Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Effect of Using Integrated Markerless Augmented Reality Learning Media on Buffer Solution Material to Improve Students Learning Outcomes

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Received: July 16, 2025. Accepted: August 10, 2025. Published: September 3, 2025

Abstract: Integrated learning media markerless augmented reality can overcome the problems faced by some students in understanding the material of buffer solutions and become a learning media that displays the three levels of chemical representation in full. The purpose of this study is to determine whether there is an effect of the use of integrated learning media markerless augmented reality on the material of buffer solutions on the learning outcomes of phase F students of SMA/MA. The research design used is a Nonequivalent Control Group Design. This study was conducted at SMA N 2 Padang in the 2024/2025 academic year. The sampling technique used in this study is a purposive sampling technique. Data for this study were collected through test techniques. The data analysis techniques used are the Normality test, the Homogeneity test, and the hypothesis test. The results of the t-test analysis (Independent Sample t-Test) with the final data obtained are the value t_{value} (2.2407) > t_{table} (2.0017) at a real level of $\alpha = 0.05$. It can be concluded that H_0 is rejected and H_1 is accepted. Thus, the use of integrated markerless augmented reality learning media on buffer solution material has a significant effect on the learning outcomes of class XI students at SMA N 2 Padang.

Keywords: Augmented Reality; Learning Outcomes; Buffer Solution; Chemical Representation.

Introduction

Chemistry is the study of the composition, properties, and changes of matter [1]. Many concepts in chemistry are abstract and difficult to grasp, especially for students who cannot directly observe the processes [2]. One topic considered complex is buffer solutions. Buffer solutions are a type of chemical material that has many abstract and complex concepts [3]. This topic is quite difficult and requires a good understanding, so students often experience misconceptions. As they require a deep understanding of the concepts of pH, types of buffers, and their applications in everyday life [4]. This difficulty is exacerbated by students' lack of mastery of prerequisite materials such as chemical equilibrium, ionization, and acid-base theory. Buffer solutions are a complex chemistry concept because they involve several prerequisite concepts, such as chemical equilibrium, ionization, and acid-base theory. Their research showed that students' inability to grasp these prerequisite concepts directly hinders the development of their understanding of buffer solutions, particularly in determining pH and understanding the mechanism of buffer action. In fact, less than 30% of 12th-grade students were able to answer questions related to chemical equilibrium, which is the main basis of buffer systems [5].

Most chemistry instruction in schools still emphasizes macroscopic and symbolic representations, while neglecting the submicroscopic level, which is crucial for understanding particle processes [6]. This means that students are better able to solve calculation problems (symbolic level) without understanding the concepts involved (submicroscopic level). As a result, students have difficulty imagining the processes or structures of substances undergoing reactions [7]. Furthermore, the media used, such as printed textbooks, student worksheets, modules, and PowerPoint presentations, do not fully help students visualize abstract concepts [8].

Interactive multimedia is a necessary solution to overcome the difficulties experienced by some students in understanding abstract concepts on the topic of buffer solutions by applying multiple representations in chemistry learning [9]. Multiple levels of representation, including macroscopic, submicroscopic, and symbolic, are very important in chemistry learning [10]. Interactive multimedia can facilitate and help students in understanding buffer solution material, especially at the submicroscopic level [11]. The presentation of Chemistry material in interactive multimedia is based on Johnstone's opinion [12] stating that the macroscopic aspect of the developed interactive multimedia is presented in the form of videos. The submicroscopic aspect is presented in the form of chemical reaction simulations, and the symbolic aspect is presented in the form of pH calculation formulas and reaction equations.

A questionnaire conducted at SMA Negeri 2 Padang revealed that 38% of students found the material on buffer solutions difficult to understand, 72% stated that many of the concepts were confusing, and 56% felt the learning media used were not motivating enough. This can be seen from the statements of teachers who use printed textbooks, student worksheets, printed modules, and PowerPoint

How to Cite:
N. Khairunnisa, N. Yuhelman, and G. Guspatni, "Effect of Using Integrated Markerless Augmented Reality Learning Media on Buffer Solution Material to Improve Students Learning Outcomes", *J. Pijar.MIPA*, vol. 20, no. 6, pp. 998–1003, Sep. 2025.
https://doi.org/10.29303/jpm.v20i6.9701

(PPT) in the learning process. Some students stated that the learning media used by teachers were not able to help them visualize existing concepts. On the other hand, the results of a teacher questionnaire completed by chemistry teachers at SMA Negeri 2 Padang indicated that they did not incorporate this multi-representation level into their teaching, particularly submicroscopic ones.

Learning motivation plays a crucial role in encouraging students to actively participate, develop interests, and improve learning outcomes [13]. This finding aligns with [14]findings that students with strong learning motivation will more easily understand chemistry concepts. Using interactive learning media can increase learning motivation and influence learning outcomes [15]. One interactive media that can be applied in learning is integrated Augmented Reality learning media [16].

One effective technology is Augmented Reality (AR), which displays 2D/3D object visualizations in real time and can improve learning effectiveness [17]. AR makes students more active, motivated, and able to understand concepts independently. In fact, 90.4% of students feel AR makes learning more interesting and enjoyable [18]. AR-integrated learning media in learning can support the smoothness and effectiveness of the learning process [17]. The use of AR in learning increases student engagement by presenting interactive elements that encourage more active participation [18]. In addition, AR is also effective as a learning medium because of its attractive appearance, which helps understanding concepts, and increases learning motivation [19].

Various AR-integrated learning media in chemistry have been developed, including AR-integrated learning media for buffer solutions developed by Abshari & Guspatni that are valid and practical [20]. However, their impact on learning outcomes is not yet known. Given these conditions and the fact that all eleventh-grade students at SMA Negeri 2 Padang own smartphones, AR media is highly feasible to implement. Therefore, this study was conducted to investigate the effect of integrated markerless AR learning media on student learning outcomes in the buffer solution topic.

Research Methods

This research was conducted at SMA Negeri 2 Padang on 11th-grade Phase F students in the even semester of the 2024/2025 academic year. The research method used was a quasi-experimental method with a posttest-only control Group Design. The form of the research design is presented as follows:

Table 1. Posttest-Only Control Group Design.

Group	Treatment	Post-test
Experimental Class	X	O_1
Control Class	-	O_2

(Source [21])

Explanation:
O_1: Final test of experimental class
O_2 : Final test of control class
X: Providing treatment to the experimental class (use of integrated Augmented Reality learning media for Buffer Solution material)

The research population was all 11th-grade Phase F students of SMA Negeri 2 Padang in the 2024/2025 academic year. The sampling technique used was purposive sampling. The purposive sampling technique is a technique for determining samples with certain considerations [21], so that class XI Chemistry 6 was obtained as an experimental class, which received treatment in the form of learning using integrated Augmented Reality (AR) learning media without markers, and class XI Chemistry 7 as a control class, which received treatment in the form of conventional learning using PPT media and printed books.

Student learning outcome data or posttest was obtained through an essay test consisting of 8 questions and has been validated using the Rasch model [22]. The data collection process in this study used a posttest after the lesson or material delivery was completed to determine the students' abilities after learning. A written essay assessment consisting of 8 questions was used as the testing instrument in this study. Furthermore, the data was analyzed using the normality test (Liliefors), homogeneity test (Fisher), and hypothesis testing using the t-test.

The Normality of Data Test

A normality test is performed to determine whether data is normally distributed. This test can be performed using the Liliefors test [23]. It begins with determining the significance level, which is at a significance level of 5% (0.05), with the following hypotheses:

H0: The sample comes from a normally distributed population

H1: The sample does not come from a normally distributed population.

$$Z = \frac{X - \bar{X}}{S} \quad [23]$$

The Homogeneity of Data Test

After the normality test and the data obtained are not normally distributed, the next step is to conduct a homogeneity test. The homogeneity test is conducted to determine whether the variance is homogeneous or not. The homogeneity test can be performed using Fisher's exact test [23].

$$F = \frac{S1^2}{S2^2} \quad [23]$$

The Hypothesis Test

The test for the similarity of two averages can be conducted by considering the normality and homogeneity of the post-test score data. The data obtained in both classes were normally distributed and had homogeneous variance, so the t-test or Independent Sample Test was used.

$$t_{value} = \frac{M_1 - M_2}{\sqrt{\frac{SS_1}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad [23]$$

Results and Discussion

Based on research conducted on 11th-grade students at SMAN 2 Padang in the even semester of the 2024/2025 academic year, the aim was to determine the effect of using integrated learning media, including a markerless augmented reality (AR) approach to buffer solutions, on the learning outcomes of 11th-grade students at SMAN 2 Padang. Learning outcomes were assessed using a post-test consisting of eight essay questions.

The experimental and control classes were treated identically in terms of teaching materials, resource books, time allocation, and teaching methods. Different treatments were applied during the learning process: the experimental class used integrated learning media, using markerless augmented reality, while the control class used conventional learning. The treatment provided to the experimental class during the learning process is expected to increase student motivation in participating in chemistry lessons in class. Thus, with this implementation, students are more motivated to actively participate in the learning process and improve their learning outcomes.

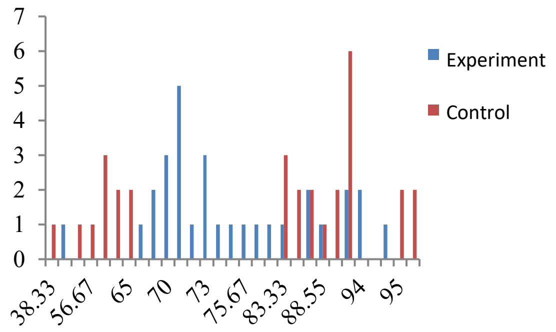

Figure 1. Data distribution

Based on Figure 1, the results of the assessment of student learning activities, data in the experimental class by implementing learning using integrated learning media marketless augmented reality on the material of buffer solutions, the lowest value is 38.33 for 1 student, and the highest value is 100 for 2 students. While in the control class without using integrated learning media, markless augmented reality on the material of buffer solutions, the lowest value is 40 for 1 student, and the highest value is 94.67 for 1 student. Meanwhile, the results of the normality test, homogeneity of data on the value of student learning activities can be seen in Table 1, and the results of the hypothesis test can be seen in Table 2.

Table 2. Results of the Normality and Homogeneity Test of Student Learning Activity Value Data

Normality			
Class	L_0	L_t	Test decision
Experiment	0.1595	0.161	Normal
Control	0.1590	0.161	Normal
Homogeneity			
Class	F_{count}	F_{table}	Test decision
Experiment	1.1857	1.8608	
Control			Homogeneous

From Table 1, the normality test shows that the L_0 value for each sample class is smaller than its Lt value. This indicates that both sample classes are normally distributed. The hypothesis test found that the calculated F-value was 1.1857, while the critical F-value (one-tailed) at a significance level of α = 0.05 with df = 29 was 1.8608. The significance value (P-value) was 0.2786. Using the following decision-making criteria:

- If $F_{count} < F_{table}$ or P > 0.05, then H₀ is accepted (data is homogeneous).
- If $F_{count} < F_{table}$ or P < 0.05, then H₀ is rejected (data is not homogeneous).

The test results show that the calculated F_{count} 1.1857 < F table = 1.8608 and P = 0.2786 > 0.05. Thus, H_0 is accepted, meaning the data from both groups have homogeneous variance.

Table 3. Results of Hypothesis Testing of Student Learning Activity Value Data

Hypothesis			
Class	t_{count}	t_{tabel}	Test decision
Experiment			
Control	2.2407	2.0017	H_0 rejected

Based on Table 2, hypothesis testing using a one-tailed t-test at a significance level of α = 0.05 yielded t_{count} = 2.2406 > t_{table} = 2.0017 and p = 0.0296 < 0.05. Therefore, it can be concluded that H_0 is rejected and H_1 is accepted. This means there is a significant difference between the posttest results of the experimental and control classes. This difference can also be seen from the average final test scores for the experimental class, which were 79.39 and for the control class, which were 76.40. From the average final test scores between the two sample classes, it can be seen that the final test score for the experimental class was higher than that for the control class. The average final test scores for the two sample classes showed a significant difference, indicating the influence of the different treatments in the two sample classes on student learning outcomes.

This is suspected because Augmented Reality technology has great potential in the world of education, as it is able to display attractive visuals in three-dimensional form and appear realistic. Learning that utilizes visual media such as AR can increase student attention and strengthen their memory of the material being studied. This is in line, which found that the use of interactive visual-based learning media can influence student learning outcomes because visual media offers an engaging presentation, facilitating student understanding [24]. Appropriate use of a variety of interactive learning media can influence student interest, motivation, and ultimately, learning outcomes.

In learning using integrated markerless AR learning media, students are more independent because they can explore the buffer solution material directly through their respective smartphones. Using AR learning media can increase students' learning independence, with a significant influence of AR [25]. This is seen when students begin to explore 3D models of substance particles in buffer solutions, such as weak acids and their conjugate bases, through augmented reality visualizations displayed on their devices. 3D visualizations help them understand the reaction of adding strong acids or bases, as well as the buffer mechanism in maintaining pH. This media also facilitates understanding of concepts at the submicroscopic level and encourages active interaction between students and teachers.

Learning in the control class uses PowerPoint (PPT) and books as the main learning resources. These media are unable to directly visualize the concept of buffer solutions, especially at the submicroscopic level. As a result, students in the control class appear less enthusiastic about participating in learning. The lack of interactivity and visualization makes students quickly feel bored, less actively involved, and have difficulty understanding abstract concepts, thus impacting low learning interest and also affecting their learning outcomes. Although the PPT contains videos that display submicroscopic visuals, it cannot fully visualize the concept directly compared to AR learning media. Learning with conventional media is less flexible, and one-way learning can be overcome with interesting, interactive and effective AR media[26].

The Markerless Augmented Reality learning media is valid and practical, complemented by interactive questions, images, animations, and videos [20]. The following augmented reality application displays are shown in Figures 2, 3, 4, and 5.

Figure 2. Initial application display

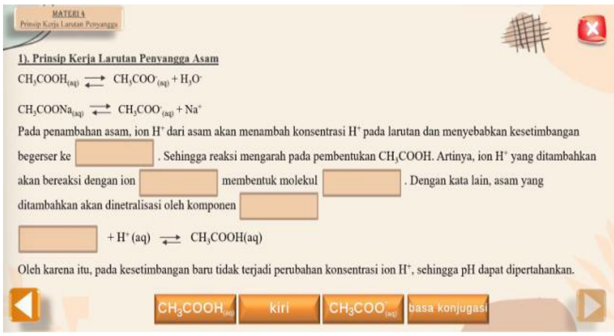

Figure 3. Questions in the application

Figure 4. Learning videos on the application

Figure 5. AR view on the app

This interactive learning media can facilitate students' discovery and understanding of concepts more effectively. This is because augmented reality-based media acts as a link between abstract concepts and concrete understanding, making learning materials easier to grasp. Furthermore, this media is able to fully display three levels of representation in chemistry: macroscopic, submicroscopic, and symbolic. Learning involving various representations provides students with the opportunity to construct and independently discover material concepts, such as buffer solutions, through learning activities that enable them to create various forms of representation, ultimately improving their understanding and learning outcomes [27].

Furthermore, Augmented Reality-based learning media tends to be preferred by students, as seen from the students in the experimental class who were given this treatment, who were more enthusiastic and interested in learning because it was newly implemented and new to the students. Students like new things with things they don't know yet, providing a different and more interesting learning experience, so they become more active in exploring the material. By using integrated learning media, marketless AR on the material of buffer solutions can make it easier for students to see objects directly that are difficult to see. AR media is a medium that can be used anywhere and anytime without using too much storage. In addition, AR has a positive influence and increases student creativity towards the development of learning outcomes and is able to make students behave scientifically [28].

Conclusion

Based on the results of research and analysis of research data that have been discussed in Chapter IV, it is concluded that the use of the integrated learning media, Markeless Augmented Reality material buffer solution, has an effect on student learning outcomes. Student learning outcomes using the use of integrated learning media, Markeless Augmented Reality material buffer solution, are significantly higher than without using integrated learning media, Markeless Augmented Reality material buffer solution, class XI SMA N 2 Padang.

Author's Contribution

Nadila Khairunnisa: Compiling research design, data analysis, and completion of scientific article writing. Nofri Yuhelman and Guspatni: Providing constructive suggestions for the perfection of the writing.

Acknowledgements
Throughout this research, I would like to express my deepest gratitude to my beloved family for their unwavering support, love, and encouragement. I would also like to express my gratitude to my supervisors for their invaluable guidance, knowledge, and inspiration. I would also like to express my gratitude to my colleagues in the Chemistry Education Study Program, who have been a constant source of inspiration and motivation.

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