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Impact of Augmented Reality-Based Interactive Worksheets on Student Achievement in Chemical Equilibrium

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ABSTRACT

Low student achievement in chemistry is often linked to difficulties in understanding abstract concepts, particularly when instructional media lack interactivity and variation. This study aims to investigate the effect of using augmented reality (AR)-based interactive student worksheets (LKPD) on students' learning outcomes in the topic of chemical equilibrium. The research employed a quasi-experimental design, specifically the nonequivalent control group design. The sample consisted of 72 students from class XI at a senior high school, divided into two groups: XI-F1 G (experimental group) and XI-F1 F (control group), each comprising 36 students. A multiple-choice test consisting of 20 items was used as the research instrument to measure students' learning outcomes. The data were analyzed using SPSS version 25, and the hypothesis was tested through an independent samples t-test at a significance level of 0.05. The results showed a Sig. (2-tailed) value of 0.001, which is less than $\alpha = 0.05$, indicating a statistically significant difference between the two groups. Based on these findings, it can be concluded that the use of interactive LKPD integrated with augmented reality media has a significant positive effect on students' learning outcomes in chemical equilibrium.

Keyword: Augmented Reality, Learning Outcomes, student worksheets.

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INTRODUCTION

The globalization era has brought fundamental changes to lifestyles, including in the field of education. One of the most prominent transformations is the rapid advancement of technology in the learning process. This development has become a major driver influencing communication, collaboration, learning processes, and teaching methods (Harahap & Nugroho, 2022). The advancement of information technology plays a crucial role in education and brings significant changes (Septarini & Kholiq, 2021).

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The current progress in Indonesian education demands improvements in the quality of science and technology mastery. One way to enhance learning outcomes is through continuous improvement of the teaching and learning process (Rumahorbo & Nurfajriani, 2022). Given the complexity of today's generation, the ability to adapt to technology is increasingly important. The integration of information technology in learning has become an effective method because it not only makes the learning material more engaging but also aligns with the characteristics of Generation Z, who are highly familiar with technology. This has become a major consideration in the selection of learning media. Rapid technological development allows for more engaging and efficient presentation of learning materials without losing the core content. One of the recent innovations in learning media is the application of Augmented Reality technology (Kartini et al., 2023).

Twenty-first-century education aims to prepare students to adapt to the dynamics of a society that is continuously evolving towards Society 5.0, where advanced technologies such as artificial intelligence integrate the physical and digital worlds. One form of technological application in education is mobile augmented reality-based learning media. In chemistry education, this technology facilitates students' understanding of abstract concepts by providing real visualizations of atoms, molecules, bonds, and molecular interactions, enabling them to interact with and observe molecular structures more concretely (Damanik et al., 2024).

Augmented Reality (AR) media allows students to interact directly with virtual objects in the real world. Students can manipulate molecular structures, observe animated reactions, conduct virtual experiments, and solve problems through interactive simulations. This approach enhances both engagement and effectiveness in learning, thereby improving students' understanding and academic performance. In the long run, the use of such technology contributes to the quality of education, especially aligning with Generation Z's preference for technology-based learning media over conventional methods (Sulistianingsih, 2022).

Chemistry teaching materials consist of content structured according to the curriculum to achieve learning objectives. Technology serves to make the learning process more efficient, interactive, and structured and can also be used as an evaluation tool. Regardless of the approach used, all learning materials aim to provide a solid understanding of concepts and their application in real-life contexts (Aldian & Wahyudiati, 2023). One type of teaching material is the Student Worksheet (LKPD), which provides structured learning guidance to help students develop the competencies required to achieve the learning goals (Winarti et al., 2024).

Interviews with chemistry teachers at MAN 2 Model Medan (State Islamic Senior High School 2 Model Medan) revealed that the school had implemented the Merdeka Curriculum in the 2024/2025 academic year and relied on printed textbooks from Erlangga as the main learning resource. However, the school has not yet provided LKPD as a learning medium, and the teaching model remains conventional, relying solely on PowerPoint and videos in teacher-centered instruction. As a result, student learning activity remains low due to monotonous and unengaging lessons.

The lack of interactive learning media, including LKPD, negatively affects student learning outcomes, where only 60% of students meet the Minimum Completeness Criteria (KKTP) of 83. One of the most difficult topics to grasp is chemical equilibrium, which requires both conceptual understanding and calculation skills. This difficulty leads to a lack of focus and challenges in solving problems. The absence of LKPD further hinders students from connecting chemistry concepts to problem-solving, thus reducing their learning activity and interest and leading to suboptimal learning outcomes. To achieve better

academic performance, it is essential to adopt engaging and interactive learning processes, one of which is implementing student-centered learning models (Nurfajriani & Samuel, 2021).

Teachers' ability to select and apply appropriate learning models plays a crucial role in improving students' conceptual understanding (Nurfajriani & Haloho, 2024). The use of media in learning can assist students in comprehending abstract material more easily (Noviyanti et al., 2023). Chemistry concepts are often perceived as complex due to the necessity of mastering foundational knowledge while simultaneously relating it to real-life situations, which presents a significant challenge in the learning process (Nurfajriani & Sari, 2024). Chemical equilibrium, a dynamic reaction, can be visualized through augmented reality, allowing students to observe color changes, particle movement, and chemical reactions in real-time. This technology offers an immersive learning experience by enabling realistic concept exploration and linking it to real-world phenomena. The use of augmented reality-based learning media in teaching chemical equilibrium proves to be an effective tool for enhancing students' comprehension. With its visual, interactive, and in-depth presentation, this technology facilitates better conceptual mastery and its application in various contexts.

To address these challenges, it is necessary to implement technology-based learning media that facilitate the learning process in the evolving Society 5.0 era. A study conducted by Bakri (2019) developed LKPD as a tool to enhance higher-order thinking skills (HOTS) in secondary education. The findings showed that LKPD equipped with videos through augmented reality effectively improved students' HOTS in Grade XII. However, the study had a limitation: the videos included did not feature animated stimuli.

METHODS

This research was conducted in January during the even semester of the 2024/2025 academic year at MAN 2 Model Medan, located at Jl. Williem Iskandar No. 7a, Bantan Timur, Medan Tembung District, Medan City. The study employed an experimental design, which falls under the category of quantitative research and is known for its effectiveness in accurately measuring cause-and-effect relationships (Arib et al., 2024). Specifically, the study used a quasi-experimental method with a Nonequivalent Control Group Design, involving both an experimental class and a control class. The research design is presented in Table 1.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental	T1	X1	T2
Control	T1	X2	T2

Description:

T1: Administration of pretest
T2: Administration of posttest
X1: Learning using interactive student worksheets (LKPD) based on augmented reality media
X2: Learning using standard school textbooks

The population in this study included all eleventh-grade students in the 2024/2025 academic year. The sample was selected using a purposive sampling technique, which involves the deliberate selection of subjects. Two classes were chosen: 36 students from class XI-F1 G served as the experimental group, and 36 students from class XI-F1 F served as the control group.

The research procedure began with school observation and preliminary interviews with the teacher to gather the necessary information. The preparation phase involved developing teaching

modules and preparing the research instruments. The implementation phase began with administering a pretest to both the experimental and control groups, followed by the learning process in both classes. The experimental class used interactive student worksheets (LKPD) based on augmented reality media, while the control class used standard chemistry textbooks. Both classes applied the same Discovery Learning model. In the final session, both groups were given a posttest. The last phase was data analysis and conclusion formulation.

The research instrument used was an objective test in the form of multiple-choice questions designed to measure students' learning achievement. A total of 35 questions were developed, covering the topic of chemical equilibrium, each with five answer choices (a, b, c, d, and e). Before being used in the study, the test instrument underwent a validation process to assess its quality based on validity, difficulty level, discrimination index, reliability, and distractor effectiveness.

The treatment instrument used in this study was an interactive LKPD based on augmented reality media focused on the topic of chemical equilibrium, developed by Dira Khairunisa from the Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan (Khairunisa et al., 2024).

RESULTS AND DISCUSSION

Instrument Analysis

The learning outcome test instrument on the topic of chemical equilibrium consisted of 35 multiple-choice questions. After being validated by subject matter experts, the test instrument was piloted with students of class XII-F1 D at MAN 2 Model Medan. The purpose of the pilot test was to assess validity, item difficulty, discrimination index, reliability, and distractor effectiveness.

Validity Test

The validity test aimed to determine the extent to which the instrument accurately measures the intended construct. Two types of validity were tested: content validity and empirical validity. Content validity was assessed by a chemistry lecturer from the Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan (FMIPA Unimed), while empirical validity was tested using data from students of class XII-F1 D. The number of respondents was 35 students, and with a significance level of $\alpha = 0.05$, the critical value (r_{table}) was 0.334. The results showed that out of 35 items, 25 met the validity criteria, while 10 items were deemed invalid. From the 25 valid items, 20 were selected based on item difficulty, discrimination index, and distractor quality.

Item Difficulty

The item difficulty analysis was conducted to assess the relative challenge posed by each question—whether the items were categorized as easy, moderate, or difficult. A good test includes a balanced mix of difficulty levels to ensure the test is neither too easy nor too difficult. Analysis results revealed that out of the 35 valid items, 3 items were classified as easy, 29 as moderate, and 3 as difficult.

Discrimination Index

The discrimination index analysis was conducted to determine how well an item could differentiate between high-performing and low-performing students. Based on the results, among the 35 items

tested, 7 were classified as good, 17 as fair, and 11 as poor in terms of discriminating power.

Reliability

The reliability test aimed to evaluate the consistency of the instrument—whether it yields stable results upon repeated application. Reliability was calculated using the Kuder-Richardson Formula 20 (KR-20) with the help of Microsoft Excel for Windows. The resulting reliability coefficient (r_{11}) was 0.8325. With a significance level of $\alpha = 0.05$ and a critical value of 0.334, it was found that $r_{calculated} > r_{table}$, indicating that the test instrument is reliable and has high consistency.

Distractor Effectiveness

A distractor is considered effective if it is selected by at least 5% of the test-takers. Based on the analysis of the 25 valid and reliable items, it was found that all items met the criteria for effective distractors, with each distractor being chosen by more than 5% of the participants. With all requirements fulfilled, the instrument was deemed suitable for data collection. A total of 20 questions were used in the final test: item numbers 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 15, 17, 18, 19, 21, 23, 24, 25, 26, 27, 29, 33, and 35.

Research Data Analysis

The research data were obtained from students' cognitive learning outcomes measured using the 20 multiple-choice items. Based on the posttest results from both the experimental and control groups, the average scores are presented in Table 2.

Table 2. Learning Outcomes Data

Class	Treatment	Pretest	Posttest
Experimental	LKPD Based on Augmented Reality	35	82.36
Control	Student Textbook	37.08	75.41

As shown in Table 2, the average pretest and posttest scores for the control group were 37.08 and 75.41, respectively, while those for the experimental group were 35.00 and 82.36. This indicates a notable difference between the two groups, suggesting that students taught using LKPD based on augmented reality achieved higher scores compared to those taught using conventional student textbooks.

Before hypothesis testing, the data were analyzed using assumption tests, namely the Shapiro-Wilk test for normality and the Levene's test for homogeneity. The final stage involved hypothesis testing to determine the significance of the treatment effects.

Normality Test

The normality test was conducted to determine whether the data obtained were normally distributed. The results of the normality test for both the experimental and control classes are presented in Table 3.

Table 3. Normality Test Results of Student Learning Outcomes

Group	Data Source	Shapiro-Wilk (Sig.)	Interpretation
Experimental	Pretest	0.068	Normally Distributed
	Posttest	0.203	Normally Distributed
Control	Pretest	0.104	Normally Distributed
	Posttest	0.103	Normally Distributed

Based on the results shown in Table 3, all significance values (Sig.) for both the experimental and control groups are greater than the significance level of 0.05. Therefore, it can be concluded that the data in both groups are normally distributed.

Homogeneity Test

The homogeneity test is conducted to determine whether the data have equal variance (homogeneous) or not. The results of this test are presented in Table 4.

Table 4. Homogeneity Test Results of Student Learning Outcomes

Levene Statistic	df1	df2	Sig.	Interpretation
2.586	1	70	0.112	Homogeneous

Based on Table 4, the obtained significance value is 0.112, which is greater than 0.05. Thus, it can be concluded that the student learning outcome data are homogeneous.

Hypothesis Testing

Hypothesis testing is used to verify the truth of the proposed hypothesis. In this study, hypothesis testing was conducted using a one-tailed Independent Sample t-Test in SPSS 25 for Windows, with the assumption that the data are normally distributed and homogeneous. The test criteria are as follows:

H_a: There is a significant effect of using interactive worksheets (LKPD) based on augmented reality media on students' learning outcomes in chemical equilibrium ($\mu > \mu_0$)

H_0: There is no significant effect of using interactive worksheets (LKPD) based on augmented reality media on students' learning outcomes in chemical equilibrium ($\mu \leq \mu_0$)

The data used in this hypothesis test were the posttest scores from the control and experimental groups, as the pretest scores between the two groups did not differ significantly. The analysis results are shown in Table 5.

Table 5. Hypothesis Test Results of Student Learning Outcomes

Variable	t	df	Sig. (2-tailed)	Mean Difference	Interpretation
Learning Scores	3.372	70	0.001	6.944	H_a Accepted

As shown in Table 5, the significance value (2-tailed) is 0.001. Based on the decision rule, if the significance value $\leq \alpha$ (0.05), then H_a is accepted and H_0 is rejected. Therefore, it can be concluded that H_a is accepted, meaning that there is a significant effect of using interactive LKPD based on augmented reality media on students' learning outcomes in the chemical equilibrium topic.

The results of the study indicate that students who were taught using augmented reality-based interactive LKPD achieved significantly higher learning outcomes compared to those who were taught using conventional school textbooks.

Discussion

A comparison of the average pretest and posttest scores between the experimental and control classes can be seen in **Figure 1**.

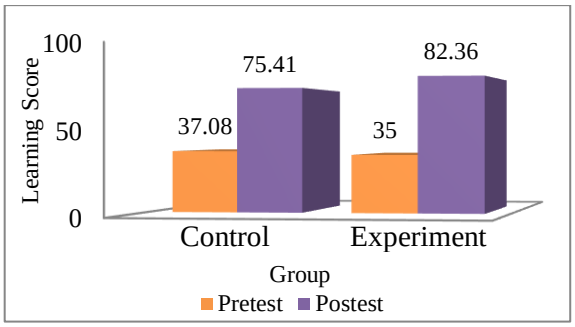

Figure 1. Diagram of Students' Average Learning Outcomes

Based on Figure 1, it can be seen that the average pretest score of the experimental class (XI-F1 G) was lower than that of the control class (XI-F1 F). However, the average posttest score of the experimental class, which used interactive worksheets (LKPD) based on augmented reality media, was higher than the control class, which used conventional printed student textbooks.

After confirming that the learning outcome data were normally distributed and homogeneous, a hypothesis test was conducted. In this study, the hypothesis testing was performed using an Independent Samples t-Test, which yielded a significance value (Sig. 2-tailed) of 0.001. Based on the decision rule, where Sig. ≤ α (0.05), the alternative hypothesis (H_a) is accepted and the null hypothesis (H_0) is rejected. Therefore, it can be concluded that there is a significant effect of using interactive LKPD based on augmented reality on the learning outcomes of students in class XI-F1 G at MAN 2 Model Medan on the topic of chemical equilibrium.

Based on the findings, the use of interactive LKPD based on augmented reality media on the topic of chemical equilibrium can significantly improve students' learning outcomes. This is because the LKPD enhances interactivity during learning and helps students understand abstract concepts more easily. The presence of 3D features within the LKPD provides realistic visualizations of chemical reactions, making abstract content more tangible. This was evidenced by the higher learning outcomes of students taught using the augmented reality-based LKPD compared to those taught using conventional textbooks.

These results are consistent with the study conducted by Santika & Guspatni (2024), which found that learning using augmented reality-integrated learning media improved students' learning outcomes on the topic of periodic properties of elements. The study reported a significance value (Sig. 1-tailed) of 0.000 < 0.05, indicating that augmented reality-integrated media effectively enhanced students' understanding of the material.

A similar study by Damayanti & Guspatni (2024) also confirmed the effectiveness of augmented reality-integrated learning media in improving learning outcomes on the topic of electrolysis cells. The study showed a significance value of 0.000 (Sig. 1-tailed < 0.05), which demonstrates that the use of such media significantly improved student achievement in understanding electrolysis concepts.

CONCLUSION

Based on the research data and discussion, it can be concluded that there is a significant effect of using interactive worksheets (LKPD) based on augmented reality media on students' learning outcomes in the topic of chemical equilibrium, with a significance value of 0.001 ≤ 0.05.

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