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Development of Augmented Reality (AR) Learning Media Integrated with STEM Learning

Halimatus Sakdiah[1*], Riza Andriani[1], Fajrul Wahdi Ginting[1], Nuraini Fatmi[1]

[1] Physics Education, Malikussaleh University, North Aceh, Indonesia

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Corresponding Author:
Halimatus Sakdiah
halimatussakdiah@unimal.ac.id

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Abstract: This research is motivated by the development of science and technology in the 21st century, especially in the fields of Augmented Reality (AR) and STEM (Science, Technology, Engineering, and Mathematics) learning which provides opportunities for students to develop work skills and mathematical abilities which lead to the formation of life competencies in the future that is the competence of Education for Sustainable Development Goals (ESDG). This AR Learning Media was developed with a 4D development design: Define, Design, Development, and Dissemination. The subjects of this research were 7th-grade science students and teachers at SMPN 1 Dewantara. Media and content validation was carried out by 2 material experts and a media expert. Instruments used Media validation sheets, materials, and student and teacher response questionnaires. Analysis was done using percentage techniques on validation sheets, teacher response questionnaires, and student responses. The results of this research are AR media prototypes that are very feasible according to material experts and appropriate according to media experts with excellent student responses and the teacher's response was very practical

Keywords: Augmented Reality (AR); Learning Media; STEM

Introduction

Knowledge is no longer enough to face developments in the 21st century (Mardhiyah et al., 2021), to be able to keep up with the flow of current technology, various competencies are needed for students (Harjani, 2022). Competency is the characteristic of someone who has a consistent ability to achieve the desired performance. The 21st century competencies are called the 4Cs (Critical Thinking, Creative Thinking, Collaboration, and Communication) (González-salamanca et al.,2020).

Education is a person's conscious effort to improve their ability to face the challenges of the 21st century (Wijaya et al., 2016) and the current surge in information technology (Syahputra, 2018). Current learning has implemented student-centered learning, meaning that teachers play a role in directing students to build their knowledge (Bayley, 2022). Cognitive understanding is the basis for achieving competency in the era of Society 5.0, so teachers must be able to innovate and utilize technology in learning (Bray et al., 2023).

One of the innovations that teachers can implement in learning is by utilizing interactive multimedia based on Augmented Reality (AR). The use of AR media encourages experts to recommend learning to be delivered innovatively and creatively using Information Technology-based facilities independently or collaboratively (Ifriza et al., 2022). Augmented Reality is an application that combines real environments and virtual environments with 2D and 3D shapes at the same time in a real environment, this is very relevant to be applied to science learning (Maulana et al., 2019).

Augmented Reality is a media that can insert information into digital content and display it in the real world. The images or animations displayed in AR are in the form of 3D animations. Utilization of Augmented Reality media is a medium that can incorporate information into digital content and display it in the real world. The images or animations displayed in AR are in

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the form of 3D animations (Syawaludin, Ahmad, Gunarhadi, 2019). Implementing augmented reality media in learning will make students absorb and remember 90% of what they have learned more quickly compared to learning only by providing videos or other things.

AR media has become an alternative use of technology for the learning process because its use can make teaching and learning activities more effective (Sahronih et al., 2023). The function of Augmented Reality is to increase a person's perception of the world around him and make several virtual and real worlds into new interfaces that can display relevant information and can be helpful, especially in the field of education (Maulana et al., 2019). The use of AR in learning activities can present a variety of contemporary technological learning innovations, especially in science learning (Rachmadtullah, R., Setiawan, B., Wasesa, A. J. A., & Wicaksono, 2022).

The advantages of using AR as a learning medium are: 1) increasing motivation because students will feel like the main character and will be encouraged to try and learn new things. 2) Encourage participation, because students gain experience in exploring so they get feedback in learning. 3) The learning process is much more enjoyable because students are freer to interact with virtual objects. 4) Easier access, because it can be accessed via smartphones, tablets, and video game devices. 5) Makes it easier to deliver material, because the material is not only presented in visual form but can also be accessed and felt as if it were real for students.

The development of AR media utilizes the mywebar.com application, this application is easy to use without the need for coding. In the application gallery itself, it provides various 3D objects that can be used by users. So making this media doesn't take a long time. The final result of using this application is that 3D visual models, photos, and videos will come to life in students' browsers on smartphones, tablets, and laptops.

Implementing innovative learning by utilizing AR media can be done by implementing STEM learning. STEM (Science, Technology, Engineering, and Mathematics) is learning to integrate subjects and correlate them with everyday life (Arifin et al., 2020). STEM learning is a type of learning that emphasizes the learning process so that students can use a scientific approach to understand various materials (Afrianti et al., 2022).

The definition of STEM about literacy in four interconnected fields is: (1) Science is the ability to identify various scientific information, then apply it in the real world and also play a role in finding solutions; (2) Technology, which is the skill of using various technologies, learning to develop technology, analyzing technology to be able to influence the thinking of students and society; (3) Engineering, is the ability to develop technology with creative and innovative designs through the combination of various scientific fields; and (4) Mathematics, is the ability to analyze and convey ideas, formulations, solve problems mathematically in their application (Sakdiah et al., 2022).

STEM learning also requires students to be able to design, develop, and utilize technology to build problem-solving innovations. The STEM approach can help students can solve problems innovatively, independently, think logically, and be technologically literate (Sunardi & Hasanuddin, 2019). Solving this problem can then hone cognitive, affective, and psychomotor skills in applying their knowledge (Sakdiah et al., 2020). STEM learning can be done by applying various scientific learning models. One learning model that is by the STEM approach is the Project Based Learning model (Slough & Milam, 2013).

This research is development research that uses the 4D development model (Define, Design, Development, and Dissemination) (Gorbi Irawan et al., 2018; HL et al., 2023). The Define stage is carried out through needs analysis regarding problems, students, and concepts/material. The design was carried out by integrating e-Modules with AR in STEM science learning to produce an initial design for AR Media. Development is the stage where expert validation is carried out on the product being developed in terms of content, construction, language, and media, then from these results, a limited trial is carried out to determine the practicality of the AR media being developed. This practicality is known from the responses of teachers and students to the media being developed. The research was conducted in class 7 at SMPN 1 and 2 Dewantara, North Aceh. Aceh-Indonesia. The parameters in this research are the feasibility and practicality of AR-integrated STEM learning media to support ESDGs from expert validation and teacher-student responses to the media being developed. Data collection was carried out using documentation techniques (literature analysis), field studies (interviews, questionnaires (content and construction validation sheets, media validation sheets, and teacher and student response questionnaires). Data analysis was carried out using percentage techniques for validity and practicality criteria of AR media which was developed.

Result and Discussion

Define

The Define stage starts with **Front-end** analysis: the solar system is abstract material so, it cannot be seen directly by students. So, in the learning process, media is needed that can show celestial objects more clearly. Apart from providing a real impression, the media

should also be able to provide activities for students in the learning process. Utilizing AR media is a viable alternative solution.

Learner analysis: the cognitive level of junior high school students is already able to understand simple abstract things, students are only able to distinguish between right and wrong things and cannot when faced with things that are right and wrong simultaneously. Students' curiosity at this level is also very high and they begin to find out things that interest them. At the junior high school level, students also begin to have critical thinking skills, so it would be very appropriate to design learning so that students discuss solving problems or completing a project. The results of the analysis of student characteristics are then used in the development of AR Media. Where the research target is grade 7 junior high school students, so this is taken into consideration in the selection of materials, images, language, animation, and formats used.

Task analysis: The implementation of learning using AR media is planned to apply a STEM learning approach. The STEM approach is an approach that teaches academic concepts and juxtaposes them with the real world, where the process cannot be separated from the application of science, technology, engineering, and mathematics. The STEM approach process is carried out by applying the Project Based Learning (PJBL) learning model. At the end of this learning model, the product is produced (Bulu & Tanggur, 2021; Purwaningsih et al., 2020; Triana et al., 2020). While completing the project, students are directed to integrate the four components of STEM by focusing on solving problems in real life so that they can train students' creativity (Aguilera & Ortiz-Revilla, 2021; Conradty & Bogner, 2018; Hanif et al., 2019; Kanematsu & Barry, 2016; Purwaningsih et al., 2020; Sirajudin et al., 2021).

Education is the main key to realizing sustainability in the PPB program in the form of Sustainable Development Goals (SDGs), especially Quality education goals where students are expected to have Education for Sustainable Development Goals (ESDGs) competencies so that they can survive in the future and be able to protect the earth now for generations to come. One of these competencies is systematic thinking skills. The benefits of this skill are 1) self-development through a more in-depth analysis process; 2) the ability to explain something clearly and easily understood; 3) learning directions and objectives can be planned clearly; 4) guiding teachers/students in systematic activities and 5) changing points of view on a problem is an inseparable system. Apart from that, systematic thinking also leads to the ability to do more dynamic and structured things based on discovery and critical thinking (Gallón, 2020; Kutty et al., 2020; Reynolds et al., 2018). This skills assessment is carried out using an observation sheet that will be carried out during the STEM-PJBL learning process with AR media on the Solar System material.

Concept analysis: identifying the form of hierarchy and details of the material that will be presented in the AR media being developed, namely the earth and solar system. The solar system material was chosen with the consideration that this material would be presented more clearly and realistically in 3D. Ar's goal is to make abstract concepts more real and clear (Radu & Schneider, 2019).

Specifying Instructional objectives: that is determining learning objectives which in this case are 1) Students can analyze the characteristics of the components of the solar system, characteristics of planets, planetary movements, celestial bodies, rotational motion, revolutions, and the occurrence of eclipses through STEM learning with AR media well and 2) Students can create miniature works of the Solar System through good project learning.

Design

Researchers created AR media by using the assemble-word application on the page https://app-edu.assemblrworld.com/, by first logging in, then creating a new project, and then entering 3D objects, text in the form of descriptions of the 3D objects displayed. The work on this assembler-word page can be seen in Figure 1.

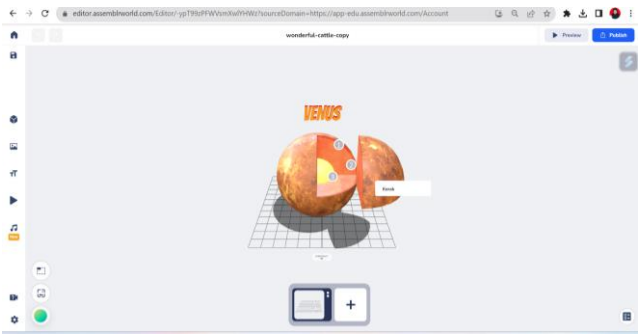

Figure 1. One of the shapes of 3D objects in the Solar System AR Media

In this application, we include every object that we need in this development, namely part of the solar system, starting from the sun, planets, asteroids, and other celestial bodies, so that up to now images of celestial bodies that have only been presented in the form of two-dimensional images have become three dimensions that look more real and are no longer just imagined by students.

After the project is completed, a media publication is carried out where this media publication is carried out to obtain the QR Code for the AR object. Publication is carried out by clicking on the publication menu which

will then show a display as shown in Figure 2. The stages of this publication are filling in object information, setting the publication to share the project and then we will get a QR for AR Media.

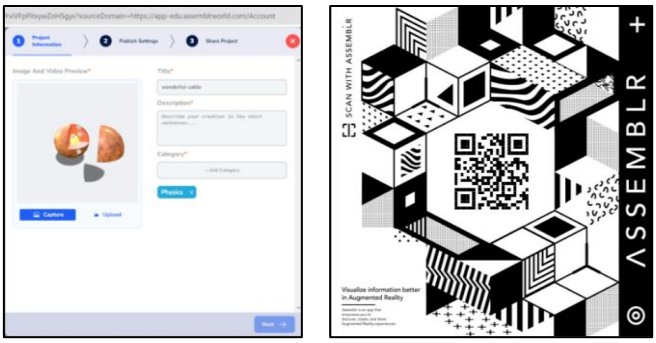

Figure 2. Display when publishing AR media into a QR code and an example of an AR object QR code

To use this AR media, simply scan the QR Code into the scanning application, and the results will display the AR media as if it were in the user's hand. An example of the finished AR Media display can be seen in Figure 3.

Figure 3. AR/QR Code Ar object that has been scanned

Development

This stage is the stage that produces a viable developer product based on expert opinions regarding the content, construction, language, and AR media being developed.

Expert Appraisal; the assessment was carried out by 2 lecturers who acted as material experts and media experts. Validation by material experts revealed that the product being developed was very feasible with an average score of 85.63%. However, in the validation process, there are still several suggestions given by experts. The suggestions are: 1) Explaining the planets in the solar system animation in general, 2) Teaching materials in the form of modules would be better given a space feel in their writing, and 3) Adding explanations related to rotation and revolution when the explanation is related to planets Earth. More **complete** content and construction validation results can be seen in Figure 4.

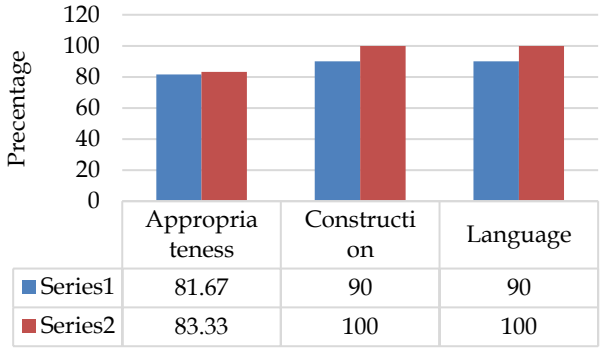

Figure 4. Material Expert Validation Results for Each Aspect

Validation by media experts obtained an average score of 77.86% in the category of feasible and/or not revised, with several suggestions for developing this media, namely: providing texture to the planets in the solar system media and providing explanations for each planet in the animation solar system. A more detailed assessment of software engineering and graphic aspects can be seen in Figure 5.

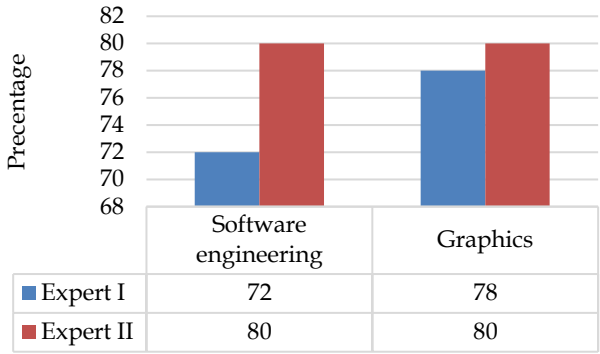

Figure 5. Media Expert Validation Results for AR Media and Modules

Developmental Testing: To see the practicality, responses, reactions, and comments of students and teachers regarding the media being developed. Then carry out revisions from the results of small-scale trials, and continuous improvements are made, resulting in an AR Integrated STEM Learning Media product that is ready to be used and tested for effectiveness. The implementation of the AR media, it was then tested in a small class, namely on 10 students of Dewantara 1 Middle School and 2 teachers in the field of physics

studies. The results of the responses observed from the ten students can be seen in the Table 1.

Table 1. Students' Responses to STEM-Based AR Media

Dimension	Indicator	Average Percentage (%)	Category
Cognitive	Understanding the material presented	75.25	Good
	Clarity of media use	82.35	Excellent
	Display suitability	81.55	Excellent
	Motivation	85	Excellent
Affective	Attractiveness	85.2	Excellent
	Curiosity	82.3	Excellent
Average Student Response		81.94	Excellent

Based on the table above, it is found that the average percentage of student responses is 81.94% with an **excellent category**. Where the highest response value was for the attractiveness indicator with a value of 85.2% and the lowest response was for the indicator of understanding the material presented with a value of 75.25% in the good category. The media practicality assessment was carried out by two teachers, the results of the assessments from the two teachers can be seen in Table 2. The average teacher response to the media was 82.5% in the **very practical** category. The lowest aspect in the interactive category is worth 80% in the very practical category and the highest aspect is efficient with a score of 85 in the very practical category.

The practicality of this media also directs it in terms of ergonomics, learning quality, and the media's ability to make learning something more fun and interesting (Pribeanu et al., 2017).

Table 2. Teacher Responses to STEM-Based AR Media

Aspect	Teacher I	Teacher II	Average (%)	Category
Effective	85	80	82.5	Very practical
Interactive	80	80	80	Very practical
Efficient	85	85	85	Very practical
Creative	85	80	82.5	Very practical
Average			82.5	Very practical

Dissemination

Packaging and Diffusion and adoption: This dissemination stage is carried out on Augmented Reality (AR) Media with the object being a QR Code of the solar system which has been packaged and registered with IPR and is then disseminated so that it can be absorbed (diffusion) or understood by other people and can be used (adoption) in their class.

Conclusion

The results of this research can conclude that the STEM-integrated AR media developed is in the very feasible category according to material experts and feasible according to media experts. Limited trials to determine the practicality of the media according to students are in the excellent category, and according to teachers in the very practical category. So from this, it can be seen that this STEM-integrated AR media can be used as a learning media. The thing that needs to be paid attention to in developing AR media is 3D objects, where these 3D objects should be made by the developers themselves because not all objects are available on the internet. Further implementation in the classroom on a large scale is needed to determine the effectiveness of STEM-integrated AR media which was developed by taking into account the internet connection in the subject school because the use of this AR media requires a stable internet connection.

Author Contributions

The authors provide equal contributions to this work.

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Conflicts of Interest

The authors declare no conflict of interest.

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