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Enhancing Student Cognition in Science Lessons Through Augmented Reality (AR) and Discovery Learning

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ABSTRACT

The rapid evolution of information technology has challenged educational institutions to adopt innovative pedagogies. Augmented Reality (AR), which enables interactive visualization through mobile devices, offers promising opportunities for science education. This study investigates the impact of AR integrated with the Discovery Learning model in improving junior high school students' cognitive understanding of solar system concepts. Utilizing a Research and Development (R&D) approach and the ADDIE model, AR-based learning media were developed and implemented with 30 Grade-7 students. The average pretest score increased on the posttest, yielding a good and moderate category. Student responses indicated strong engagement and satisfaction. The findings suggested that AR combined with discovery-based instruction significantly enhances conceptual understanding and motivation. This study contributes to advancing educational technology practices and supports Sustainable Development Goal 4 (Quality Education) by promoting interactive and inclusive science learning experiences.

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1. INTRODUCTION

In the 21st century, the development of science and technology has grown rapidly. These developments have a significant impact in various fields of life, one of which is in the field of education. The world of education plays an important role in the survival of a nation and state, because it is through education that can form quality human resources can be formed so that they can compete and compete globally (Paudel, 2021). Therefore, people expect higher education institutions (HEIs) to be responsive to their needs, provide various public and private benefits, and play an active role with various external stakeholders, because the quality of human resources in a country is determined by the quality of education (Jones *et al*., 2021). Therefore, improving the quality of education is crucial in creating a generation that is able to adapt quickly to technological and scientific developments in this modern era.

Science subjects in schools can provide benefits for students to study themselves and their surrounding environment. However, science learning is less desirable because students often feel that science learning is a difficult lesson to understand (Sahin & Yilmaz, 2019). Murphy (Murphy *et al*., 2021) also stated that low science learning outcomes can be caused by several factors, namely, the learning methods used by teachers are teacher-centered, and the position of students is only as listeners. Because teacher-centered learning methods are the least preferred learning methods (Murphy *et al*., 2021).

The basis of science learning is through experimentation or observation (i.e., discovery learning). Science education for students in primary or secondary school is important in developing creative problem-solving skills as well as helping to improve understanding of how the world and things work (Willemsen *et al*., 2024). Science education is divided into several topics, based on each scientific field. Including interesting but difficult topics in science, one of which is the topic of the solar system. The solar system is one of the topics that requires students to visualize in depth, so that students can better understand the objects around the solar system. However, it is often found that the technique of understanding science concepts that have been explained seems monotonous and less interesting (Sawu *et al*., 2023). Many junior high school students have difficulty in understanding certain physics concepts because the material is difficult to imagine and cannot be seen directly in everyday life, one of which is the solar system (Rahmatullah *et al*., 2023). This situation results in a lack of student interest in learning.

The use of learning media has an important role in science learning because it can provide direct experience to students, making it easier for students to understand a fact or information (Rahmatullah *et al*., 2023). Several learning technologies support Earth and solar system learning. According to the literature (Kohlhase *et al*., 2011), in his research, they used PlanetTXT, a text-based simulation tool for learning planetary systems. Users can write simple scripts to describe astronomical parameters. These scripts are then fed into a program that generates a 3D simulation of the planetary system, which can be viewed in the Unity 3D Editor in a virtual environment, then the results can improve students' understanding. In addition, previous research (Ming, 2023) used Scratch to help students understand the solar system. In this study, students created animations and simulations about planetary movements using Scratch. As a result, the use of Scratch not only helps students better understand the concept of the solar system, but also makes them more interested and motivated to learn, then augmented reality and virtual reality-based media (Holt, 2023; Eryatno *et al*., 2017) can also support the learning of the earth and solar system because it is more interactive and interesting so that it can increase students' interest in learning.

On the other hand, it is worth mentioning that among the technologies that have emerged in recent decades, Augmented Reality (AR) technology has taken center stage. AR technology

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allows users to visualize virtual information in real scenarios through technological devices that integrate the use of digital cameras. This technology is attractive in education because it supports visual and auditory learning styles, and is especially useful for topics where observation is a key element in the student learning process (Acosta *et al*., 2020). AR technology has been created in a number of scientific fields as an effort to streamline the learning process (Chang, 2019). AR is a technology that combines the real world with the virtual world in two-dimensional and three-dimensional forms that are applied in the real world simultaneously and accessed via an Android.

This research presents a new approach by integrating AR technology into the Discovery Learning model to improve students' understanding of the solar system concept. The use of AR enables a more immersive visualization of astronomical objects, providing an interactive learning experience that was previously difficult to achieve through conventional methods. This approach not only enhances cognitive understanding but also encourages student engagement in scientific exploration through virtual experiments that support direct observation. Thus, this research provides a more relevant and engaging learning solution, in line with the needs of the digital generation in the 21st century.

Based on the context of the problems described earlier, the authors tried to research the use of an AR learning media to help improve students' understanding of the science subject of solar system material in junior high school based on Discovery Learning.

(i) RQ 1: How is the effect of Augmented Reality based on Discovery Learning to improve student cognition in science lessons on solar system material?
(ii) RQ 2: How do students respond to the learning process assisted by Augmented Reality based on Discovery Learning to improve student cognition in science lessons on solar system material?

2. METHODS

This study employed a descriptive research design to examine the problems in grant disbursement and propose development guidelines for the subsidy disbursement system within the Faculty of Education. A survey approach was selected to collect both quantitative and qualitative data from individuals who had experience interacting with the finance and accounting department. The research aimed to understand user experiences, procedural issues, and improvement needs, particularly in the context of administrative services that support educational projects.

2.1. Participants

This study involved 30 students from grade 7 in one of the junior high schools in Bandung City, with a composition of 15 female and 15 male students. The participants were randomly selected from the classes that allowed for research at that time, based on the results of the initial observation before the study began. The school is located in a border environment between urban and regency areas, which influences students' learning difficulties. This environment is less conducive to learning due to limited access to educational facilities and technology, as well as distractions from the surrounding environment that often make it difficult for students to focus and quickly feel bored during learning.

2.2. Setting

This research was conducted in class VII of SMP Negeri 29 Bandung by utilizing a classroom specifically designed to support AR-based learning. The room is equipped with modern facilities, including AR software, interactive digital learning materials, and high-speed internet access

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connected to all devices. Students can use personal electronic devices such as smartphones, tablets, or laptops, as well as school computers available in the laboratory. Seating arrangements are arranged close together to facilitate collaboration, active discussion, and teamwork. This arrangement is intentionally designed so that students can exchange ideas, solve problems together, and deepen their understanding through social interaction. By combining AR technology and a collaborative learning environment, this research aims to improve students' 21st-century skills, including communication, creativity, and problem solving, while maximizing an immersive and engaging learning experience. The picture above is a documentation of the application of AR in the learning process in the classroom. We also showed students who are collaborating using smartphone and laptop devices to access AR-based learning media, while Figure 2 shows students who independently explore three-dimensional visual objects of the solar system through AR applications scanned from print media. These two images illustrate how AR technology can improve interactivity and concept understanding in learning.

2.3. Data Collection

Data collection was done by giving a pre-test and a post-test as the main instruments. The pre-test was conducted before learning began to measure students' initial understanding, while the post-test was conducted after learning to assess the improvement of students' understanding. Both tests consist of several categories. Each category aims to measure students' abilities in certain aspects related to the material taught. Each question in the pre-test and post-test has gone through the validation stage by expert lecturers and validity tests to ensure reliability and measurement accuracy. Validation and testing of questions were carried out to ensure that the questions were in accordance with the learning objectives and were able to measure students' cognitive abilities as a whole.

2.4. Procedure

This study was conducted to measure the effectiveness of AR-based learning media in improving students' understanding of science lessons. Seeing the effectiveness of learning with pretest and posttest tests. If the pretest and posttest results show a difference, where the posttest value is higher than the pretest value. This indicates an increase in student understanding after using AR-based learning media. The lower pretest value illustrates the initial difficulty of students in understanding the material, while the increase in the posttest shows that AR helps students understand the concepts in learning. In addition to measuring the results of student responses to augmented reality media, a questionnaire was given. The questionnaire has several categories that become aspects of its assessment. The results of each aspect are taken as the average value, so that conclusions are obtained based on certain categories. Some baseline research was conducted to get an initial picture of students' understanding before the learning intervention using augmented reality. At baseline-1, each student is given a pretest to measure their initial level of understanding of the material to be learned. This test includes a series of questions designed to evaluate students' cognitive abilities before any augmented reality-based learning intervention. The results of baseline-1 serve as initial reference data that will be compared with the results of the posttest to see the extent to which an increase in understanding occurs after the use of interactive learning media. However, before the pretest was given to students, researchers conveyed the objectives and prepared the participants. The researcher conveyed the learning objectives directly to the participants, and the participants listened to what the researcher said. After that, the researcher asked students triggering questions related to the material to be conveyed. The question was related to the Earth and the solar system, and the question was also randomly related to those around the environment.

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In baseline-2, after the pretest, students participated in learning activities using augmented reality media. At this stage, an AR-based learning intervention was conducted, where students were directly engaged with the subject matter presented through 3D visualization and AR interactive elements. The AR application allows students to see abstract concepts in a tangible form, integrated with the real world through their mobile devices, thus improving visual understanding. Students are given the freedom to interact with the material through the AR application, which not only displays related information but also allows manipulation of virtual objects, such as rotating, zooming, or observing details more closely. This AR intervention is designed to facilitate a deeper understanding of complex concepts through a more engaging visual approach. During the learning process, students are also given several quizzes to answer individually as part of the interactive material. The results of these quizzes will be discussed at the end of the lesson in a discussion session. In the discussion session, some students are asked to come forward to the front of the class to present their answers, which are then discussed with the teacher and other students. AR intervention at this stage provides a new dimension in learning, where direct interaction with virtual objects helps to clarify concepts and increase students' active participation.

In baseline-3, after the learning process is complete, students are given a posttest similar to the pretest to evaluate learning outcomes after using AR. In addition to being given a posttest, students are also given a questionnaire that contains statements regarding student satisfaction with the AR media used. The questionnaire was given directly to students, and then the results were analyzed to determine student perceptions related to aspects of ease of use, level of interactivity, and media contribution to material understanding. The data from this questionnaire is also an evaluation tool to find out which aspects need to be improved in the development of augmented reality-based learning media.

This study involved 30 students from grade 7 in one of the junior high schools in Bandung City, with a composition of 15 female and 15 male students. The participants were randomly selected from the classes that allowed for research at that time, based on the results of the initial observation before the study began. The school is located in a border environment between urban and regency areas, which influences students' learning difficulties. This environment is less conducive to learning due to limited access to educational facilities and technology, as well as distractions from the surrounding environment that often make it difficult for students to focus and quickly feel bored during learning.

Table 1 explains the steps in the Discovery Learning model, which includes five phases: Stimulation, Problem Statement, Data Collection, Verification, and Generalization. Each phase is explained through media activities or classroom activities, as well as the learning objectives to be achieved, such as arousing curiosity, developing analytical skills, verifying information, and integrating new knowledge. This table provides a systematic overview of how Discovery Learning is applied in learning the topic of the solar system.

Table 1. Table of discovery learning steps.

Discovery Learning phase	Media and classroom phase	Description
Stimulation	(i) Showing a video about planetary movement (ii) Question: "Why don't the planets collide as they orbit the Sun?"	Attracts students' attention and arouses curiosity.

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Table 1 (Continue). Table of discovery learning steps.

Discovery Learning phase	Media and classroom phase	Description
Problem Statement	Some questions: (i) "How does Earth have day and night?" (ii) "Why do the planets have different revolution times?"	Students are invited to formulate questions or problems based on the stimulus provided.
Data Collection	To answer these questions, students process the data obtained from the media provided. Then students can see the results in the form of the scores they get and the answers to these questions.	Develop the ability to analyze and synthesize information independently, as well as improve skills in individual presentation.
Verification	To find out the findings and student learning outcomes, it is necessary to prove it by discussion and discussion with the teacher. Discussions can be conducted in class with the teacher and other students.	Verify the accuracy of information and findings through joint discussions.
Generalization	After completing the learning process along with the pretest and posttest, students are given a questionnaire regarding student responses to the learning media that have been used during learning.	Help students integrate new knowledge into their broader understanding.

2.5. Data Analysis

This study applied various statistical analysis methods to evaluate the effectiveness of the lessons. Pretest and posttest data were analyzed using a normality test (Shapiro-Wilk) to test the distribution of data, followed by a t-test to identify significant differences between the results before and after the intervention. In addition, n-gain scores were calculated to measure the improvement in students' cognitive understanding, while questionnaire responses were analyzed descriptively to assess the level of learner satisfaction. Data processing was done with the help of Excel for basic calculations, while further statistical analysis was conducted using SPSS software. The pretest and posttest data that had been recapitulated in Excel were then analyzed using SPSS, where the Shapiro-Wilk normality test and paired sample t-test were run to ensure the validity of the results. The n-gain score was calculated manually using the formula (posttest-pretest)/(max score-pretest), providing a quantitative indicator of learning improvement. Meanwhile, questionnaire data were analyzed by calculating the percentage of each answer option, yielding a qualitative picture of students' responses to the developed learning. This combination of quantitative and descriptive approaches allows for a more thorough evaluation, both in terms of academic achievement and students' perceptions of the learning process.

3. RESULTS AND DISCUSSION

3.1. RQ 1: How is the effect of Augmented Reality based on Discovery Learning to improve Students' Cognitive Skills in Science Lessons on Solar System Material?

Based on the results of data analysis with descriptive statistics, it was found that the average cognitive level of students before the use of interactive multimedia (X-Pretest) was 40.68. After the use of interactive multimedia as learning materials, the average cognitive level of students increased to 65.48 (X-Posttest). The increase in learning outcomes was calculated using the gain score, which showed a value of 0.418 (X-Gain). Based on the gain category, this value falls into

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the “Moderate” category. The increase in learning outcomes is also supported by a significance value smaller than 0.05, which indicates a significant change in student learning outcomes after using interactive multimedia. Factors that can affect the improvement of learning outcomes include: 1) Some students have forgotten about the material tested, 2) The material tested previously focused more on practice than theory, 3) The material tested was not material mastered by some students, 4) Students' interest in earth and solar system material varied. With the help of interactive learning media, student learning outcomes showed a significant increase (See **Figure 1**).

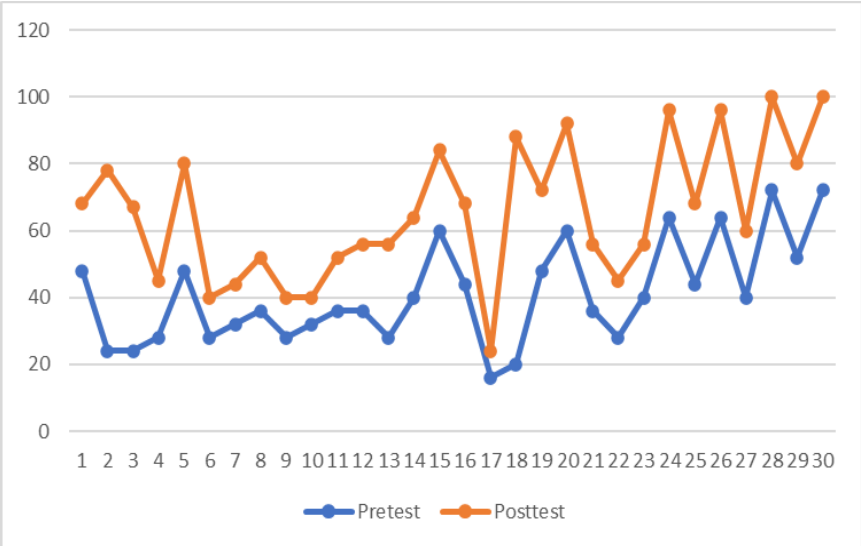

Figure 1. Comparison of pretest and posttest results.

This significant increase in learning outcomes shows that the use of Discovery Learning-based Augmented Reality can effectively help students understand the material taught, especially on the concept of the solar system. With this approach, students are more active in the learning process, conduct independent exploration, and engage in the discovery of new concepts, which overall has a positive impact on improving their cognitive abilities. In addition, the interactive visualization of AR is able to make abstract concepts easier to understand, so that students are able to connect new information with the knowledge they already have. These findings support the hypothesis that the integration of technology and innovative learning models, such as Discovery Learning, can significantly improve learning outcomes compared to traditional learning methods.

3.2. RQ 2: How do Students Respond to the Learning Process Assisted by Discovery Learning-based Augmented Reality to Improve Student Cognitive Science Lessons on Solar System Material?

Measured from the results of a questionnaire distributed to students after the learning process using Discovery Learning-based Augmented Reality media, the average response value is 84.95% in each aspect and class. This percentage falls into the “Very Good” category, indicating that students give a very positive response to the use of AR in learning. These results indicate that this learning media is not only interesting for students, but also effective in improving their cognitive abilities, especially in the material of the Earth and the solar system. Thus, the use of Augmented Reality in science learning is able to create an interactive learning experience and support better understanding of the concepts studied (See **Table 2**).

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Table 2. Student responses to media.

Assessment aspect	Item	Ideal score	Ideal Acquisition	Percentage
Mechanism	5	150	134	89.33%
Multimedia elements	2	60	48	80%
Information Structure	2	150	131	87.33%
Documentation	2	60	49	81.67 %
Content Quality	5	390	337	86.41 %

The findings robustly demonstrate that AR integrated with Discovery Learning substantially enhances students' comprehension of abstract astronomical concepts. The significant cognitive score improvement (40.68 to 65.48) with moderate N-Gain (0.418) not only confirms AR's pedagogical effectiveness but also extends previous findings (Zhang et al., 2024) through its specific application in astronomy education. Notably, the 84.95% student satisfaction rate echoes previous studies (Koparan *et al*., 2023) on mathematics research, suggesting AR's cross-disciplinary potential for boosting engagement. Three key factors contribute to this success: (i) AR's unparalleled ability to visualize complex celestial mechanics, overcoming traditional teaching limitations; (ii) the synergistic combination with Discovery Learning that promotes active concept exploration; and (iii) the exceptionally high media feasibility (96.65%), demonstrating that technological sophistication can coexist with educational rigor. This integration effectively addresses the dual challenge of teaching abstract concepts while maintaining learner motivation. These outcomes carry significant implications for STEM education reform. The study provides empirical evidence supporting systematic AR implementation, particularly when paired with inquiry-based pedagogies. Future research directions should investigate longitudinal knowledge retention and AR's scalability across diverse STEM domains. Most crucially, these findings underscore the urgent need for comprehensive teacher professional development programs to bridge the gap between emerging technologies and classroom practice. Finally, this adds new information regarding STEM, as reported elsewhere (Solihah *et al*., 2024; Rahmi *et al*., 2025; Fitrianti *et al*., 2024; Camilon *et al*., 2025).

4. CONCLUSION

This research shows that the integration of AR technology with the Discovery Learning model effectively improves students' cognitive abilities in science lessons, especially in understanding the solar system. The development of AR-based learning media obtained an average score of 96.65% (excellent category), which indicates high quality and feasible use in learning. The implementation of this media resulted in a significant increase in student understanding, as evidenced by an increase in the average score from 40.68 (pretest) to 65.48 (posttest), with an N-Gain value of 0.418 (medium category). In addition, students gave a very positive response to AR-based learning media, with an average satisfaction score of 84.95% (very good category). These findings suggest that AR-based learning media, when combined with the Discovery Learning approach, can overcome common challenges in science education, such as low student motivation and difficulty in visualizing abstract concepts. This study highlights the potential of AR technology to create a more interactive and engaging learning experience, which is crucial for promoting deeper understanding and critical thinking skills in students. For future applications, it is recommended that AR-based learning media be integrated into the science curriculum, especially for topics that require visualization, such as astronomy, biology, and physics. Further research can explore the long-term effects of AR on student learning outcomes and its applicability across different levels of education and subjects. In addition, collaboration between educators, researchers, and technology developers is essential to ensure continuous improvement and accessibility of AR-based learning tools.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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