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MAGIC BOOM CHEMICAL: A TRACKING MARKER-BASED APPROACH IN DEVELOPING CHEMICAL MOLECULE TEXTBOOK

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ABSTRACT
In Traditional teaching methods for chemical molecules, which rely on textbooks and physical modeling tools, face challenges in providing an engaging and comprehensive learning experience. This study introduces "Magic Boom Chemical," an augmented reality (AR)-based educational tool utilizing marker tracking to display three-dimensional molecular structures. A quasi-experimental method was employed, involving two groups of high school students: an experimental group using the AR application and a control group using conventional teaching methods. Pre-tests and post-tests were conducted to assess the effectiveness of the tool. Results indicated a significant improvement in students' understanding and engagement when using the AR-based media, with the experimental group achieving higher average post-test scores. The study concludes that integrating AR into educational materials can enhance learning outcomes and increase students' motivation. These findings highlight the potential of AR technology as an innovative solution for improving science education and suggest further research to refine and expand its applications.
Keywords: *Augmented Reality, Based Tracking Marker, High School, Molecular*

1. Introduction

A chemical molecule is a basic chemical unit consisting of chemically bonded atoms (Zhang et al., 2022). These molecules have distinct architectures and characteristics that may be comprehended by means of several study techniques and technologies (Barbhuiya & Das, 2023). The teaching of chemical molecules is vital, yet traditional methods often fail to provide an engaging and comprehensive experience (Clark, 2023). While current tools, such as textbooks and basic modeling equipment, offer foundational knowledge, they are insufficient to meet the needs of modern, interactive education (Clark, 2023; Watts & Rodriguez, 2023; Zhao, 2023). This study aims to address this gap by leveraging Augmented Reality (AR) technology to enhance the visualization and understanding of chemical structures.

Nowadays, the tool utilized for chemical molecule subjects is merely a board and a textbook, with its inside and rear concealed (Reyes & Villanueva, 2024). Typically, the instructor utilizes modeling tools to depict the shape of molecules. Still, learners must also comprehensively see that molecule. However, it is not feasible for each learner to have all these modeling tools with several different types of molecules. The storage space for modeling equipment, as well as the modeling tools, needs to be provided for the classroom, yet it may represent a barrier (Mammino, 2024; Gillem et al, 2021).

The limitations of traditional tools lie not only in their physical requirements, such as storage and cost, but also in their inability to fully engage students or adapt to individual learning styles. This highlights a critical gap in current educational approaches and underscores the urgency of integrating innovative technologies, such as AR, to provide interactive and accessible learning solutions (Qorbani et al, 2024; Familoni, & Onyebuchi, 2024; Creed et al, 2024).

Therefore, the use of learning media becomes progressively diverse and interactive to address the requirement of information and technology advances, particularly in the field of education. One of the widely used technologies is Augmented Reality (AR) technology (Taghian et al., 2023 Cevikbas et al, 2023; Vuță, 2020; Maulana et al, 2024). Augmented reality (AR) refers to a live view of a real-world environment whose elements are augmented by computer-generated content, such as sound or graphics. This technology allows users to interact with virtual objects that are superimposed on real-world environments, creating a multisensorial experience that can be static, dynamic, or autonomous and is not necessarily under the control of the user (Nijholt, 2023; Satria & Barus, 2022; Qiu, 2023).

Educational theories, such as constructivism and experiential learning, provide a foundation for understanding the potential of AR to improve learning outcomes. Constructivism emphasizes active learning through interaction and engagement, while experiential learning highlights the importance of hands-on experiences. AR integrates both principles by offering students the ability to interact with and manipulate three-dimensional representations of complex concepts like chemical molecules. There are two methods of using tracking methods based in Augmented reality, they are marker tracking based (Liu & Tanaka, 2021; Lestari et al, 2023; Porsch & Lehmann, 2023) and marker-less tracking based (Koumpouros, 2024; Hung et al., 2022; Cao et al., 2019; Pierdicca et al., 2022). The marker tracking needs black and white images with a thick dark border contrasting the light-white background. Thus, marker tracking suits the printed media. It represents the material in using three dimensions on the printed media, furthermore, it engages the learners to drag the marker across the page. In contrast, the marker-less tracking functions by detecting surroundings without limitation of form or structure.

This study explicitly aims to develop and test a marker-based AR textbook called "Magic Boom Chemical" for high school students. The objective is to improve students' understanding of chemical molecules by providing an interactive, three-dimensional learning experience that bridges the gap between theoretical knowledge and practical visualization.

Studies related to augmented reality have been conducted for several purposes, including advertisement (Hasan et al., 2020; Islam, 2020; Yussof et al., 2023), educational opportunities industry (Cibilić et al., 2021; Cranmer et al., 2020; Jiman & Kulal, 2023; Ozdemir, 2021; Fearn & Hook, 2023; Fitrianingsih et al., 2023; Lai & Cheong, 2022; Videnovik et al., 2020). In terms of educational opportunities, Augmented reality facilitates and engages educators and learners in learning activities. This study benefits educational technological innovation by utilizing augmented reality. By applying augmented reality, the researcher displays an interactive three dimensions shape on the textbook.

This study will integrate a marker tracking-based approach on chemical molecules intended for high school. It's identified as "Magic Boom Chemical". The marker-based tracking approach works well in educational materials. It is appropriate to implement especially in primary school textbooks, with the characteristics of black and white printing.

The research methodology includes a quasi-experimental approach with high school students as subjects. The procedures involve pre-tests and post-tests to measure learning outcomes, supplemented by feedback from teachers and students. Data collection utilizes questionnaires and validated tests, analyzed using descriptive and inferential statistics to determine the effectiveness of the AR tool.

This study develops Magic Boom Chemical: a book solid of education in which the book represents three dimensions of shapes on the printed media. Thus, this study implements chemical molecules using augmented reality, especially marker tracking-based, to encourage primary learners' motivation and knowledge in learning molecules. Furthermore, the researcher also tests the advantages of Magic Boom Chemical in learning activities using Kolmogorov-Smirnov testing (Finner & Gontscharuk, 2018; Tasdugen et al., 2020). it is expected that the results will demonstrate the effectiveness of this augmented reality-based tool in improving students' understanding of chemical molecules. The findings are anticipated to show a significant enhancement in student engagement, motivation, and comprehension compared to traditional learning methods. Furthermore, these results are hoped to provide a solid foundation for integrating augmented reality into educational practices, encouraging the development of more innovative and interactive teaching tools.

2. Literature Review

The study states that augmented reality is applicable and ideal in advertising. Promotion of Honda motorbikes at Honda dealer PT. Tunas Dwipa Matra in three dimensions using a smartphone (Hasan et al., 2020), While this application effectively showcases AR’s commercial potential, its methods and findings highlight the flexibility of AR technology, which can be adapted for educational purposes.

Another study focuses on the use of augmented reality in learning physics and reports a significant difference in learning outcomes between using AR and traditional manual methods (Lai & Cheong, 2022). This study suggests that AR-based educational games can enhance the quality of the learning process, which is supported by research showing that AR increases students' interest in learning mathematics by making the experience more engaging and enjoyable (Videnovik et al., 2020).However, these studies primarily emphasize general education and mathematics, lacking detailed exploration of AR’s potential in more specialized science topics like chemistry.

Research also examines the advantages and disadvantages of implementing augmented reality (AR) in the teaching of primary science using a service design methodology. According to this study, augmented reality (AR) can deliver pertinent digital information in a way that is entertaining to students in real time, supporting their learning (Fearn & Hook, 2023; Kleftodimos et a;, 2023). The research gap of this study is, this study implements the augmented learning in developing chemical molecule textbook intended for primary learners and find out the improvement statistically. Despite these positive findings, the study does not delve into the specific impact of AR on understanding complex scientific concepts such as chemical molecules, leaving room for further exploration.

Other research develops android based media learning using augmented reality in geometry for junior high school learners. This study explains the good responses of the students in geometry learning, especially three dimensions shapes using augmented reality. It also adds that augmented reality helps learner understanding of geometry. Unfortunately, the study does not show significant increase of learners’ understanding in geometry learning (Fitrianingsih et al., 2023).

Other studies explore AR applications in the tourism sector. For instance, an AR application was developed to display data about the Malaysian tourism industry, providing detailed information on various destinations (Jiman & Kulal, 2023). This demonstrates AR’s ability to integrate visual information with practical utility, a characteristic that can also be leveraged in educational tools to make learning more interactive and informative.

In this study, "Magic Boom Chemical" is developed by combining visual information, a three-dimensional molecule shape, and a marker-based tracking system. It can be operated on android-based cellphones. Through an appealing perspective and design of three-dimensional molecule, learners benefit a great comprehension related to the concept of molecule in chemical subjects especially in primary level. Furthermore, since the material is readily accessible via android-based gadgets the learners can access it anytime, anywhere. While previous studies demonstrate the effectiveness of AR in various fields and general education, few focus on its application in chemistry, especially at the primary and high school levels. Additionally, most research explores the theoretical potential of AR without addressing practical implementation challenges, such as usability, accessibility, or content relevance. This study fills these gaps by not only developing a tool specifically for chemical molecule visualization but also testing its effectiveness statistically, thereby contributing novel insights into AR's role in science education.

3. Research Methods

This study used quantitative method using quasi experimental approach (Cham et al, 2024; Hao et al., 2024). There were control and experimental groups in this study. The researcher gave the pre-test in the beginning for the learners in control and experimental groups. Itwas followed by treatment. The control group was given traditional molecule properties while the experimental group was given magic boom chemical. Then the control and experimental groups were given post-test. The design can be seen in table 1

Table 1 – The Design of the Group

Groups	Pre-test	Treatment	Post-test
Experiment	O	X_1	P
Control	O	X_2	P

Description of Table 1:
O = pre-test (the test required to show learners' comprehension before treatment)
P = post-test (Test required to show learners' comprehension after treatment)
X_1 = Magic boom chemical (learning media applied in experimental group)
X_2 = Traditional molecule properties (learning media applied in control group)

The population in this study were students of class X at the High School (SMA) Pelita Bunda which consisted of 5 classes. The samples of this study were 34 students from class X-5 and 34 students from class X-D. this study used purposive cluster sampling. The criterion of the sample was the samples must have the same average score of the previous exam. Class X-C was the control group and class X-D was the experimental group. A set of questions involving 10 questions was prepared as pre-test and post-test. Before the test was given the questions were administered to the learners outside of the sample to test the validity and reliability of test in terms of differentiator index, difficulty index and reliability.

Based on table one, it can be inferred that the first step was giving the learners as samples of this study the pre-test. The pre-test was used to figure out learners' early knowledge regarding chemical molecule topic. Pre-test was conducted to calculate level of homogeneity of learners' knowledge in both control and experimental group. The next step was treatment. The experimental group was taught by using magic boom chemical, while the control was taught by traditional molecule property. The third step was giving the post-test. Post-test was used to find out the effect of the treatment by calculating learners' average result on the test.

4. Results

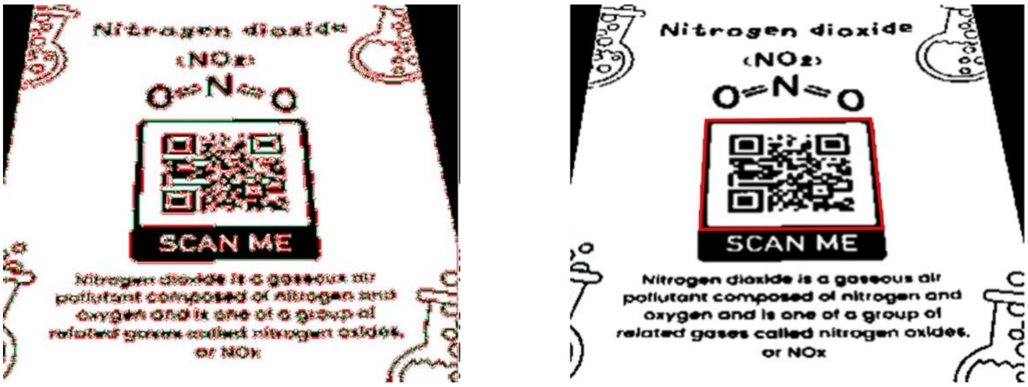
Since the augmented reality offers the data in the actual setting, the program must first determine the users' location and setting. In general, the individual observes the area using lenses that integrates camera and augmented reality technology. Therefore, the program requires the user to recognize the camera's position and orientation. With a synchronized lens, the program can then generate simulated objects in the proper locations. The word tracking refers to the calculation of a camera's relative pose (location and orientation) in real time. It is a key component of augmented reality (Ozdemir, 2021).

On the "Magic Boom Chemical" application, the identification procedure on a book using a marker begins with the submission of the picture process. The picture taken from the lenses is processed in the processor. After the picture is processed, the step is continued to thresholding process. This step produces a black and white picture. The purpose of this step is to identify the pattern of the shape taken from the camera (Ogawa & Mashita, 2021; Wu et al., 2023). The identification process involves extraction of contour, detection of the corner, the normalization of patten and matching template. The stage of contour extraction as well as recognition of the corner can be seen in Fig. 1.

(a)   (b)

Fig. 1. The process of (a) contour extraction and (b) corner recognition

As seen in Fig. 2 the extraction process and recognition of corner process detects the black frame of the picture. Therefore, the image should be in black and white to get the spot of the corner.



(a)   (b)

Fig. 2. The process of (a) extraction and (b) corner recognition

The following step of the marker identification procedure is structure standardization and matching the templates, as shown in Fig. 3. The technique of pattern normalization, which seeks to equalize marker form, allows the process of template matching.

Fig. 3. Normalization of the pattern and matching template

The final stage is to estimate the posture and location. This step produces digital entity over the marker. In this step there is a coordinate system involving three coordinates that plays a crucial part in the process as shown in Fig. 4.

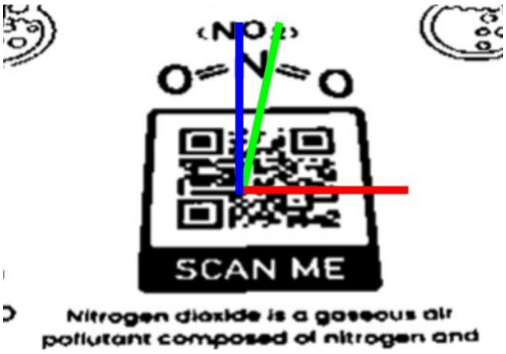


Fig. 4. the coordinate system marking

Augmented reality textbook is intended to be as entertaining as possible for the learners so that students enjoy working with them. Fig. 5 displays marks on each page of the "Magic Boom Chemical" textbook, indicating that the marker-based tracking approach was applied. If the learner guides the lens to that marker, an object in three dimensions of chemical molecule that corresponds to the object on that page will appear, as seen in Fig. 6.

(a) (b)

Fig. 5. The design of (a) book with a marker of magic boom chemical and (b) the process of simulated cube appears on the screen (b)

4.1 Testing beta version of magic boom chemical

After the beta version of magic boom chemical was developed, it was tested to the learners in SMA Pelita Bunda Samarinda. The instructor taught the learners and facilitated them with the magic boom chemical textbook. In this stage the researcher distributed the questioner to the instructor and learners to evaluate the magic boom chemical.

This study involved two instructors and eight learners to give responses on a set of questionnaires which consist of five statements related to the content and visual design of the magic boom chemical. Each Likert point answer is summarized in Table 2, with 6 representing strongly agree and 1 representing strongly disagree. There are 17 items in the user acceptance test that assess content, graphical user interface, multimedia elements, and navigation. Then, the responder value's percentage average may be calculated in formula (1).

$$x = \frac{9+68+369+468}{17\ x\ 10\ x\ 6}\ x\ 100\% = 88.72\% \quad (1)$$

Table 2 – Beta Testing Result

Item (weight)	Strongly Disagree (1)	Somewhat Disagree (2)	Disagree (3)	Agree (4)	Somewhat Agree (5)	Strongly Agree (6)
Content						
The content is clear				2 (20%)	4 (40%)	4 (40%)
The content is easy to understand					4 (40%)	6 (60%)

Item (weight)	Strongly Disagree (1)	Somewhat Disagree (2)	Disagree (3)	Agree (4)	Somewhat Agree (5)	Strongly Agree (6)
The content is related to Chemical Molecule					5 (50%)	5 (50%)
The content in Magic Boom Chemical is interesting				3 (30%)	3 (30%)	4 (40%)
GUI						
Learning Menu Scene				3 (30%)	5 (50%)	2 (20%)
Scan Menu Scene				2 (20%)	4 (40%)	4 (40%)
Quiz Menu Scene			1 (10%)	2 (20%)	5 (50%)	2 (20%)
About Menu Scene					4 (40%)	6 (60%)
Multimedia Element						
Appropriate font type					5 (50%)	5 (50%)
Appropriate font size					3 (30%)	7 (70%)
Appropriate graphics				2 (20%)	6 (60%)	2 (20%)
Appropriate button					4 (40%)	6 (60%)
Appropriate color					5 (50%)	5 (50%)
Appropriate audio			2 (20%)	3 (30%)	3 (30%)	2 (20%)
Navigation						
Navigation is easy					3 (30%)	7 (70%)
Navigation is clear and concise					4 (40%)	6 (60%)
Scan the QR code clear					5 (50%)	5 (50%)
Total			3 (1.77%)	17 (10%)	72 (42.35%)	78 (45.88%)
Weighting			9	68	360	468
UAT Percentage						88.72%

Based on results, respondents strongly agree (50%) that the content was related to molecule chemical. One responder selected disagree in the GUI, Quiz Menu Scene, while the others selected somewhat agree. Magic Boom Chemical used a variety of multimedia components, such as text size, type, images, buttons, colour, and audio. With the exception of audio, the majority of respondents selected somewhat agree and strongly agree. Only two respondents (20%) selected disagree. According to the results, 45.88% of respondents selected strongly disagree. The final total for UAT Percentage has resulted 88.72%, indicating that the application may be used effectively.

The limitations were related to the occlusion and the distance. In terms of occlusion the three dimensions object only occurred when the camera shot the entire marker. In other words, if the marker was not visible completely then three dimensions object could not be produced on the screen. There were maximum distances in the process of capturing the picture and producing the three dimensions object on the screen effectively. The appropriate distance was important for the program to get detail and recognize the pattern. The required distances of camera and marker are shown in table 3.

Table 3 – The Required Distances of The Lenses and Marker

Marker size (cm)	Camera distance (cm)
4 × 4	47
6 × 6	64
8 × 8	83
12 ×12	120
16 ×16	161

Table 3 shows that different marker sizes need different distance. It can be concluded that the smaller the picture or marker the shortest the distance is. Meanwhile the bigger the picture or marker the longer the distance needed by the lenses and the marker.

The last limitation is lighting. Lighting is very important for the user to capture a clear picture from the lenses and produce a good object on the screen. If there is a lack of brightness, then the object cannot be produced.

4.2 The evaluation learning

The researcher administered the post-test to investigate the effectiveness of magic boom chemical. Therefore, the researcher analyzed the post test result of the control group given treatment using traditional learning media compared to experimental group which was given treatment using magic boom chemical. The average score of the final test (posttest) of the control class was 77,76 while the final test (posttest) of experimental group was 78.24. From the posttest results in the experimental group, there was an increase in learning outcomes after using the media.

4.2.1 Descriptive Statistic

1. Pre-test

The average value of pre-test in control group, class X-C, using traditional learning media and experimental group, class X-D, using magic boom chemical are as shown in table 4.

Table 4 – descriptive statistics pre-test

	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
XC	34	32	68	42,972	8.996
XD	34	38	66	42,785	8.276
Valid N (listwise)	34				

Table 4 shows that the average value in pre-test of learners in class XC (control group using traditional learning media) was 42.972. The highest score was 68, while the lowest score was 32. The table also shows that the average value in pre-test for learners in class XD (experimental group using magic boom chemical) was 42.785.the highest score is 66, while the lowest score was 38.

2. Post-test

After the treatment using different learning media, the researcher distributed and analyzed the post-test result of the analysis in class as shown in table 5

Table 5 – descriptive statistics post-test

	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
EC_XC	34	60	94	77.76	11.944
EC_XD	34	24	96	78.24	14.936
Valid N (listwise)	34				

Table 5 shows the average value of post-test. Class XD as the experimental group got an average value of 78.24. The highest score of a learner was 96, while the learners' lowest score was 24. In contrast class XC as the control group has an average value of 77.76. The learners' highest score was 94 while the lowest learners' score was 60.

4.2.2 Inferential statistic

1. Pre-test

The normality test using the Kolmogorov-Smirov test was used to determine whether the data is normally distributed or not. Based on the testing using SPSS, the experimental table obtained sig (P) = 0.092 and the control class sig (P) = 0.061 by comparing the value of α = 0.05, the experimental class obtained sig (P) = 0.092> 0.05 and the control class sig (P) = 0.061> 0.05. therefore, that H0 is accepted. It can be concluded that both data are normally distributed as seen in table 6.

Table 6 - Normality Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
XC	.147	34	.061	.868	34	.001
XD	.139	34	.092	.880	34	.001

The Homogeneity Test using Lavene's test was used to determine homogeneity. In testing the equality of variance in this study. The significance level was α = 0.05. Based on table

7, the probability value is 0.099, because the p value> α, 0.099> 0.05, then Ho is accepted. It can be concluded that the population has homogeneous variance.

Table 7 – Homogeneity Test

Levene Statistic	df1	df2	Sig.
2.367	2	99	.099

One-way ANOVA testing is used to see the differences in students' initial abilities between the control class and the experimental class. Based on table 8, the results of the pretest on both classes had a value of F count < F table, which was 1.039 < 2.69, so H0 is accepted so that it is concluded that there was no difference in initial abilities between the experimental class and the control class.

Table 8 – Anova

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	468.784	2	234.392	1.039	.358
Within Groups	22342.706	99	225.684		
Total	22811.490	101			

2. Post-test

Data normality testing used One sample Kolmogorov smirnov test. Based on table 9, the posttest data obtained the probability for the group was 0.192, the probability value for the control group was 0.184. The level of testing used was α = 0.05 and the p value> α for both classes, then Ho is accepted so that both classes are normally distributed.

Table 9 - Normality Test

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
1	.126	34	.192	.955	34	.172
2	.127	34	.184	.899	34	.004

To test the homogeneous, this study used Levene's test. The test results showed in table 10 that the posttest results had a significant value of 0.095. Because the value with a significant level of α = 0.05, so 0.095> 0.05 (p> α) then H0 is accepted. It can be inferred that both classes of the population are homogenous.

Table 10 – Homogeneity test

Levene Statistic	df1	df2	Sig.
2.408	2	99	.095

Based on this table 11, the values obtained were Fcount = 5.268 and Ftable = 2.88, which means Fcount > Ftable, Thus Ho is rejected. It can be concluded that there were differences in learning outcomes between students who used edugame and traditional learning media.

Table 11 – Anova

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	716.529	2	358.265	5.268	.007
Within Groups	6732.882	99	68.009		
Total	7449.412	101			

5. Discussion

The effectiveness of Augmented Reality (AR) in enhancing high school students' understanding of chemical molecules was examined in this study. The experimental group, which utilized the "Magic Boom Chemical" AR-based tool, achieved slightly higher post-test scores compared to the control group, which relied on traditional learning methods. This finding is in line with prior research that highlights AR's ability to significantly improve learning outcomes, particularly in complex subjects like chemistry (Hasan et al., 2020; Lai & Cheong, 2022; Chen & Liu, 2020). Numerous studies have demonstrated AR's potential to enhance student engagement and comprehension, especially when dealing with abstract scientific concepts, such as those found in chemistry (Cranmer et al., 2020; Fearn & Hook, 2023; Liu et al., 2023). The positive impact of AR tools on students' learning experiences is also echoed in studies by Videnovik et al. (2020) and Cibilić et al. (2021), which suggest that AR significantly increases student engagement in subjects like mathematics and physics.

This study extends these findings to the field of chemistry, where AR has shown promise in aiding the visualization of molecular structures (Qiu, 2023; Maulana et al., 2024; Ripsam & Nerdel, 2024). The results support the growing body of literature suggesting that AR can provide valuable educational benefits by facilitating more interactive and engaging learning experiences. These findings are consistent with the work of Lai & Cheong (2022), who observed similar improvements in learning outcomes in physics. Furthermore, Cevikbas et al. (2023) confirm that AR tools increase student motivation by offering a dynamic, interactive learning environment, which also aligns with the improvements observed in this study. Both studies highlighted that students who used AR-based tools were more engaged and motivated than those who relied on traditional teaching methods.

Despite these promising results, the increase in the experimental group's post-test scores was modest, with an average score of 78.24 compared to 77.76 in the control group. Although this difference is statistically significant, the improvement is relatively small, suggesting that the effectiveness of AR might vary depending on students' prior knowledge and familiarity with technology (Satria & Barus, 2022). This finding mirrors the work of Videnovik et al. (2020), who found larger differences between experimental and control groups, likely due to the design of the AR application or the complexity of the educational content. Unlike more immersive AR applications that integrate real-world interactions (Qorbani et al., 2024), the "Magic Boom Chemical" tool in this study utilized a marker-based AR system within a static textbook format, potentially limiting the depth of interaction. Studies by Porsch & Lehmann (2023) and Liu & Tanaka (2021) indicate that more interactive, hands-on AR applications generally have a greater impact on student learning. In contrast, the relatively static nature of the "Magic Boom Chemical" tool may have not fully capitalized on the interactive potential of AR.

The pre-test results showed similar baseline knowledge in both groups, suggesting that any differences in post-test scores were likely due to the treatment rather than initial disparities in knowledge. This supports the argument of Fearn & Hook (2023), who suggest that AR can effectively level the playing field by providing access to interactive, engaging learning experiences that traditional methods may lack. Therefore, while AR in this study proved effective in enhancing student engagement and comprehension, the degree of improvement may vary depending on the design and interactivity of the AR tools used.

This research adds to the body of knowledge on the potential of AR in chemistry education, particularly by showing that AR tools can make abstract concepts like chemical molecules more accessible and engaging for students (Ozdemir, 2021; Porsch & Lehmann, 2023; Olim et al., 2024; Bullock et al., 2024). However, it also emphasizes the need for further refinement of AR applications to maximize their effectiveness in educational settings. Future research should explore more interactive AR applications that allow students to manipulate and explore molecular structures in real-time, as suggested by studies like those of Koumpouros (2024) and Satria & Barus (2022). Such advancements could further enhance the educational benefits of AR tools in chemistry education.

The integration of AR in this study differs from previous research in several key ways, particularly in the design of the AR tool. While many studies have utilized more immersive AR systems (Cranmer et al., 2020; Videnovik et al., 2020; Du & DeWitt, 2023), the "Magic Boom Chemical" tool in this study used a marker-based AR system within a textbook format. This study suggests that future AR educational tools should consider more immersive and interactive experiences, such as those that allow students to engage with virtual chemical structures and reactions in real-time (Lestari et al., 2023; Maulana et al., 2024). Such enhancements could significantly improve the efficacy of AR in enhancing students' understanding of complex scientific concepts. this study contributes new insights into the application of AR in chemistry education, offering a foundation for future research in this field.

6. Conclusion

The study developed a textbook to learn chemical molecule by integrating augmented reality namely magic boom chemical. The magic boom chemical is intended for primary school learners and it is developed as the alternative of the previous traditional learning media. The magic boom chemical is used by capturing the picture on the textbook then the shape of three dimensions object appears on the screen. It has many advantages, such as it entertains the learners in the learning process, and it is also feasible to be used in smart phone.

Based on the results it was obtained that Fcount = 5.268 and Ftable = 2.88, which means Fcount > Ftable, Therefore, Ho is rejected. It can be concluded that there were differences in learning outcomes between students who used edugame and traditional learning media. The average score of the final test (posttest) of the control class was 77.76 while the final test (posttest) of experimental group was 78.24

There are some limitations of magic boom chemical developed in this study such as the three dimensions object only occurs when the camera shot the entire marker. In other words, if the marker is not visible completely then three dimensions object cannot be produced on the screen. It is also found that there are maximum distances in the process of capturing the picture and produce the three dimensions object on the screen effectively. The appropriate distance is important for the program to get detail and recognize the pattern. Therefore, the next researcher is suggested to use a better tracking method such as marker less tracking, and the further exploration is needed to identify the optimal design of AR tools that maximize student engagement and learning outcomes, and to investigate the long-term effects of AR on students' scientific understanding and academic achievement

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