related to learning media according to the current era. The interview instrument in this study was:

Table 1
Interview Guidelines for Teachers

No.	Indicator	Questions
1	Student Development and Learning Habits	Current student development and learning habits, especially in understanding science or solar system materials
		The extent to which students are interested in materials related to space, planets, and the solar system
		Whether students tend to be enthusiastic about learning activities that use visual or interactive media
2	The Need in Teaching Planetary Themes	What are some of the challenges you face when teaching the theme of planets and the solar system?
		What aspects need to be improved to make learning the planetary theme more effective
		Views on the use of augmented reality in facilitating learning about the planet
3	Material Characteristics and Learning Outcomes	What are the important characteristics of planetary matter and the solar system that should be conveyed to students?
		What are the learning outcomes you are targeting when teaching planetary themes?
4	Used Learning Media	What media are currently used to teach planetary themes
		Do teachers feel that the available media is enough to meet the learning needs of this theme?

Source: Personal Document

Table 2
Interview Guidelines for Students

No.	Indicator	Questions
1	Learning Experience and Habits	Interest in space, planets, and solar system themes The learning way that best helps understand the matter of the planets and space
2	Use of Learning Media	What media are usually used by teachers when teaching about planets Have students ever used augmented reality-based learning media?
3	Preferences and Expectations for New Learning Media	Are students interested in using augmented reality-based media to study planets and the solar system What kind of features do students expect from learning about planets to make learning more interesting

Source: Personal Document

Meanwhile, the data collection technique uses a questionnaire to find out the validation results by experts regarding the feasibility of the media developed by researchers. In addition, the questionnaire is also used to determine the practicality of the media developed with the questionnaire instrument in this study, including:

Table 3
Media Practicality Questionnaire Instrument

No.	Statement
1	Level of student participation in media use
2	Level of student interest in using media
3	Level of student involvement in learning using media
4	Level of student understanding after using media
5	Student's ability to understand material concepts
6	Level of student satisfaction with learning experiences using media
7	level of student comfort in using media
8	Ease of operating media

Source: Personal Document

Data were analyzed quantitatively and qualitatively(Anam et al., 2023). Qualitative data in the form of interview results and responses, suggestions, criticisms, input obtained from observations, and comments from the questionnaire. Data were processed so that they could be concluded logically, meaningfully, and systematically. Furthermore, this conclusion can be used to improve the media being developed. Quantitative data in the form of scores from the questionnaire results are calculated using the formula (Sugiyono, 2015):

$$P = \frac{\sum X_i}{\sum X} \times 100\%$$

Details:

P = Percentage

Xi = Total number of scores obtained

X = Ideal score total

100% = Constanta

To make decisions regarding the values obtained from the questionnaire results, the following criteria must be followed:

Table 4
Questionnaire Result Value Criteria (Sugiyono, 2015)

Level of achievement (%)	Qualification
80% - 100%	Very good
60% - 79%	Good
50% - 59%	Enough
< 49%	Low

Source: Personal Document

Result

This research produces a planetarium virtual laboratory learning media product based on augmented reality to support quality education appropriate to the current era. The results of the research are described according to the following stages:

Teacher and Student Needs Analysis Stage

The first stage involved an analysis of the needs of teachers and students in the IPAS to support quality education in line with the current era, followed by providing solutions. Data was gathered in this stage through interviews with classroom teachers and sixth-grade students at a Madrasah Ibtidaiyah in Lamongan. The results of the interviews were summarized by the researchers as follows: 1) Students today are highly dependent on technology, 2) The majority of students are accustomed to using their smartphones for learning, 3) Many IPAS teachers have not yet implemented technology-assisted learning, 4) There is a need for improvement in IPAS learning by the current era of students, using AI technology, 5) Attractive visualization is necessary when explaining material with the help of AI technology, such as explaining planets.

Based on various findings from the analysis phase, the researcher developed an educational media product using engaging 3D visualization through augmented reality. This product was developed to present lifelike visual images of all planets along with

complete descriptions of each planet, allowing students to directly observe realistic visualizations, thereby enhancing the quality of learning.

Learning Media Design Stage According to Teacher and Student Needs

From the various analyses that have been carried out, the next step is for the researcher to design learning media, starting from preparing materials that are tailored to learning objectives, preparing images and animations that support the visualization of all planets, then the researcher creates images for image scan codes based on augmented reality along with the design of instructions for using the media, continuing to create learning media with the help of the Assembly Edu application.

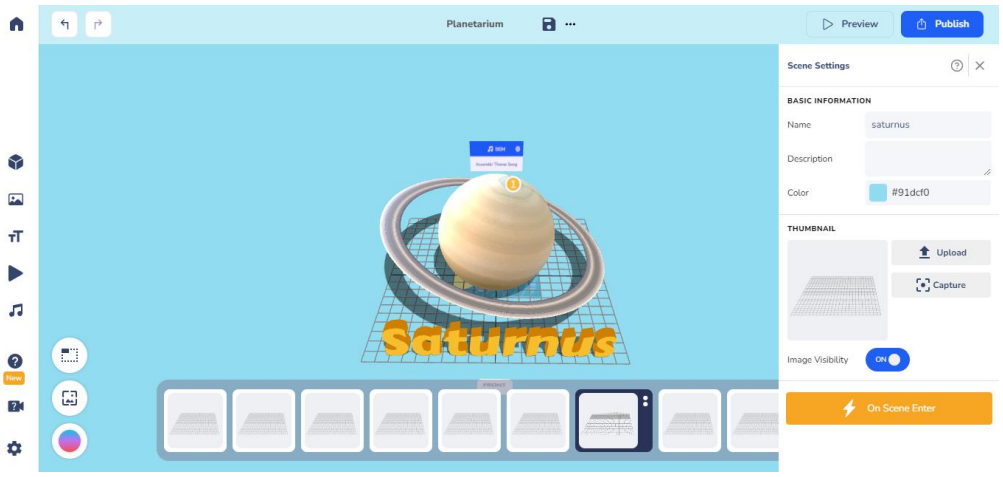


Figure 2
Example of Creating a Virtual Laboratory Planetarium Learning Media Design
Source: Personal Document

Development Stage of Virtual Laboratory Planetarium Learning Media Based on Augmented Reality

After the design process, the learning media was developed with the following steps: 1) subscribe to the Assemblr Edu application, 2) login to the link https://edu.assemblrworld.com/ 3) start entering images, animations, songs, and materials in the application, 4) create an image code for an augmented reality scan so that 3D animation can be seen when used, 5) then click preview to see the results of making the Planetarium Virtual Laboratory media, 6) carry out the publishing process when the developed learning media is appropriate. After the learning media was developed, the researcher validated it with two expert media validators, two validators of IPAS material, and 10 Education practitioners. In addition to assessing whether the learning media is

valid or not, the validators also provide suggestions and input for improving the learning media. The following is an explanation of the validation results from all validators:

Table 5
Material Expert Validation Results

No.	Statement	Validator score 1	Validator score 2
1	The content of the material in the learning media is to the objectives of science learning.	5	5
2	The content of learning media can develop the realm of student action	4	4
3	The content of learning media can develop the realm of student attitudes	5	4
4	The content of learning media can develop students' knowledge domains	5	5
5	The presentation of learning media content is clear and appropriate	5	5
6	The presentation of learning media content is easy to understand	5	5
7	Presentation of sequential learning media content	4	5
8	Presentation of complete learning media content	5	5
9	Presentation of learning media content according to the character of grade VI students	5	5
10	The display of images in learning media is by the content of the material	5	5
11	Learning media helps students in independent learning	5	5
12	The language in the learning media is easy to understand	5	4
Score result		**58**	**57**
Maximum score		**60**	

Source: Personal Document

Based on the calculation table of the validation questionnaire from the first validator, the material expert, the result was a score of 58 from a maximum score of 60. Next, the researcher calculated using the following formula.:

$$V = \frac{TseV}{S-Max} \times 100\%$$

$$V = \frac{58}{60} \times 100\%$$

$$V = 96\%$$

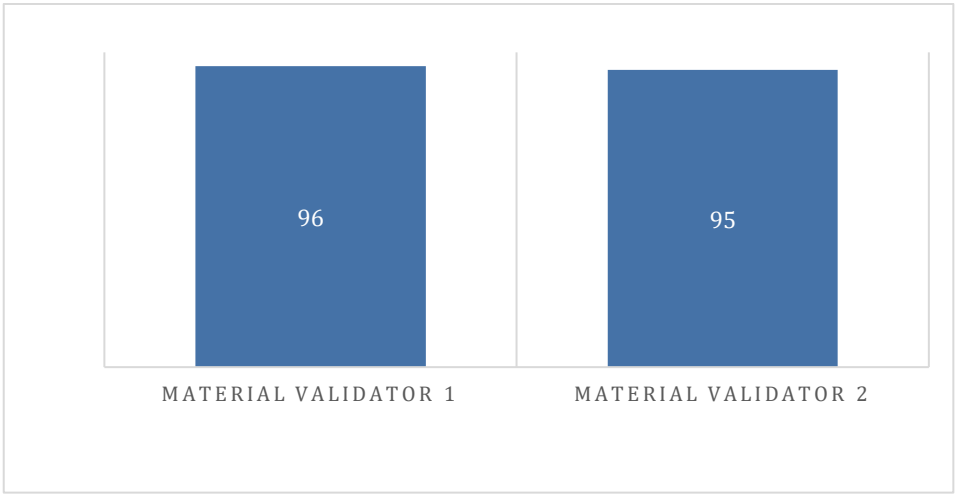
Meanwhile, for validation from the second validator, the material expert obtained a score of 57 from a maximum score of 60 with the calculation:

$$V = \frac{TseV}{S-Max} \times 100\%$$

$V = \frac{57}{60} \times 100\%$

$V = 95\%$

The results of validating the suitability of the class VI IPAS teaching materials from the calculation of the values are described in the following table.:



Figurer 3
Results of Validation of Class VI IPAS Material
Source: Personal Document

If calculated the percentage of validator material 1 got a result of 96% and validator material 2 got a result of 95% with the provision on a Likert scale in the very good category. So it can be concluded that the material in the virtual laboratory planetarium is suitable to be applied to students in class VI IPAS learning. In addition to material validation, researchers also validated learning media with the following validation results.:

Table 6
Quantitative Data of Media Design Validation Results

No.	Statement	Validator score 1	Validator score 2
1	The identity of the learning media is clear	5	5
2	The guidelines for learning media are clear	5	5
3	The size of the letters on the learning media is appropriate	5	4
4	The learning media font is appropriate	5	4
5	The colors chosen in the learning media are appropriate	5	4
6	The images selected in the learning media are appropriate	5	5
7	Suitability of button layout, captions, images, and backgrounds on learning media	5	5

No.	Statement	Validator score 1	Validator score 2
8	Learning media helps students in learning IPAS about planets	5	5
9	Learning media can be run well	4	5
10	Buttons work well	5	5
11	Interesting learning media for elementary school children in the era of society 5.0	5	5
Score result		**54**	**52**
Maximum score		**55**	

Source: Personal Document

Based on the results of the validation questionnaire from the media feasibility validator above, then the researcher calculated using the following formula:

$V = \frac{TseV}{S-Max}$ x 100%

$V = \frac{54}{55}$ x 100%

V = 98%

Meanwhile, for validation from the second media expert validator, the result was a score of 52 from a maximum score of 55 with the calculation:

$V = \frac{TseV}{S-Max}$ x 100%

$V = \frac{52}{55}$ x 100%

V = 94%

So the results of the validation of learning media from the calculation of these values are described in the following table.:

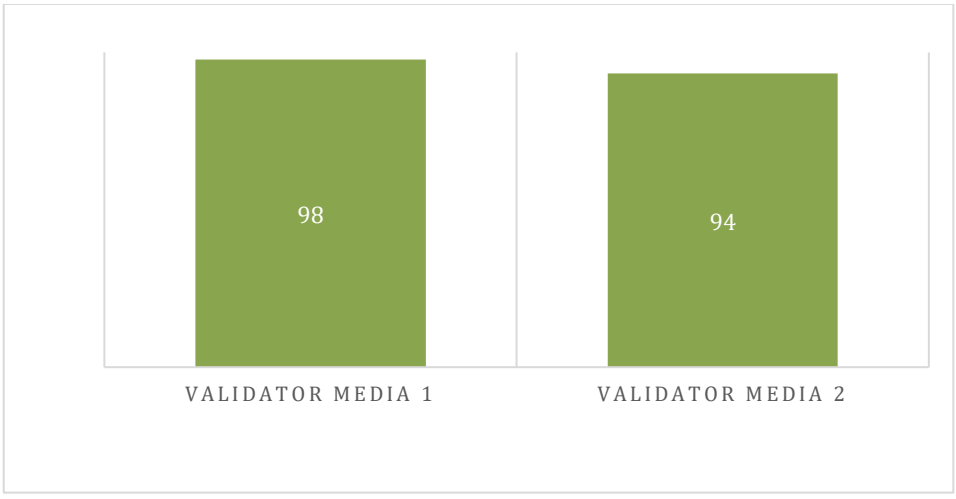


Figure 4
Media Design Validation Results
Source: Personal Document

From the calculation results, the first validator gave a score of 98% and the second validator got a score of 94% with the provisions on the Likert scale being in the very good category. So it can be concluded that the virtual laboratory planetarium media is feasible to be applied to students in Class VI IPAS learning.

The final validation with expert education practitioners with 10 validators we involved resulted in the following data being obtained.:

Table 7
Expert Validation Results of Education Practitioners

No.	Statement	Validator Assessment									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Suitability of content to learning objectives	5	5	4	4	5	5	4	4	5	4
2	Accuracy of learning material content	5	4	5	5	4	5	5	5	5	4
3	The material in the learning media is described in full	5	4	4	4	5	4	4	5	5	4
4	The material in the learning media is arranged systematically	5	4	4	4	5	4	5	5	4	4
5	Accuracy of language used in explaining the material	4	5	5	4	4	5	5	5	4	5
6	The sentences used can clarify the picture	5	3	5	5	4	4	5	4	5	4
7	The material presented in the learning media is easy to understand	5	5	5	5	5	4	4	5	5	5
8	The selection of images in learning media is in accordance with the content of the material	4	5	4	4	5	4	4	4	4	5
9	The learning media developed is able to visualize the planets in the solar system.	4	4	5	4	4	5	5	5	5	4
10	Suitability of learning media to the characteristics of today's students	5	4	5	5	4	5	5	5	4	5

No.	Statement	Validator Assessment									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
11	Suitability of learning media with learning materials	5	5	3	5	5	5	5	4	5	5
12	Easy to operate learning media application	4	4	5	5	5	5	4	5	4	4
13	The learning media developed makes it easier for students to understand the material.	5	5	5	5	5	4	4	5	5	5
14	The learning media developed can help students learn independently.	5	4	4	5	5	5	5	5	5	5
Score Result		**66**	**61**	**63**	**64**	**65**	**64**	**64**	**62**	**60**	**63**
Average score		**63**									
Maximum score		**70**									

Source: Personal Document

Based on the results of distributing the validation questionnaire above, the researcher then calculated using the following formula:

$V = \frac{TseV}{S-Max}$ x 100%

$V = \frac{63}{70}$ x 100%

V = 90%

From the results of the calculation in the table above, it is known that the results of the validation of the IPAS learning expert on the virtual laboratory planetarium media got a total score of 63 out of a maximum score of 70. If the percentage is calculated, the result is 90% with the provisions on the Likert scale being in the very good category. So it can be concluded that this virtual laboratory planetarium media is feasible to be applied to students in class VI IPAS learning.

In addition to the assessment from the validator above, the following suggestions and input for improvements were also obtained from the validator:

Table 8
Validator's Suggestions and Input Results

Media Validation	Material Validation
The background for the scan is better if the sky is not a plain image. There is a nuance of the sky with a sprinkling of stars.	Adding the characteristics of each planet so that students can more clearly see the differences between each planet.
At the opening of the media, the display of the planets is arranged in order from the sun as the center to the last planet..	

Source: Personal Document

After several revisions and the validator stated that it was feasible, the media developed by this researcher could be implemented to grade IV students.

Implementation Stage of Virtual Laboratory Planetarium Learning Media Based on Augmented Reality

After the validation is declared valid, the next step is to implement it to grade VI students of Madrasah Ibtidaiyah with three cycles, namely; 1) the first time it is applied to individuals selected randomly as many as 5 students only. Limited trials are carried out to conduct intensive observations and record important things done by students that will be used as material for improving the initial product, 2) the second cycle with a small group of 25 students so that the product developed meets the standards, 3) then students as a whole by implementing the virtual laboratory planetarium learning media based on augmented reality in 10 schools in Lamongan with a total of 166 students. This last trial is used to find data on the effectiveness of the media developed.

Steps in implementing virtual laboratory planetarium learning media based on augmented reality are by downloading the assembler edu application on the playstore. Then scan the following image:

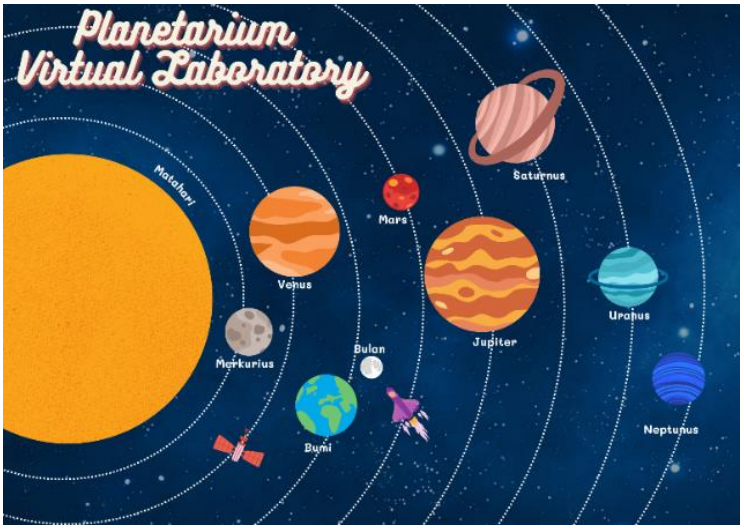


Figure 5
Image for Virtual Laboratory Planetarium Media Scanner
Source: Personal Document

After the students successfully scan the image, a 3D visualization of a real planet will appear above the image. Students can start exploring the planets from Mercury to Neptune complete with descriptions of each planet.

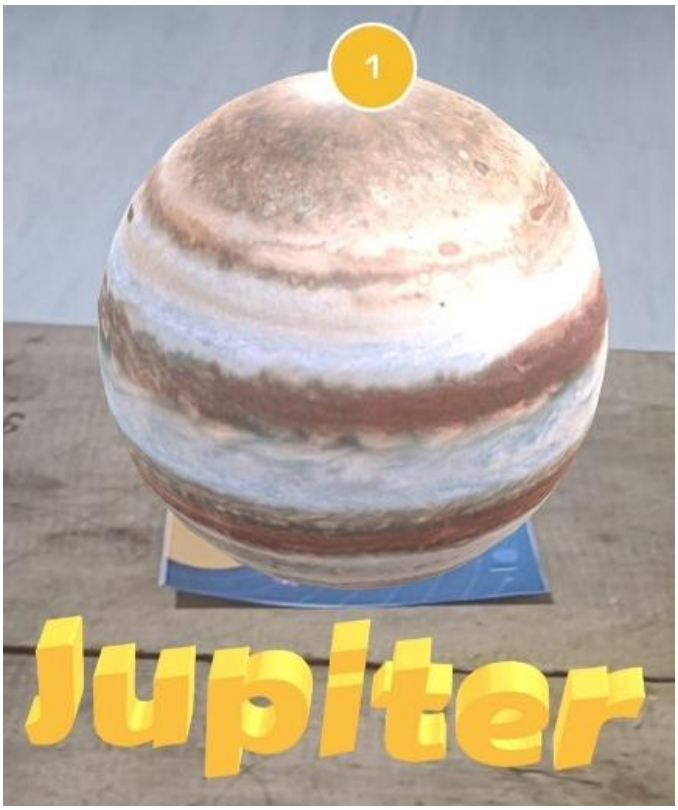


Figure 6
Augmented Reality View of One of the Planets in Media
Source: Personal Document

The image above is an example of the appearance of a planet visualization from an image scanned using the assembler edu application. The 3D image like a real one can provide a clear and interesting picture for students to learn.

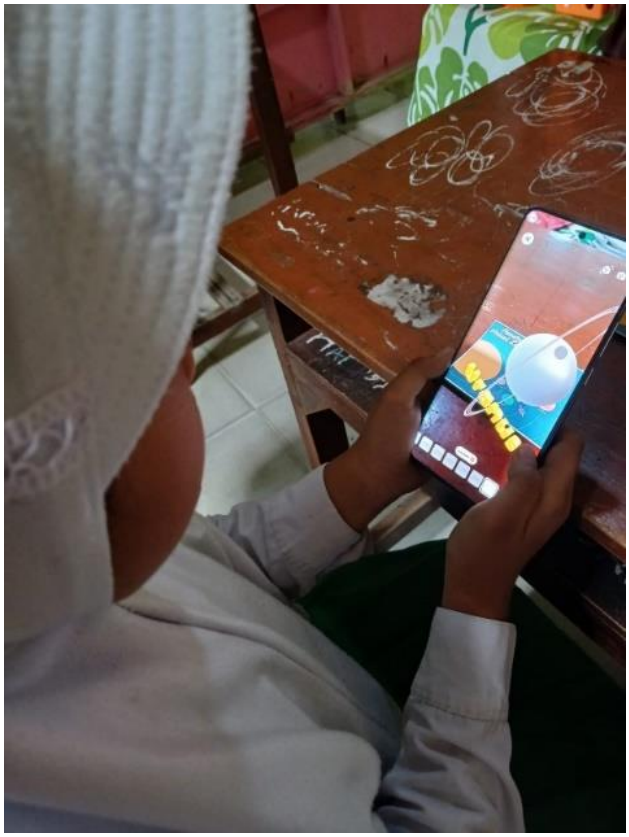


Figure 7
Students Use Virtual Laboratory Planetarium Learning Media
Source: Personal Document

From the results of the researcher's documentation, it describes that students are using virtual laboratory planetarium learning media to learn in a fun way in accordance with the current digital era. So that the existence of media using the help of Artificial Intelligence, it can help explain abstract material to support the focus of national priorities related to the green economy, especially quality education. After the learning process using virtual laboratory planetarium media was completed, the researcher distributed questionnaires to all students to see the effectiveness of this learning media as a learning media that supports quality education in the era of society 5.0. From the results of 166 questionnaires that have been summarized and calculated by the researcher, the average score of the entire questionnaire was 64 out of a maximum score of 70. So if it is expressed as a percentage, it is as follows:

$$V = \frac{TseV}{S-Max} \times 100\%$$

$$V = \frac{64}{70} \times 100\%$$

$$V = 91\%$$

The results of the calculation of the percentage of the questionnaire distributed to all students obtained a result of 90% with the provisions on the Likert scale being in the very good category. So it can be concluded that this virtual laboratory planetarium media is effectively applied to students in Class VI IPAS learning to support quality education in the era of society 5.0. The effectiveness of augmented reality-based learning media in supporting quality education in the era of Society 5.0 is very significant.

Evaluation Stage of Augmented Reality-Based Virtual Laboratory Planetarium Learning Media

After obtaining the results of the practicality of the augmented reality-based virtual laboratory planetarium learning media along with its comments, the researcher also evaluated the attractiveness and shortcomings of the product developed in this study. These results were obtained from the analysis of comments and observations made by the researcher during the study. The attractiveness of the product developed is: that with the help of augmented reality technology, students can experience an in-depth and realistic exploration of the solar system, directly from their devices. This feature allows students to interact with clear 3D models of the planets, strengthening conceptual understanding through immersive visualization. In addition, the Planetarium Virtual Laboratory presents a more interesting and efficient way of learning, encouraging the active involvement of students in the learning process while making it easier for teachers to explain complex material. This product is also very flexible, and accessible anywhere and anytime, making it a modern solution for innovative science education.

The disadvantages of this developed product are: a supporting device is needed because some students' mobile phones have to wait a long time. In addition, the intensive use of augmented reality technology can require large battery power and memory, which has the potential to disrupt the smoothness of use during the learning process. In terms of content, although the augmented reality visualization is interesting, the interaction provided may still be limited, so not all complex astronomical concepts can be conveyed in depth. Future evaluations should consider the development of more interactive features,

expanding device compatibility, and providing lighter augmented reality-based learning alternatives so that more people can access them.

Discussion

In the era of technology 5.0, advancements such as augmented reality have significantly impacted the world of education, particularly in learning media (Noptario et al., 2024). Teachers and students are now faced with the demand to enrich the teaching and learning process to make it more interactive, personalized, and adaptive to the needs of the 21st century (Yuliawati et al., 2023). This technology offers great potential to help improve the quality of learning, making it more effective, efficient, and enjoyable. Here are some of the needs of teachers and students in expanding learning media using technology with the assistance of artificial intelligence and augmented reality (Tuwoso et al., 2021). Teachers require access to various technology-based learning resources that can be accessed anytime and anywhere. This can include applications, online platforms, or augmented reality devices that can support both face-to-face and remote learning. AI technology also enables teachers to automatically create content, quizzes, and learning materials, allowing them to focus more on direct teaching and mentoring students (Sriadhi et al., 2022).

Augmented Reality offers a more engaging and comprehensive learning experience. Learners can bring learning objects to life through augmented reality technology, for example, seeing planets in 3D format as if they were in front of their eyes (Sapta & Nisa, 2024). This helps learners more easily understand abstract concepts that are difficult to explain in conventional ways, as well as making the learning process more enjoyable and motivating them to be more actively involved, like learning media design using the Assemblr Edu application (Wannapiroon et al., 2021). Learning media design using the Assemblr Edu application allows teachers and students to create interactive and visual learning experiences through augmented reality technology. With Assemblr Edu, teachers can easily create 3D content that visualizes abstract concepts or complex learning materials so that students can see and interact with these objects in a real environment through their devices (Carrión et al., 2023). This application offers a variety of user-friendly templates and tools, allowing anyone without in-depth technical skills to design engaging learning media that supports active learning. Students can participate in learning

through augmented reality content that can be accessed anytime and anywhere, making the learning process more fun, immersive, and fit the needs of the digital era (Majid et al., 2023).

The feasibility indicators of augmented reality-based learning media help ensure that the technology is appropriate and effective in the context of education(Khan et al., 2019). The feasibility indicators of augmented reality-based learning media are that the material in the learning media directly supports and is following the learning objectives set; augmented reality-based learning media can integrate and complement other learning materials; augmented reality-based learning media functions well on devices used by students, such as smartphones or tablets without lag or technical problems; 3D graphics, animations, and audio in augmented reality-based learning media are of high quality, clear, and support understanding of the material; augmented reality-based learning media can be easily accessed by students, including those with special needs or technological limitations; augmented reality-based learning media can increase student involvement and motivation in the learning process through attractive visual and interactive elements (Marini et al., 2022).

Augmented reality offers an innovative approach by presenting a real and interactive learning experience, allowing students to interact directly with lesson content in a realistic three-dimensional format (Sabitri et al., 2024). This makes it easier for them to understand complex concepts that are difficult to explain with just text or static images (Hidayati Rofiah et al., 2024). In the era of Society 5.0, where advanced technology and the need for skills-based learning are increasing, augmented reality provides opportunities for students to learn actively and exploratively (Maulidia et al., 2023).

By using augmented reality technology, learners can visualize and manipulate virtual objects in a real-world context, which improves understanding and retention of the material (Sapta & Nisa, 2024). In addition, augmented reality media supports a variety of learning styles, from visual to kinesthetic, and can be tailored to meet the individual needs of learners (Yamtinah et al., 2023). Through higher engagement and personalized learning experiences, augmented reality media contributes to improving the quality of education and students' readiness to face challenges in the ever-evolving digital era (Uriarte-Portillo et al., 2023).

Augmented reality-based learning media offers several advantages that make it stand out in the context of modern education (Putra et al., 2024). One of the main advantages is its very strong visualization capabilities; augmented reality allows learners to see and interact with three-dimensional objects directly in their real environment, making it easier to understand abstract concepts that are difficult to explain with traditional methods. For example, in science lessons, learners can see real structures or shapes in real time, which increases their engagement and understanding. In addition, augmented reality can increase learner motivation and engagement by providing a more interactive and enjoyable learning experience. This medium also supports various learning styles, from visual to kinesthetic, by allowing learners to learn through direct exploration and interaction (Wijayanto et al., 2023).

However, some drawbacks need to be considered. Cost and Infrastructure are major challenges; creating augmented reality content and purchasing the necessary devices can be expensive, and not all schools have the budget or technology infrastructure to support an effective augmented reality implementation. Additionally, the learning curve for using augmented reality technology can be prohibitive; teachers and students may need time to adapt to new applications and devices (Rahmatullah et al., 2021), and may require training to maximize the use of the technology. Other drawbacks include technical and accessibility issues; augmented reality media requires fairly powerful hardware and a stable internet connection, which may not always be available to all students. Finally, there are privacy and data security issues that need to be addressed, as augmented reality technology often involves the collection of user data that must be carefully managed to protect students' personal information (Eldokhny & Drwish, 2021). Overall, while augmented reality-based learning media offers great potential to enhance students' learning experiences and understanding, these challenges must be considered and addressed to ensure successful and sustainable implementation.

Conclusion

The learning media was developed and validated by the first two expert media validator 98% and the second validator 94%. The first validator of science subject matter also got a result of 96% and the second validator of 95%. 10 Education practitioners validated with a score of 90%. All value results from validators are in the very good

category. The results of the implementation with sixth-grade students at Madrasah Ibtidaiyah Lamongan showed that 90% of students rated the media in the very good category. Thus, it can be concluded that this virtual planetarium laboratory medium is valid and can be applied to sixth-grade students to teach planetary with more quality.

Acknowledgment

Acknowledgment to all schools and those who helped complete this research.

Declaration of Conflicting Interests

All authors declare no conflict of interest.

Funding

This research received Direktorat Jenderal Pendidikan Tinggi Kementerian Pendidikan dan Kebudayaan Republik Indonesia funding.

Orcid iD

Rofiatun Nisa' https://orcid.org/0000-0002-3082-3492

Ahmad Isroil https://orcid.org/0000-0001-7757-0325

References

Abdurrahman, A. (2019). Meningkatkan Hasil Belajar IPA Materi Tata Surya dengan Media Planetarium pada Siswa Kelas VI SDN Semundal Tahun Pelajaran 2018/2019. *JISIP (Jurnal Ilmu Sosial Dan Pendidikan)*, *3*(2). https://doi.org/10.58258/jisip.v3i2.761

Abigial, S. (2022). Pengembangan Media Pembelajaran di Era Society 5.0. In *Yayasan Kita Menulis*. Kita Menulis.

Anam, S., Nashihin, H., Taufik, A., Mubarok, Sitompul, Hamela Sari, Manik, Yuni Mariani, Suparto, Arsid, I., Jumini, S., Nurhab, Muhamad Irpan, Solehudin, W, Nurul Eko, & Luturmas, Y. (2023). Metode Penelitian (Kualitatif, Kuantitatif, Eksperimen, dan R&D). In *Journal of Chemical Information and Modeling*. 53, (9).

Carrión, F., Verónica, R., Alba, E. C., & Vargas-Saritama. (2023). The Use of Augmented Reality through Assemblr Edu to Inspire Writing in an Ecuadorian EFL Distance Program. *International Journal of Engineering Pedagogy*, *13*(5), 121–141. https://doi.org/10.3991/ijep.v13i5.38049

Chen, Y., Wang, Q., Chen, H., Song, X., Tang, H., & Tian, M. (2019). An overview of augmented reality technology. *Journal of Physics: Conference Series*, *1237*(2). https://doi.org/10.1088/1742-6596/1237/2/022082

Dash, A. K., Behera, S. K., & Dogra, D. P. (2024). PlutoAR: a scalable marker-based augmented reality application for interactive and inclusive education. *Multimedia Tools and Applications*, *83*(19), 57685–57708. https://doi.org/10.1007/s11042-023-17756-x

Eldokhny, A. A., & Drwish, A. M. (2021). Effectiveness of Augmented Reality in Online Distance Learning at the Time of the COVID-19 Pandemic. *International Journal of Emerging Technologies in Learning*, *16*(9). https://doi.org/10.3991/ijet.v16i09.17895

Frincu, S., & Frincu, M. (2025). Enabling Interdisciplinary Learning and Research through AI-Driven Transliteration of Historical Documents: A Case Study Proposal from Digital Humanities. *International Journal of Humanities Education*, *23*(1), 1–24. https://doi.org/10.18848/2327-0063/CGP/v23i01/1-24

Gunčaga, J., & Záhorec, J. (2024). STEM Education Using Digital Tools in Undergraduate Teacher Education. *Communications in Computer and Information Science*, *2130 CCIS*, 336–350. https://doi.org/10.1007/978-3-031-63235-8_22

Hidayati Rofiah, N., Sinta, T. N. A., & Dewi, R. (2024). Development of Articulate Storyline Media for Enhancing Learning Outcomes in Natural and Social Sciences Among Elementary School Students. *Al-Bidayah : Jurnal Pendidikan Dasar Islam*, *16*(1), 19–40. https://doi.org/10.14421/al-bidayah.v16i1.9559

Huang, T. C., Chen, M. Y., & Hsu, W. P. (2019). Do learning styles matter? Motivating learners in an augmented geopark. *Educational Technology and Society*, *22*(1), 70–81.

Imronah, I., Parmin, P., & Widiatningrum, T. (2022). The Effectiveness of the Planetarium Android Learning Application Virtual Observatory on Solar System Material. *Journal of Innovative Science Education*, *11*(1). https://doi.org/10.15294/jise.v10i1.49258

Jhuang, Z. J., Lin, Y. C., & Lin, Y. T. (2024). Effects of Developing an Interactive AR Plant Structure Experiment System for Elementary Natural Science Course. *International Journal of Information and Education Technology*, *14*(8), 1145–1154. https://doi.org/10.18178/ijiet.2024.14.8.2143

Khan, T., Johnston, K., & Ophoff, J. (2019). The Impact of an Augmented Reality Application on Learning Motivation of Students. *Advances in Human-Computer Interaction*, *2019*. https://doi.org/10.1155/2019/7208494

Lai, A. F., Chen, C. H., & Lee, G. Y. (2019). An augmented reality-based learning approach to enhancing students' science reading performances from the perspective of the cognitive load theory. *British Journal of Educational Technology*, *50*(1), 232–247. https://doi.org/10.1111/bjet.12716

Latif, J. J. K., Triputra, A. A., Kesuma, M. A., & Maulana, F. I. (2023). Design and Development a Virtual Planetarium Learning Media Using Augmented Reality.

Procedia Computer Science, *227*. https://doi.org/10.1016/j.procs.2023.10.577

Liao, C. H. D., Wu, W. C. V., Gunawan, V., & Chang, T. C. (2024). Using an Augmented-Reality Game-Based Application to Enhance Language Learning and Motivation of Elementary School EFL Students: A Comparative Study in Rural and Urban Areas. *Asia-Pacific Education Researcher*, *33*(2), 307–319. https://doi.org/10.1007/s40299-023-00729-x

Majid, N. W. A., Rafli, M., Nurjannah, N., Apriyanti, P., Iskandar, S., Nuraeni, F., Putri, H. E., Herlandy, P. B., & Azman, M. N. A. (2023). Effectiveness of Using Assemblr Edu Learning Media to Help Student Learning at School. *Jurnal Penelitian Pendidikan IPA*, *9*(11). https://doi.org/10.29303/jppipa.v9i11.5388

Marini, A., Nafisah, S., Sekaringtyas, T., Safitri, D., Lestari, I., Suntari, Y., Umasih, Sudrajat, A., & Iskandar, R. (2022). Mobile Augmented Reality Learning Media with Metaverse to Improve Student Learning Outcomes in Science Class. *International Journal of Interactive Mobile Technologies*, *16*(7). https://doi.org/10.3991/ijim.v16i07.25727

Maulidia, L. N., Suparno, S., & Rosyidah, U. J. (2023). A Systematic Literature Review on Technology-Based Learning Media in ECE to Face Society 5.0 Era. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *7*(5). https://doi.org/10.31004/obsesi.v7i5.4997

Mohamed Hashim, M. A., Tlemsani, I., Mason-Jones, R., Matthews, R., & Ndrecaj, V. (2024). Higher education via the lens of industry 5.0: Strategy and perspective. *Social Sciences & Humanities Open*, *9*(January), 100828. https://doi.org/10.1016/j.ssaho.2024.100828

Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2023). Metaverse and Blockchain in Education for collaborative Product-Service System (PSS) Design towards University 5.0. *Procedia CIRP*, *119*. https://doi.org/10.1016/j.procir.2023.01.008

Noptario, Ade Tinofa, N., Khoirotun Nisa, A., Abdullah, F., & Nazri bin Nordin, T. S. (2024). Revitalizing Digital-Based Basic Education in an Effort To Strengthen Students' Critical and Creative Thinking in the Pancasila Student Profile Program At Madrasah Ibtidaiyah. *Al-Bidayah : Jurnal Pendidikan Dasar Islam*, *16*(1), 1–18. https://doi.org/10.14421/al-bidayah.v16i1.9556

Pahmi, S., Hendriyanto, A., Sahara, S., Muhaimin, L. H., Kuncoro, K. S., & Usodo, B. (2023). Assessing the Influence of Augmented Reality in Mathematics Education: A Systematic Literature Review. *International Journal of Learning, Teaching and Educational Research*, *22*(5), 1–25. https://doi.org/10.26803/ijlter.22.5.1

Ponraj, R. P., Ravindran, V., Ragunathan, S., Swaminathan, K., & Sigamani, T. (2023). Society 5.0 and explainable artificial intelligence—implications. In *XAI Based Intelligent Systems for Society 5.0*. https://doi.org/10.1016/B978-0-323-95315-3.00009-7

Putera, R. F., Marlina, S., Ladiva, H. B., Mahfudzah, A., & Qalbi, Z. (2024). Development of Smart Apps Creator Learning Media for Civics Learning in Elementary Schools. *AIP Conference Proceedings*, *3220*(1), 234857. https://doi.org/10.1063/5.0234857

Putra, M. A., Madlazim, M., & Hariyono, E. (2024). Exploring Augmented Reality-Based Learning Media Implementation in Solar System Materials. *IJORER : International Journal of Recent Educational Research*, *5*(1). https://doi.org/10.46245/ijorer.v5i1.440

Rahmatullah, Ramadhanti, D., Suwarno, R., & Kuswanto, H. (2021). Literature Review: Technology Development and Utilization of Augmented Reality (AR) in Science Learning. *Indonesian Journal of Applied Science and Technology*, *2*(4).

Rifky, S., Putra, J. M., Ahmad, A. T., Widayanthi, D. G. C., Abdullah, G., Sunardi, S., & Syathroh, I. L. (2024). Pendidikan Yang Menginspirasi: Mengasah Potensi Individu. Yayasan Literasi Sains Indonesia

Runco, M. A. (2023). Creativity: Research, Development, and Practice. In *Creativity: Research, Development, and Practice*. https://doi.org/10.1016/C2017-0-03318-9

Sabitri, Z., Rahayu, S., & Meirawan, D. (2024). The implementation of augmented reality-based flipbook learning media in improving vocational school students' critical thinking skills in the era of society 5.0. *Jurnal Pendidikan Teknologi Kejuruan*, *7*(1). https://doi.org/10.24036/jptk.v7i1.35223

Sahari, S., & Wahyudi. (2020). Pengembangan Media Tata Surya Berbasis Macromedia Flash Sebagai Inovasi Pembelajaran DARING Untuk Siswa SD. *Jurnal Pendidikan Dasar Nusantara*, *6*(1). https://doi.org/10.29407/jpdn.v6i1.14711

Sapta, A., & Nisa, U. K. (2024). the Use of Formative Evaluation in the Development of Spatial Buildings for Elementary School Students Based on Augmented Reality. *Al-Bidayah : Jurnal Pendidikan Dasar Islam*, *16*(1), 151–172. https://doi.org/10.14421/al-bidayah.v16i1.9583

Saputro, B. (2021). Best Practices Penelitian Pengembangan (Research and Development) Bidang Manajemen Pendidikan IPA. In *Academia Publication.*

Setiawan, B., Rachmadtullah, R., Farid, D. A. M., Sugandi, E., & Iasha, V. (2023). Augmented Reality as Learning Media: The Effect on Elementary School Students' Science Processability in Terms of Cognitive Style. *Journal of Higher Education Theory and Practice*, *23*(10), 58–69. https://doi.org/10.33423/jhetp.v23i10.6182

Sugiyono. (2015). Metode Penelitian Pendidikan. Bandung. *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, Dan R&D)*.

Uriarte-Portillo, A., Zatarain-Cabada, R., Barrón-Estrada, M. L., Ibáñez, M. B., & González-Barrón, L. M. (2023). Intelligent Augmented Reality for Learning Geometry. *Information (Switzerland)*, *14*(4). https://doi.org/10.3390/info14040245

Vashisht, S. (2024). StellarScape: Explore the Solar System with AR Cube. *2nd International Conference on Intelligent Cyber Physical Systems and Internet of Things, ICoICI 2024 - Proceedings*, 681–686. https://doi.org/10.1109/ICoICI62503.2024.10696244

Wannapiroon, P., Nilsook, P., Kaewrattanapat, N., Wannapiroon, N., & Supa, W. (2021). Augmented Reality Interactive Learning Model, using the Imagineering Process for the SMART Classroom. *TEM Journal*, *10*(3).

https://doi.org/10.18421/TEM103-51

Wijayanto, B., Luthfi, Z. F., Suci, F. R. Z., Operma, S., Pernando, J., & Johnstone, J. M. (2023). Augmented Reality-Based Mobile Learning: Enhancing Student Spatial Intelligence. *Journal of Higher Education Theory and Practice*, *23*(9). https://doi.org/10.33423/jhetp.v23i9.6135

Winarni, E. W., & Purwandari, E. P. (2019). The effectiveness of turtle mobile learning application for scientific literacy in elementary school. *Journal of Education and E-Learning Research*, *6*(4), 156–161. https://doi.org/10.20448/journal.509.2019.64.156.161

Wu, J. A., Sandjaja, T. A., & Kurniawan, Y. (2024). Augmented Reality Revolution in Early Childhood Year and Elementary Learning: Systematic Literature Review. *2024 6th IEEE Symposium on Computers and Informatics, ISCI 2024*, 60–65. https://doi.org/10.1109/ISCI62787.2024.10668146

Yamtinah, S., Elfi Susanti, V. H., Saputro, S., Ariani, S. R. D., Shidiq, A. S., Sari, D. R., & Ilyasa, D. G. (2023). Augmented reality learning media based on tetrahedral chemical representation: How effective in learning process? *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(8). https://doi.org/10.29333/ejmste/13436

Yuliawati, F., Pangestu, S. A., Yogyakarta, U. N., Al, M. I., & Prambanan, M. (2023). Analysis of Teacher Errors in Applying The Problem-Based Learning Model In The Teacher Professional Education Program-In-Service Program. *Al-Bidayah : Jurnal Pendidikan Dasar Islam* 14 (1). https://doi.org/10.14421/al-bidayah.v14i1.1023

This page is intentionally left blank