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Development of Astronomy Learning Modules on the Subject of the Solar System Integrated with Augmented Reality Videos

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Abstract: The rapid development of science and technology makes the teaching and learning process easier. In using technology, media is needed that can provide practicality in supporting learning. The aim of this research is to develop learning media in the form of an integrated Augmented Reality (AR) module for learning physics on the topic of the solar system. Objective: This research develops learning media in the form of modules that are integrated with Augmented Reality (AR) in physics learning on the topic of the solar system. Method: Development research by following Level 1 R&D Research Steps. With minimum standards for good/feasible product validation. As a result of the development results, the module is worthy of being viewed from the media and the context of the content of the solar system material. Apart from that, supporting applications that are capable of producing augmented reality based animations are also feasible both in terms of image selection so that the resulting animations are also in the feasible category. In terms of use, the integrated augmented reality module in physics learning has the potential to improve the quality of student learning.

Keywords: Augmented reality; Learning media; Module, Solar system

Introduction

In the current era of information and communication technology, learning is increasingly transformed to become more interactive and interesting for students. Through technology, students can be helped to achieve efficient and interactive learning (Kiryakova et al., 2018). One technology that has attracted attention in the context of learning is Augmented Reality (AR) (Adji et al., 2023; Widiasih et al., 2023). AR is a technology that combines the real world with virtual elements, thus enabling users to interact with virtual objects in a real environment (Duh et al., 2014; Hwang et al., 2016; Ugwuanyi et al., 2020; Wu et al., 2013). The use of AR in learning is expected to increase students' understanding and interest in learning material, including in the field of astronomy.

Astronomy is a branch of science that studies celestial bodies, their motions, and their relationships with other natural phenomena. Astronomy learning is considered important because it allows students to understand physics concepts and develop observation and analysis skills. The introduction of astronomical concepts is important in learning astronomy as part of learning science (Akhsan et al., 2023; Shaafi et al., 2023). The use of AR is important in learning physics, including astronomy which will be difficult to understand if it is only learned through imagination (Lima et al., 2022).

Astronomy learning in its conventional form often faces several obstacles, such as limited interesting learning media and lack of interactivity in the learning process. This can result in students losing interest and having difficulty understanding complex material. So that the potential use of AR is to simulate the conditions of the solar system and explain the characteristics of the members of the solar system (Cai et al., 2014).

With the integration of AR technology in astronomy learning, it is hoped that students can experience a more enjoyable and interactive learning experience. AR can provide three-dimensional

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visualization of celestial bodies, simulate planetary movements, and observe natural phenomena in real-time. This can help students understand astronomy concepts better. The use of AR in learning so far has produced something good when it is associated with learning motivation (Khan et al., 2019). Saltan et al. (2017) also found evidence that the use of AR improves academic performance, student engagement, student motivation, and student satisfaction. The potential and advantages of technology, when implemented in physics learning, will reinforce each other. In recent years, the student experience in technology-enabled learning has been seen as an effective way to teach and learn physics (Saltan & Arslan, 2017). Research related to increasing the use of technology in learning is increasingly focusing on emerging technologies such as augmented reality, mobile learning, and learning analysis as an effort to increase user satisfaction and experience through existing multimedia (Whatoni & Sutrisno, 2022). AR makes it possible to combine virtual content with the real world well (Azuma et al., 2011).

This study aims to develop learning modules based on augmented reality that can be used in learning astronomy. In the future, this designed module is expected to be able to increase students' understanding of astronomical concepts and increase their interest in studying this field. It is hoped that the results of this research can make a positive contribution to the development of a more innovative and interesting astronomy education. The developed AR-based learning module is expected to be an effective alternative in improving the quality of astronomy learning in schools.

Method

This research is a development research that aims to develop learning modules that are integrated with augmented reality. Research and development is conducted using Level 1 research and development measures. The activity plan is to produce a product that will be validated internally (expert opinion and practitioners). The development design can be seen in Figure 1.

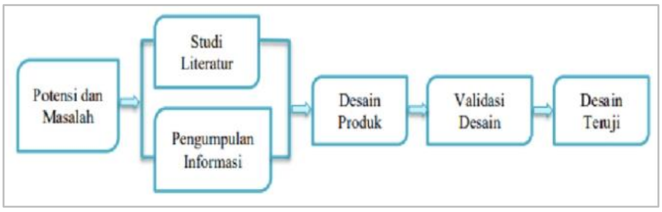

Figure 1. Level 1 R&D research steps

Data Collection and Analysis

Techniques the data collection instrument, as a part of development research, is a very important element because it determines whether the data obtained by the researcher is good or not. In Table 1, a description of the aspects assessed, the instruments used, the observed data, and the respondents involved in this study are presented.

Table 1. Description of the Aspects Assessed in the Development of Augmented Reality Integrated Practicum Modules

Objective	Method of collecting data	Data Collection Instruments
Knowing the potential use of the media	Interview	Interview sheet
	Observation	Observation sheet
AR integrated module validity	Questionnaire	Questioner

Based on Table 1 it can be seen that to test the product validity, the instrument used was a questionnaire given to the learning design experts and material experts. Questionnaires about product effectiveness used test sheet instruments and observation sheets.

Data analysis in this study was carried out in a qualitative descriptive manner to process data in the form of input, criticism, suggestions, and responses, and descriptive statistical data analysis was used to process data obtained from questionnaires and test sheets.

Validity

Validity is a method that can be used to determine the feasibility of the media being developed. In this study, content validity was conducted to determine the feasibility of the content and media presented in the developed media (Yamtinah et al., 2021). Data on the validity and applicability of the model and its tools were analyzed using descriptive statistical analysis techniques by calculating percentages using the following equation:

$$\text{Achievement Level} = \frac{\Sigma x}{SMI} \times 100\% \quad (1)$$

Description:
$\sum x$ = Total score
SMI = Ideal Maximum Score
The criteria are set out in Table 2 as a guideline for interpretation.

Table 2. Assessment Criteria and Conclusions by Material and Media Expert Validators

Achievement Level (%)	Qualification
81-100%	Very Good
61-80%	Good
41-60%	Good Enough
21-40%	Not Good
< 20%	Very Bad

The product in the form of a learning activity module on integrated augmented reality astronomy material is declared valid and feasible from a technical point of view if it is at a score of ≥ 75.00 or meets the minimum criteria of good (Sari et al., 2021).

Result and Discussion

Development of an Integrated Augmented Reality Astronomy Learning Module

Module development supported by Augmented Reality (AR) is undertaken using the R & D Level 1 model. The ensuing paragraphs present the outcomes of creating an astronomy learning module aided by Augmented-based animation. The initial phase encompasses the analysis of potential issues, comprising two facets: a literature review and data compilation. Insights regarding field conditions were gleaned from observations conducted during the learning process.

The subsequent stage is design. This phase entails crafting learning media, encompassing the formulation of media objectives, designing topologies and flow systems, and selecting assets. Materials, including animations, slated for integration within the developed media, will be incorporated into the application.

Augmented Reality (AR), an innovative technology based on computers, combines digital data, content, and images within educational context. As a result, virtual elements are displayed in real-time through the medium, appearing as markers that correspond to the camera's viewpoint (Ningrum et al., 2021).

Through the utilization of this technology, students gain an accurate visualization of the solar system, which is imparted via Android mobile devices. The appearance of the modules developed as teaching media can be seen in Figure 2.

To support the module is an application, as shown in Figure 3. Figure 3 is a display of the solar system application that will support modules that are integrated with augmented reality-based animation.

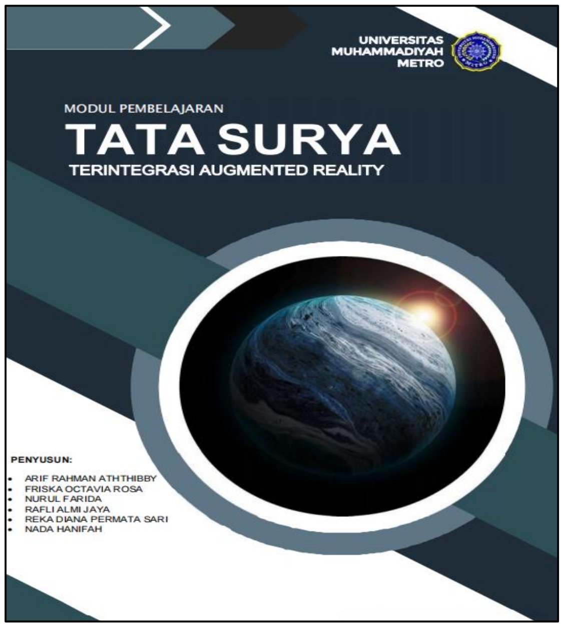

Figure 2. Module cover view

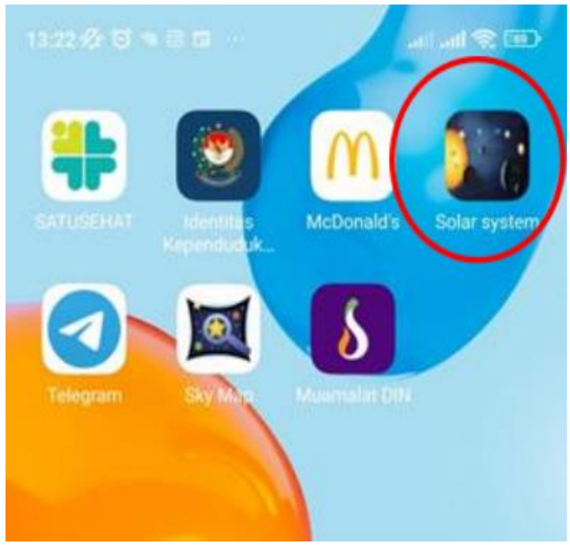

Figure 3. Display of the solar system Apk application on the screen

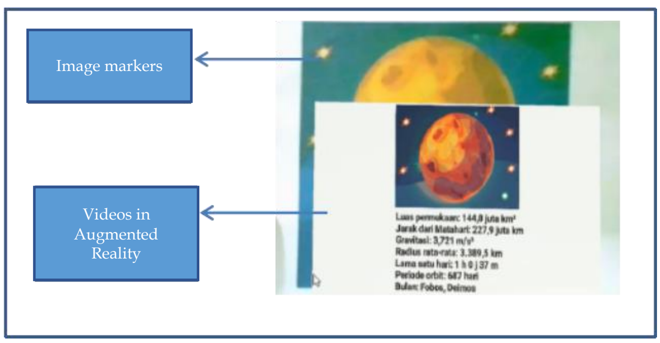

Figure 4. Target Image of planet mars and video in augmented reality

After the installation process on the device is complete, each image contained in the module has been integrated with Augmented Reality-based video. In general, Augmented Reality products consist of a module with an image that functions as a marker that has been attached to a video that will automatically activate when the camera of an Android device that has the solar system application installed apk is activated. An overview of the display of images in the module as markers and supporting videos can be seen in Figure 4.

The next stage is the validation process. The validation stage consists of 3 assessments, namely modules as media, animation as support, and a combination of both modules and applications to support learning modules. The initial part that is validated is the module. The results of the module validation from 3 experts obtained the results as presented in Table 3. Media in the form of a module integrated with Android-based augmented reality was tested for its feasibility using a validity assessment instrument in the form of a questionnaire with a Likert scale.

Table 3. Validation of the Context and Content Aspect Modules

Aspect	Percentage	Qualification
Cover	95.83	Very Good
Ilustration	72.22	Good
Format	88.33	Very Good
Contents	83.33	Very Good
Language	91.67	Very Good

The instrument used uses 5 aspects of assessment with 17 question items. Based on the results of the assessment, it is known that the developed module is in the very good category, so it is feasible to use. So it can be concluded that specifically the developed module is suitable for use both in terms of media and content which includes the scientific field of astronomy, especially on the topic of the solar system.

Table 4. AR-Based Animation Validation

Aspect	Percentage	Qualification
Utility	87.5	Very Good
Practicality	86.11	Very Good
Positive Response	87.5	Very Good
Follow-up	91,67	Very Good

The next aspect is the assessment of AR applications that support the module. The results of the AR-based animation validation assessment can be seen in Table 4. This section consists of 11 questions to obtain a quality profile of animation and augmented reality-based programs to support learning modules

The proper results obtained from the validators also went through several revisions of the appearance. Several animations early in the development process failed to appear as targeted. After going through revisions and improvements, the animation is able to appear as targeted. So, in general, the animation that is displayed through the AR application is feasible. In Table 5, the results of validating the integrity of the module and application as a learning tool are shown. Based on the results of the assessment, it is known that the astronomy learning module on the subject of the solar system, integrated with augmented reality videos, is feasible to use.

Table 5. Validation of Media and Animation as Media

Aspect	Percentage	Qualification
Accuracy of Illustrations on Cover	75.00	Good
Suitability of the material with the media	83.33	Very Good
Image quality in the material description	83.33	Very Good
Image placement accuracy	91. 67	Very Good
Image size accuracy	83. 33	Very Good
Text quality	91. 67	Very Good
Table quality	91. 67	Very Good

Advantages and Disadvantages of Augmented Reality Integrated Astronomy Learning Module

The results of the development show that modules that are integrated with AR are able to present different perspectives in learning on the topic of the solar system. Images in the module can be converted into a more dynamic animation format. Animation, as shown in Figure 6, shows the identity and character of each member of the solar system. This is because AR allows users to interact with animations produced by multimedia components and the real world at the same time (Cheng & Tsai, 2013).

One advantage of Augmented Reality (AR) is its capacity to blend virtual elements (such as text, images, and animations) seamlessly into the real world, enhancing the learning experience (Challenor & Ma, 2019) by making it more enjoyable and captivating (Alyousify & Mstafa, 2022). This enables learners to engage in practical learning and actively acquire knowledge.

In contrast to conventional learning media, which rely on traditional methods, AR serves as a learning medium that offers valuable feedback. Particularly in physics education, including astronomy, AR usage broadens the array of available learning resources for students, encompassing both physical tools (Lu et al., 2020) and digital resources (Roopa et al., 2020). Augmented reality is an effective way to provide useful learning materials.

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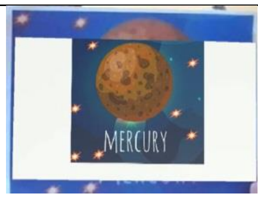
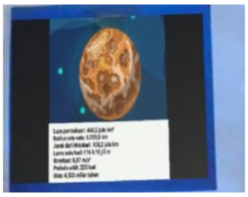
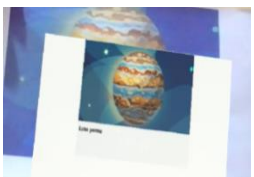
Table 6. Image Target Display and AR Display

Image Targets	Scan Results	Description
		When the application is activated, and the device's camera is pointed at the target image of mercury, an animation of the mercury data line will appear
		When the application is activated, and the device's camera is directed to the target image of Venus, an animated line of Venus data will appear
		When the application is activated and the device's camera is pointed at the target image of the Earth, an animated line of Earth data will appear
		When the application is activated and the device's camera is pointed at the target image of the mars, an animated line of mars data will appear
		When the application is activated and the device's camera is pointed at the target image of Jupiter, an animated line of Jupiter data will appear
		When the application is activated and the device's camera is pointed at the target image of Saturn, an animated line of Saturn data will appear
		When the application is activated and the device's camera is pointed at the target image of the uranus, an animated line of Uranus data will appear
		When the application is activated and the device's camera is pointed at the target image of the neptume, an animated line of Neptune data will appear

However, integrating AR-based media, including modules as seen in this study, has certain drawbacks. It demands suitable equipment and learning materials that optimally display 3D models, ensuring accurate visual representation (Thees et al., 2020). Additionally, a challenge with AR adoption is that applications containing augmented reality require ample storage space, necessitating larger memory capacity for application downloads (Cieza & Lujan, 2018; Ropawandi et al., 2023). Specifically, for AR applications intended to support module work optimally, an Android device with specifications such as 4 GB RAM, 16 MP camera, Android 5.0 Operating System, and a 1.8 GHz Dual-core Processor is necessary.

The future holds increasing adoption of augmented reality in education due to its diverse advantages (Alyousify & Mstafa, 2022; Garzón et al., 2019; Purwaningtyas et al., 2022; Tzima & Styliaras, 2019). Augmented reality's integration into learning represents a new stride in learning technology (Aththibby et al., 2021), fostering self-directed learning and empowering students to gain knowledge and skills through novel environments and information tools (Kiryakova et al., 2018). Utilizing augmented reality for astronomy education in the future can enhance students' fundamental qualities, aligning with educational philosophy and teaching reforms (Chang et al., 2022).

Conclusion

In summary, the research outcomes indicate the suitability of solar system modules concerning both media and content context. Additionally, supporting applications capable of generating AR-based animations are deemed feasible, covering aspects such as image selection and the resulting animations. Moreover, the integration of augmented reality modules in physics education shows potential for improving the quality of learning. These findings propose an alternative approach to physics education, particularly focusing on the solar system topic, through the development of augmented reality-based digital media. However, a limitation of this study is the reliance on a limited number of sources, comprising 30 international and national articles. Nonetheless, future implementation of modules integrated with augmented reality could enrich the learning process and enhance its quality. In conclusion, the research findings suggest that: 1) the solar system modules are suitable in terms of media and content context; 2) supporting applications capable of producing AR-based animations are also feasible, encompassing image selection and resulting animations; and 3) the integration of augmented reality modules in physics education holds potential for enhancing learning quality. These findings offer an alternative for physics education, specifically in the solar system topic, through the development of augmented reality-based digital media. A limitation of this study is the use of a limited number of sources, totaling 30, comprising international and national articles. Future implementation of modules integrated with augmented reality could enrich the learning process and elevate its quality.

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Author Contributions

The four of us as authors of this article worked from preparation research proposals to writing reports and journal articles. The first author conceptualized the astronomical material and prepared images to become markers. The second and third authors prepared the application and helped with the product validation process. While the fourth author assisted in the limited testing process of the application being developed.

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Conflicts of Interest

The authors declare that there were no conflicts of interest in the writing of this article.

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