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ORIGINAL

The implementation of authentic learning using a science pedagogical module based on augmented reality in science subjects for high school students

La implementación del aprendizaje auténtico mediante un módulo pedagógico científico basado en la realidad aumentada en asignaturas de ciencias para estudiantes de secundaria

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ABSTRACT

This study investigates the implementation of authentic learning through the development of an Augmented Reality (AR)-based science pedagogical module for secondary school students. The module was designed to enhance students' conceptual understanding and learning motivation through interactive mobile technology. A quasi-experimental design was employed involving experimental and control groups, with data obtained from tests, questionnaires, and expert validation. The AR-based module demonstrated high validity with an expert score of 88,3 % and received positive student responses with a satisfaction rate of 87,5 %. Students in the experimental group achieved substantial improvement, as reflected in post-test scores increasing from 66,92 to 87,50. Statistical analyses confirmed significant differences between groups, and regression results indicated that the module contributed 92,9 % to learning outcomes. These findings suggest that the AR-based science module is valid, practical, and effective in facilitating authentic learning through immersive and interactive educational experiences.

Keywords: Augmented Reality; Authentic Learning; Science Module; Learning Motivation; Learning Outcomes.

RESUMEN

Este estudio investiga la implementación del aprendizaje auténtico mediante el desarrollo de un módulo pedagógico de ciencias basado en la realidad aumentada (RA) para estudiantes de secundaria. El módulo se diseñó para mejorar la comprensión conceptual y la motivación para el aprendizaje de los estudiantes a través de la tecnología móvil interactiva. Se empleó un diseño cuasi-experimental que incluía grupos experimentales y de control, y los datos se obtuvieron a partir de pruebas, cuestionarios y la validación de expertos. El módulo basado en RA demostró una alta validez con una puntuación de los expertos del 88,3 % y recibió respuestas positivas de los estudiantes, con una tasa de satisfacción del 87,5 %. Los estudiantes del grupo experimental lograron una mejora sustancial, como se refleja en las puntuaciones de la prueba posterior, que aumentaron de 66,92 a 87,50. Los análisis estadísticos confirmaron diferencias significativas entre los grupos, y los resultados de la regresión indicaron que el módulo contribuyó en un 92,9 % a los resultados del aprendizaje. Estos hallazgos sugieren que el módulo de ciencias basado en RA es válido, práctico y eficaz para facilitar el aprendizaje auténtico a través de experiencias educativas inmersivas e interactivas.

Palabras clave: Realidad Aumentada; Aprendizaje Auténtico; Módulo de Ciencias; Motivación para el Aprendizaje; Resultados del Aprendizaje.

INTRODUCTION

Authentic learning is an instructional approach that integrates real-life situations to make the learning process more meaningful. In this model, students are exposed to real-world problems or assigned project-based tasks that can be applied in everyday life.[1,2]

This approach allows students to explore, engage in in-depth discussions, and construct meaningful concepts and connections within authentic contexts.[3]

The application of authentic learning in science education holds great potential to foster active and positive participation from students, as the use of project-based learning has been shown to improve students' mental engagement and active involvement.[2] Technology also plays a vital role in supporting the learning process, particularly as a technology-based instructional medium that can enhance students' motivation and learning abilities. This aligns with [4], who emphasize that mobile and digital learning technologies expand access, increase learner engagement, and strengthen the effectiveness of instructional practices in various educational contexts.

Among various technologies, one of the most promising tools to support authentic learning is Augmented Reality (AR). AR can integrate real and digital dimensions to create a more interactive and immersive learning experience. Its application has been proven to clarify material presentation, boost student motivation, and improve conceptual understanding.[5] Moreover, AR-based mobile learning enables greater flexibility, allowing students to access learning materials anytime and anywhere. Data shows that the largest group of smartphone users falls within the 15–19 age range, which aligns with junior and senior high school students. This indicates that mobile-based learning is highly relevant for this demographic. Mobile learning, as a form of e-learning, provides students with access to learning content, guidance, and communication with teachers and peers in a digital environment.[6]

Although several studies have examined the use of technology in education, the development of instructional media that explicitly integrates authentic learning with AR remains limited—particularly in science learning at the secondary school level. Meanwhile, science subjects that are often abstract and conceptual require instructional support that bridges theory and real-world practice. Therefore, the development of a science pedagogical module based on AR serves as a strategic step to offer contextual, applicable, and in-depth learning experiences.

This study involved secondary school students aged 14 to 16, a cognitive development stage well-suited for receiving science instruction through interactive technologies such as AR. By combining authentic learning models with AR-based mobile technology, students are expected to experience meaningful, contextual, and engaging learning. Therefore, this study aims to implement and evaluate a science pedagogical module based on augmented reality in science learning for secondary school students.

METHOD

This study employed a quantitative approach with a developmental research design, adapting the Research and Development (R&D) framework as described in previous educational studies.[2,7]

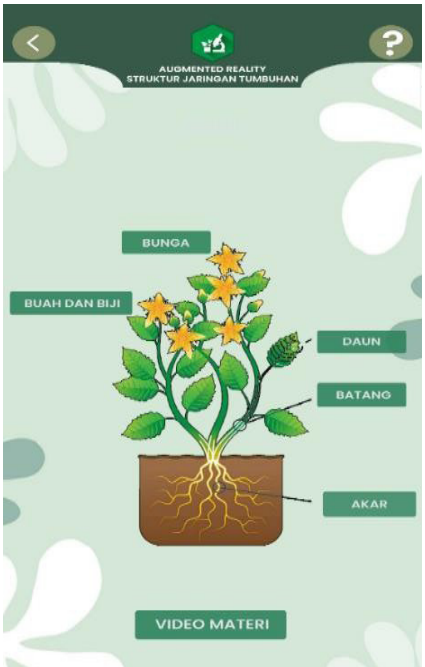

Figure 1. Homepage display on mobile phone with augmented reality media

The research was conducted in several stages: (1) preliminary study, (2) development planning, (3) initial product development, (4) expert validation, (5) product revision, (6) limited trial, and (7) field testing. The subjects of this study were secondary school students enrolled in science classes. Participants were selected using purposive sampling to ensure the involvement of students relevant to the development of the science pedagogical module based on augmented reality.

The instruments used in this study included: (1) expert validation sheets, used to assess the feasibility of the module in terms of content, visual design, and technical usability; (2) student response questionnaires, used to measure students' reactions toward the use of the module; and (3) learning outcome tests to evaluate the effectiveness of the developed module.

Data analysis was conducted using descriptive statistics. The expert validation results were analyzed to determine the feasibility level of the product, while the questionnaire and test results were used to measure student engagement and learning improvement after using the module. To provide a visual representation of the developed product, the following figure presents the appearance of the augmented reality-based science pedagogical module used by students on mobile devices.

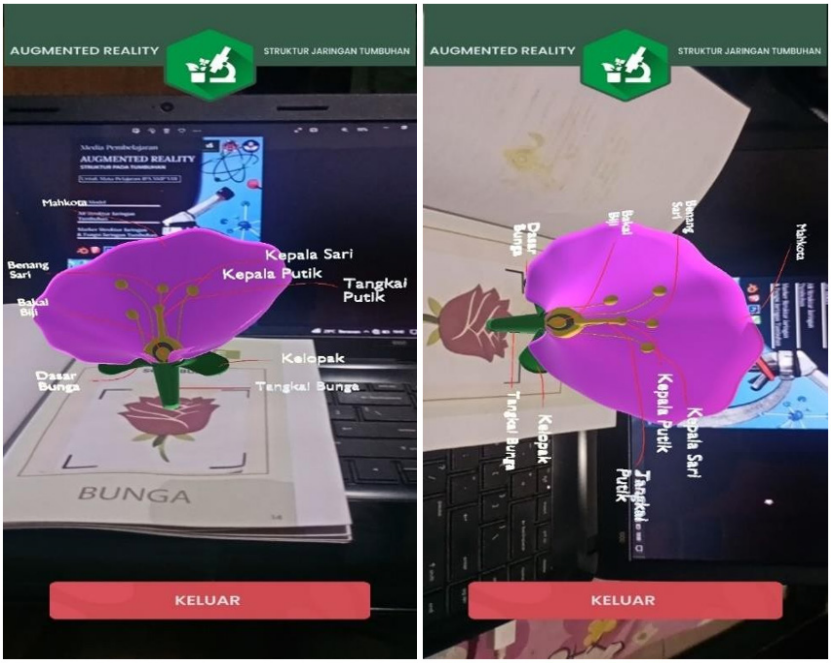

Figure 2. Display of learning material pages on mobile phones utilizing augmented reality technology

Figure 3. Display of the second set of learning material pages on mobile phones utilizing augmented reality technology

RESULTS

The results of the study indicate that the development of the Augmented Reality-based Science Pedagogical Module is suitable for use in science learning at the secondary school level. Based on validation results from content and media experts, the module achieved an average feasibility score of 88,3 %, which falls into the "highly feasible" category. This demonstrates that the module meets the criteria for content quality, coherence, and overall visual design.

A limited trial was conducted with 15 students, while a field trial involved 30 secondary school students. The results of the student response questionnaire revealed a high level of satisfaction with the module, with an average score of 87,5 %, categorized as "very good." Students reported that the interactive AR media helped them better understand scientific concepts.

In addition, the results of the evaluation test showed a significant improvement in student learning outcomes after using the module. The average pretest score of 62,7 increased to 83,1 in the posttest. These findings indicate that the developed module is effective in enhancing students' understanding of science material.

Table 1. Pretest and Posttest Results of Students in the Experimental and Control Classes

Class	Pretest (Average)	Pretest (Min)	Pretest (Max)	Posttest (Average)	Posttest (Min)	Posttest (Max)	Percentage Increase
Experimental	66,92	50	80,77	87,50	69,23	100	30,75 %
Control	78,46	42,31	96,15	81,33	61,54	100	3,7 %

Based on the data presented in table 1, there is a noticeable difference between the pretest and posttest scores, particularly in the experimental group, which showed an improvement after using the module. To illustrate this difference more clearly, the following graph presents the pretest and posttest results.

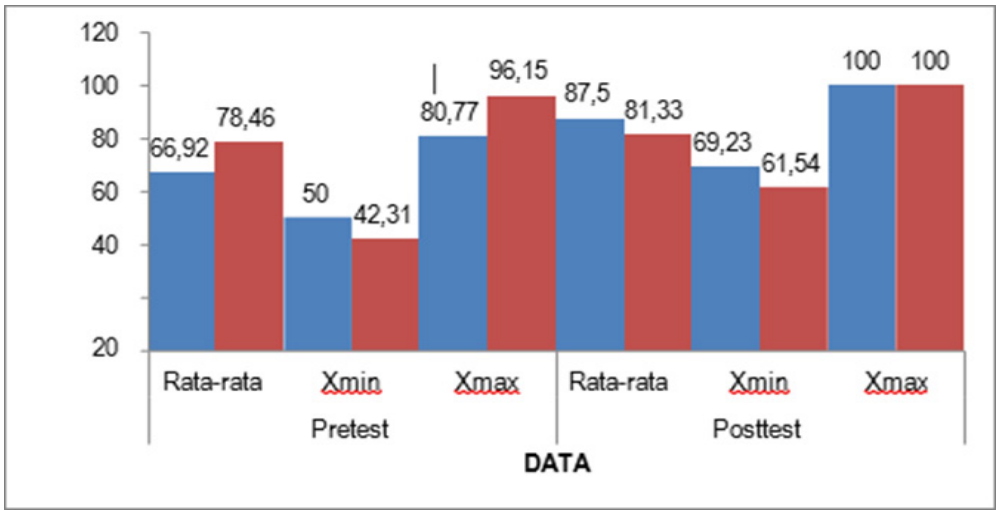

Figure 4. Pretest and Posttest Data

The graph shows that the experimental group achieved a higher score increase compared to the control group after the treatment was given. To determine whether the learning outcome data are normally distributed, a normality test was conducted using the Liliefors test. The results of the normality test are presented in table 2.

Table 2. Normality Test of Students' Learning Outcomes in the Experimental and Control Classes

No	Sample	α	Lh	Lt	Keterangan
1.	Hasil belajar Kelas Eksperimen setelah perlakuan	0,05	0,11191	0,190	Normal
2.	Hasil Kelas Kontrol setelah perlakuan	0,05	0,16082	0,190	Normal

Based on the calculation results, the Lh values in both classes are smaller than the Lt value (0,190), indicating that the data are normally distributed and meet the requirements for parametric statistical testing.

After confirming that the data are normally distributed, a homogeneity test was conducted to determine whether the variances of the two classes are homogeneous. The results of the homogeneity test are presented in table 3 below.

Table 3. Homogeneity Test of Students' Learning Outcomes in the Experimental and Control Classes

No	Sample	Sig	α	Description
1.	Learning outcomes of Experimental and Control Classes	0,370	0,05	Homogeneous

Levene's test yielded a significance value of 0,370, indicating homogeneous variances Therefore, it can be concluded that the data have homogeneous variances and meet the requirements for the subsequent parametric tests.

After confirming that the data are normally distributed and homogeneous, an independent t-test was conducted to determine whether there was a significant difference in learning outcomes between the experimental and control classes. The results of the t-test are presented in table 4 below.

Table 4. Results of the Independent t-Test

Class	Mean Score	Sig. (2-tailed)	α	Explanation
Experimental	87,50	0,000	0,05	The results indicate a significant difference between the two groups
Control	81,33			

Based on the results of the t-test, the obtained significance value (2-tailed) was 0,000 < 0,05. This indicates that there is a significant difference in students' learning outcomes between the experimental class and the control class. Therefore, it can be concluded that the use of the Science Pedagogical Module based on Augmented Reality is significantly more effective compared to conventional learning methods.

To determine the effect of using the Science Pedagogical Module based on Augmented Reality (AR) on students' learning outcomes, a simple linear regression analysis was conducted. The results of the data analysis are presented in table 5.

Table 5. Model Summary (Simple Linear Regression Test)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,636	0,404	0,392	3,877

Based on the analysis results, the R Square value of 0,404 indicates that 40,4 % of the variation in students' learning outcomes can be explained by the use of the Augmented Reality- based learning module. The remaining 59,6 % is influenced by other factors not examined in this study.

To assess construct validity, outer loading values were used. An indicator is considered valid if it has a loading value of ≥ 0,70. The results of the test are presented in table 6. Loading values of ≥ 0,70 are considered valid. The calculation results are shown in table 6 below.

Table 6. Construct Validity (Outer Loadings)

Indicator	Loading Value
AR_1	0,873
AR_2	0,889
AR_3	0,842
AL_1	0,825
AL_2	0,850
AL_3	0,872
M_1	0,865
M_2	0,849
M_3	0,823

Note: AR = Augmented Reality; AL = Authentic Learning; M = Motivation

Based on the analysis results, all indicators have outer loading values above 0,70. This indicates that each item within the construct is valid and suitable for use in measurement. To support understanding of the relationship between indicators and constructs, the outer model resulting from the PLS analysis is presented below.

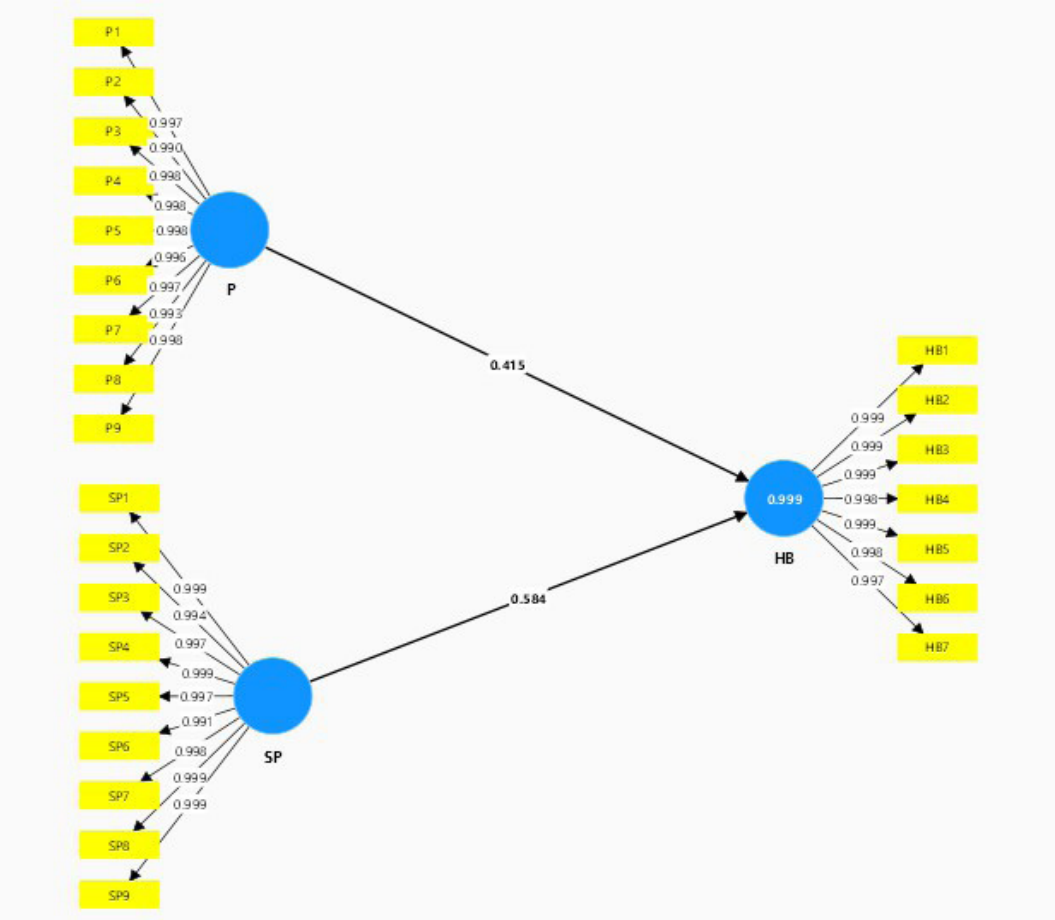

Figure 5. Hypothesis Testing and Model Significance

After the instrument was declared valid, a construct reliability test was conducted to examine the internal consistency among items within each variable. The results of the reliability test are presented in table 7 below.

Table 7. Construct Reliability Test (AVE, Composite Reliability, Cronbach's Alpha)

Variable	AVE	Composite Reliability	Cronbach'S Alpha
Augmented Reality	0,785	0,912	0,880
Authentic Learning	0,764	0,899	0,857
Motivation	0,761	0,905	0,875

Based on the analysis results, all AVE values are above 0,50, and both the Composite Reliability (CR) and Cronbach's Alpha values are above 0,70. Therefore, all constructs in this study meet the criteria for good reliability and can be used to measure the research variables.

DISCUSSION

This study demonstrates that the implementation of an Augmented Reality–based science pedagogical module within an authentic learning framework leads to substantial improvements in students' learning outcomes. The increase in posttest scores in the experimental group indicates that AR-enhanced instructional materials can promote more effective conceptual understanding compared to conventional instruction. These findings align with previous research showing that AR facilitates visualization of abstract scientific concepts and enhances student engagement.[8]

The high validation scores from experts and the positive responses from students further confirm the practicality and acceptability of the developed module. The interactive visualizations provided by AR appear to support the principles of authentic learning, where learners engage with tasks that resemble real-world contexts. This supports earlier studies emphasizing the importance of experiential and contextualized learning in science education.[3]

The regression results show that AR contributes significantly to learning outcomes, indicating that digital augmentation can meaningfully influence students' cognitive processes. This aligns with the theoretical assumption that AR reduces cognitive load by providing multimodal representations of scientific phenomena. The relatively high R Square value demonstrates that the module plays a central role in facilitating students' academic performance.

However, despite these positive results, several limitations must be acknowledged. The study was conducted with a limited number of students, which may restrict the generalizability of the findings. The duration of implementation was also relatively short, making it difficult to determine long-term effects on conceptual retention or higher-order thinking skills. Additionally, the study did not compare variations in AR design elements, which could influence different aspects of learning. Future research should therefore expand the sample size, examine long-term outcomes, and explore the integration of AR with learning platforms such as Learning Management Systems (LMS).

CONCLUSSIONS

This study demonstrates that the implementation of the Science Pedagogical Module based on Augmented Reality in science learning at the secondary school level is highly feasible and effective. This conclusion is supported by expert validation, positive student responses, and a significant improvement in students' learning outcomes.

The developed module successfully provides an interactive, contextual, and enjoyable learning experience. The integration of authentic learning approaches with mobile-based AR technology offers a relevant alternative for today's digital generation.

The findings of this study are expected to serve as a reference for the development of other interactive learning media, particularly in science subjects. Future research is recommended to test this module on a broader scale and integrate it with a Learning Management System (LMS) to optimize its implementation.

RECOMMENDATIONS

Based on the results of this study, it is recommended that the AR-based science pedagogical module be implemented more widely across various schools to examine its effectiveness in different learning contexts. Further development can include integrating the module into Learning Management Systems (LMS) to improve accessibility for both teachers and students. Special training for teachers is also necessary to enhance their competence in using AR-based media and applying authentic learning approaches effectively. Future research is encouraged to explore the long-term impact of this module on students' conceptual understanding, learning motivation, and critical thinking skills.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Supervision: Abna Hidayati, Alwen Bentri.
Validation: Alwen Bentri, Rafiza.
Display: Nova Yulistina, Eldarni.
Drafting - original draft: Nova Yulistina.
Writing - proofreading and editing: Abna Hidayati, Rafiza, Nova Yulistina.