

ASTROLEARN: INNOVATIVE ASTRONOMY LEARNING MEDIA TO IMPROVE STUDENTS' ETHNOSCIENCE LITERACY AND CRITICAL THINKING SKILLS

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Abstrak

Materi pelajaran alam semesta dan tata surya merupakan salah satu materi yang relatif sulit dipahami oleh siswa. Salah satu penyebab dari masalah ini adalah karena pembelajaran belum banyak dikaitkan dengan konteks kehidupan sehari-hari, termasuk konteks budaya lokal. Saat ini, masih sulit ditemukan media pembelajaran yang dapat merepresentasikan materi alam semesta dan tata surya dalam tampilan tiga dimensi. Oleh sebab itu, dalam riset ini dikembangkan media pembelajaran ASTROLEARN yang layak dan menarik. ASTROLEARN adalah media edukasi astronomi yang didasarkan pada kearifan lokal dan dilengkapi dengan aplikasi melalui komik, video, flipbook, dan guideobook project tentang materi tata surya, hukum gravitasi Newton, dan hukum Kepler. Selain itu, terdapat ASTROLEARN Box yang berisi proyek kearifan lokal Jawa menggunakan augmented reality. Penelitian ini menggunakan model pengembangan ADDIE. Hasil penelitian menunjukkan bahwa media pembelajaran ASTROLEARN menjadi solusi efektif dalam meningkatkan kualitas pembelajaran. Menariknya, ASTROLEARN menjadi media pembelajaran fisika yang mampu meningkatkan literasi etnosains dan keterampilan berpikir kritis siswa sekaligus secara signifikan..

Kata Kunci: ASTROLEARN; Pranata Mangsa; Augmented Reality; Literasi Etnosains; Keterampilan Berpikir Kritis

Abstract

The subject matter of the universe and the solar system is one of the subjects that is relatively difficult for students to understand. One of the causes of this problem is that learning has not been widely linked to everyday life, including the context of local culture. Currently, it is still difficult to find learning media that can represent the material of the universe and the solar system in a three-dimensional display. Therefore, in this research, a suitable and attractive ASTROLEARN learning media was developed. ASTROLEARN is an astronomy education media based on local wisdom and equipped with applications through comics, videos, flipbooks, and guidebook projects on the material of the solar system, Newton's law of gravity, and Kepler's laws. In addition, there is an ASTROLEARN Box that contains a project of Javanese local wisdom using augmented reality. This research used an ADDIE development model. The results showed that the ASTROLEARN learning media is an effective solution in improving the quality of learning. Interestingly, ASTROLEARN is a physics learning media that can significantly improve students' ethnoscience literacy and critical thinking skills simultaneously.

Keywords: ASTROLEARN; Pranata Mangsa; Augmented Reality; Ethnoscience Literacy; Critical Thinking Skills

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INTRODUCTION

One of the goals of education is to help students understand what is conveyed verbally, both in numerical form and in terms of conceptual frameworks. Most of the physics concepts that students learn in schools are still at an abstract level, and most of them cannot understand the main concepts or the relationships between the concepts they learn (Dara Amin et al., 2019). This is supported by data from the Indonesian Education Assessment Center, which states that the average score for the 2019 national examination for private high schools was 46 (Ministry of Education and Culture, 2019). This score is the second lowest after mathematics. In general, the characteristics of the solar system material are abstract, which makes it difficult for students to understand. Its abstract nature and lack of good visualization often cause students to consider learning about celestial bodies or astronomy difficult to understand (Febriyanto et al., 2024). This is in line with the author's findings from a survey showing that 22% of 11th-grade high school students in Malang have difficulty understanding the material on the universe and the solar system. Teachers usually use images that are already presented in textbooks, which do not move when teaching solar system material. Thus, the image media used is unable to provide a response and the display provided is less realistic. As a result, students tend to become passive and uninterested in the material, so they are not interested in learning (Putra et al., 2021). In fact, with the development of the 4.0 industrial era, which initially focused on students, the orientation has now shifted to collaborative learning between teachers and students (Eltias et al., 2024). In addition, teachers stated that solar system material requires learning media because it is difficult to find in the surrounding environment where students can observe it directly (Putri et al., 2022).

One of the most important concepts in physics is mechanics, which covers Newton's laws, which are broad and complex. As a result, students often have misconceptions about this material (Fitriyah et al., 2023). The material covers Newton's first, second, and third laws, as well as the kinematics of linear and circular motion. In addition, Newton's law of gravity and Kepler's laws are closely related because they both explain planetary motion. Newton's law of gravity and Kepler's laws are also included in the category of abstract physics material because of the relationship between celestial objects that cannot be presented in the classroom (Listiaji et al., 2019). In order to make the concepts presented more tangible and observable, learning media can be a solution in delivering physics material as a simplification or a model.

The use of conventional learning methods often fails to attract the interest and motivation of today's students (Sembiring et al., 2025). In fact, learning media is very important to help teachers deliver material in a more effective way (Wafiq et al., 2021). Unique learning technologies usually attract students' attention and make them more motivated (Epros et al., 2024). This is evidenced by the results of a survey conducted, which found that 70% of students prefer learning using educational videos and 58% like attractive images and displays during the learning process. In achieving effective learning in the 21st century, the project-based learning model is considered to be able to improve students' critical thinking, collaboration, communication, and creativity (Putra, 2024). Based on the results of a survey conducted in 2024, 77% of students are interested in learning physics material related to everyday life through a cultural approach. This approach is called ethnoscience, which connects local wisdom with science. The science subject on the universe and solar system is one example of the implementation of the ethnoscience learning model (Pamungkas et al., 2017). This implementation can be an alternative way to demonstrate the beliefs of the people of the past, which are then combined with scientific material, and as a form of cultural preservation, one of which is through the Pranata Mangsa calendar.

The integration of learning with an ethnoscience approach to the subject matter of the universe and solar system is very important to implement, especially given the significant

influence of outside cultures, which has led to a decline in high school students' knowledge of local culture. Based on data and facts in the field, 81% of students are unaware of the traditional calendar system, which was once an astronomical knowledge originating from Java. Moreover, scientific concepts related to the traditional calendar system, such as astronomy, climate, seasons, and seasonal indicator plants, are vital to study and reintroduce to the public as part of Indonesia's national identity (BRIN Publisher, 2023). If this learning is integrated, it will result in quality learning and greatly contribute to the realization of Permendikbud Ristek No. 56/M/2022 related to Point 4 of the Sustainable Development Goals (SDGs) and the Pancasila student profile strengthening project.

Currently, there are many educational media on the universe and solar system available on the market that are still unable to engage students actively in the learning process. Moreover, research related to the use of technologies such as STEAM-based augmented reality on science literacy competencies and student learning outcomes is still relatively rare (Asyri & Asyri, 2024). Based on this, the author initiated an innovation in astronomy education media based on the local wisdom of Pranata Mangsa, which accommodates two innovations, namely a STEAM learning system based on Javanese local wisdom, namely Pranata Mangsa, integrated with augmented reality and using the project-based learning model. The branding used is "ASTROLEARN", a local wisdom-based astronomy education media equipped with a learning application containing content presented through videos, comics, flipbooks, and project guidebooks on the solar system, Newton's law of gravity, and Kepler's laws. It is also complemented by the ASTROLEARN Box, which contains Javanese astronomy local wisdom projects integrated with augmented reality that can enhance ethnosience literacy and critical thinking.

METHOD

The research and development method used was the ADDIE model, which consists of the steps of analysis, design, development, implementation, and evaluation. The research was conducted at State Senior High School (SMAN) 9 Malang during the first semester of the 2024/2025 academic year. Interviews, observations, documentation, validation questionnaires, and pre-test and post-test questions were employed to obtain data. Furthermore, the research subjects were 11th-grade physics students. Analysis, as the first stage, involved gathering various relevant sources on misconceptions about the material, the curriculum used, and the importance of learning media. Design, as the second stage, involved creating media designs based on the previous analysis. At this stage, research instruments are also designed, including product validation sheets by media and material experts and student response questionnaires. Next, the development stage begins with the creation of media in accordance with the design results made in the previous stage. In addition, product feasibility tests were carried out by media and material experts. Then, the implementation stage was carried out to determine the effectiveness of the learning media product. The product was tested on 32 grade XI students majoring in physics. Evaluation was the stage of reviewing student and validator feedback.

Data analysis from the expert validation questionnaire and student response questionnaire was the initial stage of data processing. The Likert scale was implemented to collect data from both validation questionnaires to measure the level of expert perception and student response to the use of ASTROLEARN media in learning. This Likert scale consisted of four answer choices, namely strongly agree (SA), agree (A), disagree (D), and strongly disagree (SD). In addition, product feasibility testing was carried out through an analysis of the validity sheet and student response questionnaire. Then, the percentage obtained was divided by the maximum score, multiplied by 100%, and interpreted based on the product feasibility test score criteria proposed by Setiawan et

al. (2024), with categories of 85%-100% very feasible, 70%-85% feasible, 50%-70% not feasible, and 1%-50% very not feasible..

Pre-test and post-test scores were analyzed to determine how students learned both before and after using the created learning media. To determine whether the data could be considered normal, a normality test was conducted by a t-test. However, in cases where the data were considered non-normal, the Wilcoxon test was used. Furthermore, data analysis methods were used to identify improvements in ethnoscience literacy and critical thinking skills through the use of the N-Gain test. The analysis was performed by calculating the difference between the post-test and the pre-test scores, then dividing by the maximum score and subtracting from the pre-test score. The N-Gain findings were categorized into 3 groups as proposed by Hake (1998): high category (> 0.7), medium ($0.3 - 0.7$), and low (< 0.3). Then, the average standard gain results were converted to percentages and categorized based on the interpretation of standard gain effectiveness, namely the ineffective category (< 40), less effective ($40 - 55$), quite effective ($56 - 75$), and the effective category (> 76).

RESULT

The first analysis was analyzing misconceptions among students in the subjects of the universe and the solar system, as well as Newton's law of gravity and Kepler's laws. At this stage, the researchers also determine the students' needs in accordance with the applicable curriculum and find out what kind of learning media can support student learning. In this activity, the researchers interviewed physics teachers to examine the problems with the use of media. The interview results showed that teachers still use the lecture method in their teaching, which is also influenced by the lack of supporting learning media. Thus, the researcher attempted to incorporate technology-based media into learning activities. The design stage was carried out after completing the first stage and entering the second stage. This design stage involved several designs in the development of learning media, including: (a) drafting the design of the application and learning materials in accordance with the previous analysis and the collection of various data during the creation of the learning device application using Android, (b) designing the learning project flow, starting from the time management in organizing learning to the design of the project result reporting strategy, (c) and determining the evaluation assessment of the ASTROLEARN product.

The design of the ASTROLEARN application consisted of several excellent features, namely: (1) a guide feature to learn about the features and uses of the ASTROLEARN app, (2) a competency feature, available to users, which includes learning outcomes and learning objectives, (3) concept map feature, containing concept maps or connections between material on the universe and solar system and material on Newton's law of gravity and Kepler's laws, (4) galaxy talks (discussion forum feature), where students and teachers can talk about learning by sending messages and photos, (5) cosmic cartoons (comic feature), a feature that can build student character through a process of readiness, identification, and internalization, (6) stellar quest (games feature), containing interesting games that users can play while learning about the universe and solar system, (7) local stars (local wisdom feature), containing videos and explanations about local wisdom, particularly Pranata Mangsa, which is related to the universe and solar system, so that users can learn about the history of local wisdom, particularly Pranata Mangsa, (8) stellar AI-insight (artificial intelligence feature), where users can interact with artificial intelligence about the universe and solar system in more detail, (9) astro explorer (exploration feature), which will include additional features such as pre-tests, flipbooks, educational videos, and post-tests based on local wisdom, and (10) astro AR-vision (augmented reality feature), to display planetary objects in 3D and interactively.

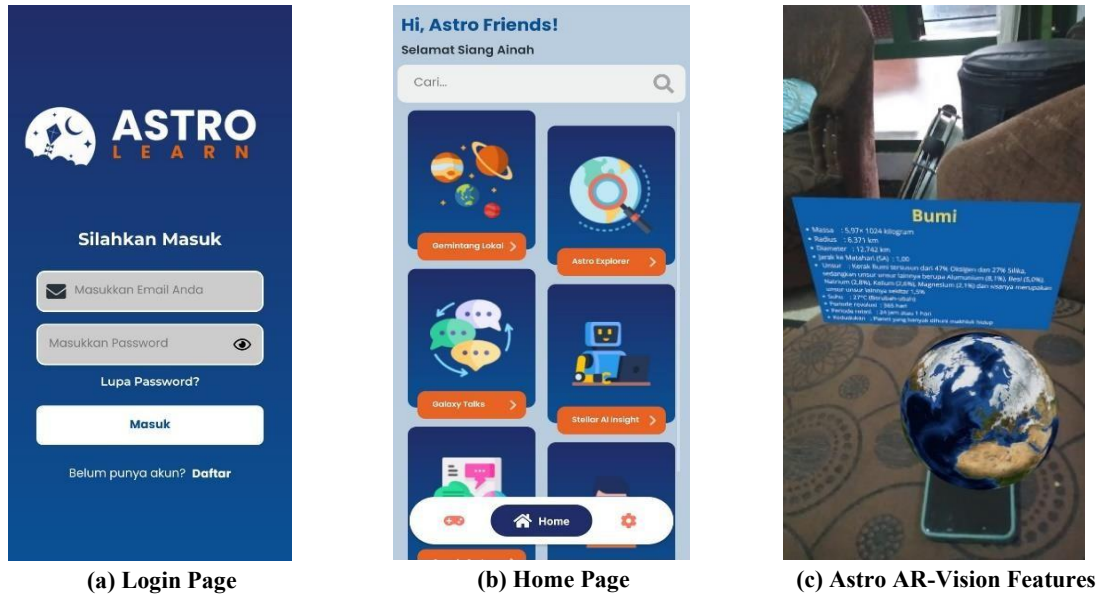


Figure 1. Interface ASTROLEARN Application

The development stage was the third stage, which includes: (a) creating the ASTROLEARN application, (b) developing augmented reality as a visualization of the concepts of the universe and solar system, as well as Newton's law of gravity and Kepler's laws, and (c) validating the material, media, and design of the ASTROLEARN learning media. The following figures are a preview of the ASTROLEARN application as a learning medium based on the local wisdom of Pranata Mangsa integrated with augmented reality.



Figure 2. ASTROLEARN Learning Media Kit Device

Product feasibility testing was conducted to obtain feedback from media and material experts. The results of this feedback were used to revise the product, as shown in the following diagram. Product feasibility tests were obtained from media experts with scores for each assessment indicator, namely 85% (highly valid) for ease of use and navigation, 100% (highly valid) for visual appearance, 75% (valid) for media integration, and 100% (highly valid) for media benefits. Thus, the percentage achieved by media experts was 90%, which was considered highly valid.

Table 1. Validation Results by Media Experts

Assessment Indicators	Percentage (%)	Category
Ease of use and navigation	85	highly valid
Visual appearance	100	highly valid
Media integration	75	valid
Media benefits	100	highly valid

The product feasibility test results from subject matter experts for each indicator are as follows: material relevance achieved a percentage of 87% (highly valid), material presentation achieved a percentage of 85% (highly valid), independent practice and grammar achieved a percentage of 81% (valid), and effect on learning strategy achieved a percentage of 83% (valid). Thus, the achievement of the subject matter expert is 84% with a valid level.

Table 2. Validation Results by Subject Matter Experts

Assessment Indicators	Percentage (%)	Category
Material relevance	87	highly valid
Material presentation	85	highly valid
Independent practice and grammar	81	valid
Effect on learning strategy	83	valid

The pilot learning tool development was carried out with student participants in a real classroom during the implementation. After implementation through learning activities, an initial evaluation was conducted to provide feedback on the physics lessons on the universe and solar system, as well as Newton's law of gravity and Kepler's laws. Based on the analysis of the response questionnaire, the student response rate was 88%, placing them in the excellent category.

Table 3. Student Questionnaire Responses

Aspects	Number of Statements	Average (%)	Category
Media interface	6	89	very good
Feasibility of the content	8	87	very good
Usability	5	87	good
Usefulness and learning Motivation	5	88	very good
Total Overall	28	88	very good

The normality test results were obtained from the pre-test and post-test scores, with a significance value > 0.05 (pre-test 0.07 and post-test 0.05), so the Shapiro-Wilk P-value was normally distributed. After the normality test, the hypothesis test analysis was continued using the T-test. The hypothesis test results were < 0.001 , indicating a comparison between the pre-test and post-test results. The N-Gain score percentage was 56%, which is categorized as moderate. From these analysis results, it can be said that the use of ASTROLEARN learning media was quite effective in improving ethnoscience literacy and critical thinking. Furthermore, the evaluation stage was the final process of innovating astronomy-based educational media integrated with the Pranata Mangsa and augmented reality. This was conducted by revising after assessments, suggestions, and evaluation input from validators

DISCUSSION

The government continues to strive to make critical thinking, creativity, communication, and collaboration skills a requirement in 21st-century education. With this, it is possible to gradually implement changes to the 2013 curriculum using innovative learning models and methods (Kemdikbud, 2016). Education in the 21st century is not the same as education ten years ago. The main difference lies in student learning outcomes. The approach to education must be updated to meet the demands of 21st-century education because modern learning outcomes require students to have cognitive skills. In addition, the education level must be adjusted to teach students metacognitive skills, including critical thinking skills (Azrina et al., 2020). The results of data on Indonesian students' science literacy achievements in PISA 2018, which was participated in by 78 other countries, obtained an average score of 396, which is far below the PISA average score of 500 (OECD, 2019). This shows the importance of learning media during the learning process. Learning media is very important for the learning process. Thus, it can be used to attract students' interest in lessons and improve their understanding. However, the fact on the ground is that the use of learning media is still low, resulting in students experiencing learning difficulties.

Technology is one of the innovations in learning. Research shows that digital learning devices improve conceptual understanding. Digital learning can help teachers deliver material better to students and increase student motivation (Gjelaj et al., 2020). Augmented reality (AR) technology has the ability to connect digital data to the real world (Castañeda et al., 2018). Object recognition (images) will display information about the object in the form of 3D images and sounds that correspond to the characteristics of the image object. Applying AR to the learning process offers many advantages. In learning activities, AR can increase student attention and improve their satisfaction with the material they are learning (Santos et al., 2016). The ASTROLEARN learning application is one of the learning media based on Android applications and learning media kits. The ASTROLEARN learning media is a medium that integrates augmented reality (AR) technology that students can use to learn about abstract concepts and local Javanese culture, namely Pranata Mangsa. This learning media application can improve ethnoscience literacy and critical thinking.

The ASTROLEARN learning media itself went through several stages of ADDIE model development, consisting of analysis, design, development, implementation, and evaluation. The first stage involved analyzing misconceptions that students had about the universe and solar system, as well as Newton's law of gravity and Kepler's laws. Then, this stage also conducted an analysis to determine the needs of students in accordance with the applicable curriculum and to find out what kind of learning media could support student learning. In this activity, the researchers also conducted interviews with physics teachers to find out the problems with using media. Next, the design stage was carried out after the first stage. This design stage included several designs in the development of learning media. Then, the development stage was entered, which was divided into several more stages, including: (a) Creation of the ASTROLEARN application, (b) Development of augmented reality as a visualization of the concepts of the universe and solar system as well as Newton's law of gravity and Kepler's laws, and (c) Validation of the material, media, and design of the ASTROLEARN learning media. This resulted in product feasibility from media and material experts.

The results of the study were verified by testing the products by media and material experts. The results of product feasibility testing by media experts showed that 90% of the products were in the highly valid category. The results of product feasibility testing conducted by media experts, taking into account each assessment indicator, showed that the ease of use and navigation indicators achieved a percentage of 85% (highly valid), visual appearance reached a percentage of 100% (highly valid), media integration reached a percentage of 75% (valid), and media benefits reached a percentage of 100% (highly valid). Furthermore, media experts provided recommendations and comments about ASTROLEARN as a learning medium. Their suggestions included that (1) the application often freezes when in use, and (2) there are no mobile phone models or specifications that must be used, which hinders the use of augmented reality. Conversely, the product feasibility test by subject matter experts for each indicator produced the following percentages: material relevance reached 87% (highly valid), material presentation reached 85% (highly valid), independent practice and grammar reached 81% (valid), and effect on learning strategy reached 83% (valid). Thus, the achievement of the subject matter experts was 84% at a valid level. Then, suggestions and input were also obtained from the subject matter experts, namely that they were still a little or not confident enough to integrate questions related to Pranata Mangsa culture. The results of the product feasibility analysis by media and material experts, as well as the recommendations and input provided, indicate that ASTROLEARN is a learning medium that is feasible to be tested on students after revision. This is reinforced by research conducted (Nurmanto, 2020) on the use of AR in the Magic Book Profession Introduction

application for early childhood education. The results show that the developed media falls into the “Highly Feasible” category with a score of 91%. Based on research conducted by Wulandari (2020) on the development of Android-based physics learning media at State Senior High School 3 Ngabang, this was also reinforced. The results of the study showed that the percentage of media expert validation was 87% with excellent criteria, the percentage of material expert validation was 76% with excellent criteria, and the percentage of design expert validation was 80% with excellent criteria. Therefore, it can be concluded from the results of product validation and testing, as well as from previous research, that Android-based physics learning tools and augmented reality technology are the right choice for physics learning methods.

The next step was to move on to the implementation stage, during which trials were conducted with students. The results of the student response questionnaire analysis showed a response rate of 88%, placing it in the “very good” category. Then, tests were conducted before and after learning to determine whether the learning media could improve ethnoscience literacy and critical thinking skills. The purpose of this test was to determine whether these skills could be improved through learning media. After obtaining the pre-test and post-test results, normality tests, hypothesis tests using the t-test, and N-Gain tests were conducted to determine whether the learning media had successfully improved student learning outcomes. The normality test results from the pre-test and post-test showed a significance > 0.05 value of 0.07 for the pre-test and 0.05 for the post-test, so it can be concluded that the Shapiro-Wilk P-value was normally distributed. After the normality test was completed, the t-test was used to analyze the hypothesis. The hypothesis test result < 0.001 indicated that the pre-test and post-test results are significantly different.

The N-Gain score percentage was found to be 56%, which was in the moderate category. The analysis results showed that ethnoscience literacy and critical thinking skills can be improved well by using ASTROLEARN as a learning tool. Based on research conducted by Affandi et al., (2020), which looked at how e-learning can improve the achievement of grade-X physics students. The results showed an increase in student learning outcomes, with an average effectiveness score of 69% and a lowest score of 21%. This was reinforced by research by Atiaturrahman et al. (2022) on the role of the science, technology, engineering, arts, and mathematics (STEAM) model in improving critical thinking and science literacy in elementary school students. The results of the study showed that the role of STEAM improved students' ability to collaborate, communicate, think critically, and analyze data. The results of data analysis and previous studies showed that learning media can improve student learning outcomes. Next, the evaluation stage was the final stage of the Pranata Mangsa local wisdom-based astronomy education media innovation integrated with an augmented reality application. This kit was modified after receiving feedback from validators and students as users. Therefore, this product is considered to help realize “quality education” as defined in Permendikbud Ristek No.56/M/2022 and the Sustainable Development Goals, particularly the Pancasila student profile strengthening project.

CONCLUSION

The ASTROLEARN application as a learning medium in physics lessons was categorized as highly valid, with a percentage of 90% from media experts. Then, it was categorized as valid, with a percentage of 84% from subject matter experts. In addition, from the results of the questionnaire obtained from 32 students, a response percentage of 88% was obtained with a very good category. Therefore, both the pre-test and post-test showed normal results, with a significance value of above 0.05 (pre-test 0.07 and post-test 0.05), so that the Shapiro-Wilk P-value was normally distributed. After the normality test, the hypothesis test analysis was continued using the t-test.

The hypothesis test results were $< .001$, indicating that the pre-test and post-test results were significantly different. Then, an N-Gain score percentage of 56% was also obtained, which was categorized as moderate. Thus, the use of ASTROLEARN can be an effective solution in the learning process.

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