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The Application of Augmented Reality Platform for Chemistry Learning

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***Abstract* - In this project, a new learning platform was developed. This project uses the technology of Augmented Reality (AR) to develop a graphic animation platform for learning purposes. By applying virtual objects with animations for learning, it helps to engage users and increase their learning efficiency. Besides, the AR platform combines hardware (i.e.s smartphone, headset, and target marker) and software (i.e., Unity, Vuforia, and C#) for the operation. The AR application allows the interaction of the virtual objects by grabbing target marker toward each other or touching the virtual button in the real environment. This can increase the immersion and interaction of the user when learning chemistry. In addition, the "Chemical Learn" experiments were designed to study the effectiveness of the AR platform compared to the traditional platform as well as to conduct user satisfaction surveys. The overall results showed that the AR learning platform can improve the learning efficiency of users in chemistry compared to traditional learning methods. Moreover, users who participate in the survey are generally satisfied with the AR. It is believed that with the rising trend of technology, it is only a matter of time before people become familiar with the AR platform.**

Keywords—Augmented Reality Platform, Chemical Learn, Traditional Platform, Survey, Virtual Objects.

I. INTRODUCTION

Education is a process of knowledge and skills transfer from one generation to another. It helps the new generation to have a comfortable and advanced living environment. The method of education can be teaching, training, discussion, simulation or researching [1],[2]. This can help the new generation have a better future

Not only that, with the advance of technology, the student learning process can be improved. The traditional way of learning is to use the physical book. However, the book contents only show the static condition of a scene with very little interaction with the students, which hardly brings much imagination to the students, especially for a complex structure like chemistry. Besides, some experiment in chemistry is dangerous and expensive to perform. This will make it difficult for students to deeply understand the structures of chemical compositions, thus reducing the efficiency of learning chemistry.

In order to have more interaction, less danger, and an immersive approach when performing activities, an immersive platform with the use of technology such as augmented reality (AR) and virtual reality (VR) [3] had to be introduced. Recently, the use of AR technology in education has become more popular. AR is a technology

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that enhanced the scene of the real world by adding three-dimensional (3D) virtual objects to provide more engagement and immersion in the learning process. While there has been research on the use of AR in education, there is still a lack of research on the use of AR in specific disciplines, such as chemistry. Therefore, the objective of this project is to design 3D virtual objects on an AR platform to teach object-oriented computing related to chemistry. The chemistry content in this research will follow the Sijil Pelajaran Malaysia (SPM) for S4 and S5 students. Students will be using either a smartphone or AR headset to operate the AR app and learn about the 3D virtual chemical compositions that appeared in the real world [4],[5].

The research has used a few modern tools such as Unity [6],[7], Vuforia [8] and target marker [9] to design the AR platform [10], [11]. An experiment named "Chemical Learn" was designed to study the effectiveness of the AR platform as well as to conduct user satisfaction surveys.

Based on the result of the satisfaction surveys and the experiment, it showed that the developed "Chemical Learn" in AR platform significantly increases the willingness to learn on subject Chemistry. Not only that, users for both different groups had a better learning gradient when they used the "Chemical Learn".

II. Related work

In augmented reality, there are several features used to shows virtual objects in the real world. Two common features used in AR learning applications are target market and world tracking. A description on the use of those features in the application will be shown in the following.

A. Curiscope Virtuali-Tee

FIGURE 1 shows an example of a user using the application of Curiscope Virtuali-Tee with a smartphone. Curiscope Virtualli-Tee is used to learn the internal organs of the human body by displaying virtual objects in AR. The application will track a specific image which is the target marker printed in the T-shirt. Thus, a virtual human internal organ is displayed on the smartphone screen with an image of the T-shirt in the background. The user not only can view the virtual object but also can interact with it through the screen. This can enhance the imagination of the user in perceiving the organ [12].

FIGURE 1. Example of using Virtualli-Tee [12].

TABLE 1. Characteristic of curiscope virtuallie-tee.

Characteristic	***Curiscope Virtualli-Tee***
Tracking Target	T-shirt with specific marker
Playing method	On-screen
Function distance	Far (~15 cm to 91.44 cm)
SDK requirement	No SDK require

Table 1 show characteristics of Curiscope Virtualli-Tee. The application uses a T-shirt with a specific image printed on it as a target marker to let the smartphone to tracking the coordinate of the human body. For gameplay, Curiscope Virtualli-Tee was developed in such a way that users interact with virtual internal organs through the smartphone screen. Since Curiscope Virtualli-Tee uses target tracking it does not require any SDK, indicating that any portable device with enough processor speed is possible to run the application.

B. Catchy Words AR

FIGURE 2 show another related work named Catchy Words AR, which is used to learn words through a smartphone. Using this application, the 3D alphabet will pop out and float in the real world which can be viewed from the screen. Users can then interact with the alphabet by touching the screen and moving it to specific places in the correct order to form a meaningful word [13].

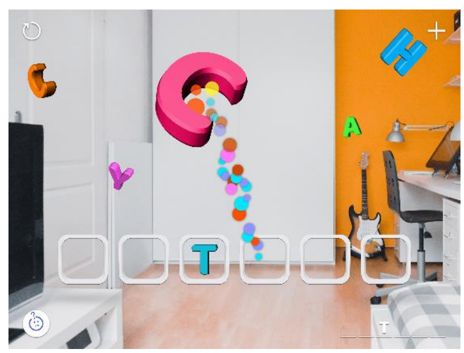

FIGURE 2. The gameplay of catchy words AR on screen [13].

TABLE 2. Characteristic catchy words AR.

Characteristic	**Catchy Words AR**
Tracking Target	No target needed
Playing method	On-screen
Function distance	No specific function distance
SDK requirement	Require AR Core

Based on the characteristic shown in Table 2, it can notice that Catchy words AR do not require any target marker. This is because this application is using a world-tracking feature that tracks the geographical location, i.e., ground floor in the real world. Its playing method is interaction on-screen. However, if the alphabet is too far away from the user, the user may need to move their body or even walk towards the alphabet. This might be uncomfortable for the user who has a physical disability in walking or moving. Compared to the target marker, the world-tracking feature may take a longer time to assess the location in the real world before starting the AR application. In addition, the application requires the AR Core SDK to run, so it is not compatible with any smartphone that does not have the SDK.

III. MATERIAL AND METHOD

From those two features, the target marker is chosen to be used in designing the AR application named "Chemical Learn". This is because it only needs an object with specific characteristics to be the target. It also does not need the use of SDK, indicating that any smartphone that above android 8 is available to use. Details about the design of "Chemistry for Learning" are described in the following parts.

A. Configuration of AR System

Figure 3 shows the configuration of the AR application system.

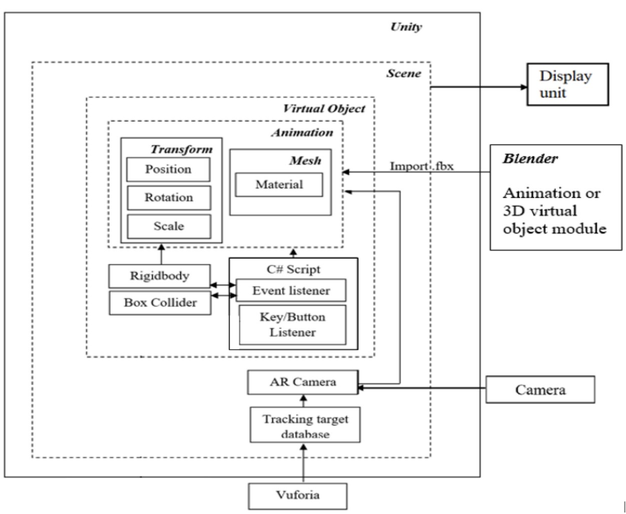

FIGURE 3. System configuration.

Input camera will capture the target marker of the image and send it to AR application to further process. The "Vuforia", which is a software engine, is used to handle the database of tracking targets. The application's main body will be handled by a software engine called "Unity" [14]. The system has a scene with several virtual objects, and the processed scene will be displayed through a display unit. The scene consists of an AR camera, a database of tracking images, and 3D virtual objects. Another software called "Blender" is used to design virtual objects and animation. Those virtual objects consist of several pieces of information such as box collider, rigidbody, transformation, mesh, and animation. The box collider component is used to determine the "touching" and "trigger" of the virtual object. The rigid body is a component that uses to apply gravity and velocity to the objects. The transformation consists of the position, scale, and rotation of the objects. The mesh consists of the color, skin, and material of the object. The C# Script will then be used to combine "rigidbody" and "box collider" to trigger the event listener of the objects. After that, the AR Camera will refer to the target marker location to organize the appearance of virtual objects.

B. Target Marker

The target marker is an image that informs the application of the coordinates of a virtual object in the real world by using image tracking. The image tracking used in this paper is from Vuforia. Users are allowed to modify the target marker as shown in FIGURE 4.

FIGURE 4. A different version of the target marker.

The optimal target marker size is in the range of 6 to 9 cm. Version 1 of the target marker uses a similar approach to the QR code, where the target image will contain the information within the image. However, this version is difficult to provide a good target marker because the area labeled with yellow is a buffer area where the AR camera did not pick up any features. Any feature that overlaps with the yellow area will lose during tracking. So, version 2 of the marker is designed with a gap added. However, version 1 and version 2 have a common limitation in that there are too many repeating sizes and orientations within the markers. This will make it less efficient for the camera to locate its target marker [15]. A good marker should have a gap for the buffer, and patterns with different orientations, sizes, and lengths. This can increase the stability of the tracking and also the range of tracking. Thus, version 3 has been designed by following those criteria.

C. AR Headset

FIGURE 5. Flow chart of the overall program.

AR headset or known as AR glasses as shown in Figure 5 is a headset that is worn on the head and does not require the user to hold the smartphone with their hands. It is similar in concept to VR headset, but the difference is that it does not require any lenses and the screen will be the same for both eyes to view.

D. Main Program

The AR application was designed to have two modes for the player to learn. These 2 modes are “Lecture” mode and “Sand Box” mode as shown in Figure 6.

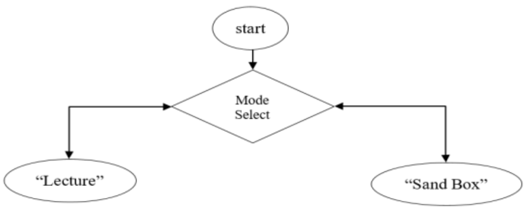

FIGURE 6. The overall program flow chart.

E. “Lecture” mode

“Lecture” mode has limited interaction with the virtual object and is more on reading. This mode provides a good visualization of learning the structure of the object, especially with the chemical molecule. The program flow of the “Lecture” mode is shown in FIGURE 7.

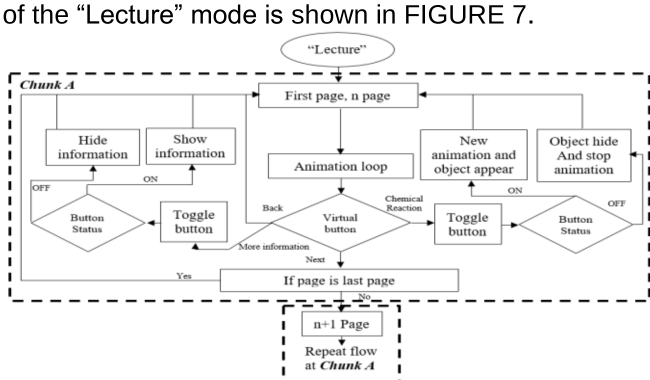

FIGURE 7. The “Lecture” mode flow chart.

In the “Lecture” method, they initially go to the first page and virtual objects with animation will be applied to that page. The program will then waiting users to interact with the virtual button. Initially, the algorithm of a virtual button only has a press-to-release function, which means it would be turned off after the user released them. By modifying the algorithm, the button becomes a toggle button that switches to OFF and ON each time the user clicks it. There will be four buttons in the program. First is the “Back” function for returning to the previous page or if it is already the first page, it will return to the same page. Second is the “More Information” button which is used to displays more information on the page when the state changes to ON and hides that information if it is OFF. The same applies to the "Chemical Reaction" button. When changed to "ON", a hidden object will be shown and a new animation will be applied, and vice versa.

F. “Sand Box” mode

The “Sand Box” mode allows users to interact with the virtual objects. This mode provides the user the opportunity to merge virtual objects by dragging and colliding objects on the screen, which will then become new objects. This can provide a good interaction for the user especially in learning chemical reactions.

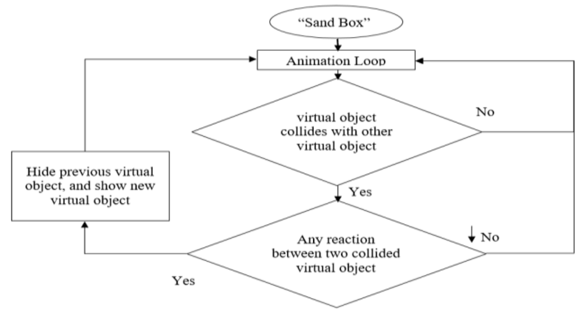

FIGURE 8. “Sand Box” mode flow chart.

Figure 8 shows the flow chart of “Sand Box” mode. Same as “Lecture” mode, animations in “Sand Box” mode will continue to be applied to the virtual objects until the users interact with the virtual button. Next, each virtual object will constantly detect if a collider from another virtual object is coming in. If a collision with other objects is detected, the algorithm will check which types of objects have been collided and will display the corresponding new objects.

G. An experiment of study efficiency

FIGURE 9 shows the step of the experiment study efficiency, which takes 3 weeks. The purpose of the experiment is to understand the effectiveness of the new learning platform design in the project compared to the traditional learning platform.

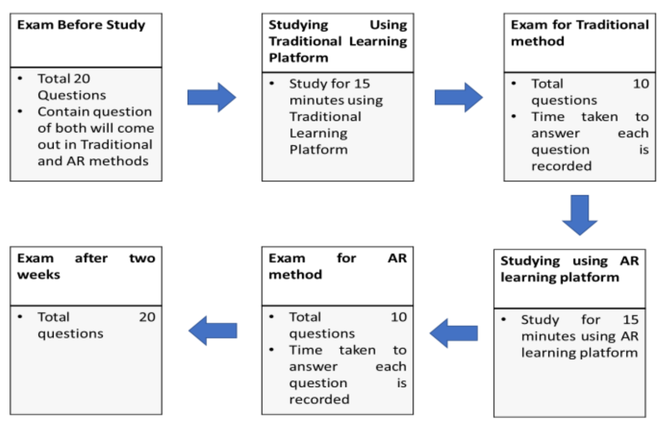

FIGURE 9. Experiment step of study efficiency.

There are 11 users had involved in the experiment. They had divided into 2 groups, 6 out of 11 users had categorized into the first group which they have experience in subject Chemistry before, the 5 remain users which had no experience in subject Chemistry will be as categorized in the second group. The users will give 20 questions in the exam, 10 questions come from a traditional learning platform (i.e., using the book) and 10 will come from an AR learning platform. After completing the 1st exam, users are given 15 minutes to learn using the traditional learning platform. Later, users will answer 10 questions coming from the paper. The users will then repeat the same step, but this time using the AR learning platform. In this platform, "Lecture" and "Sand Box" modes are available to users, and the total learning time is also 15 minutes. After that, the user needs to answer 10 questions coming from the AR application. The user will then be told to come back in 2 weeks and do another 20 questions. They have been informed that they were not allowed to use these two platforms for learning during these two weeks.

When designing the questions for both the traditional and AR learning platforms, each question on both platforms had the same difficulty and total score. The scores obtained from answering the question on both platforms will be calculated and compared.

H. Analysis Data Calculation

To determine the study efficiency of the traditional and the AR learning platforms, the scores obtained after answering the questions will be used as the input data in the following formulation.

Equation 1 shows the learning gradient where it is used to calculate the difference of scores between each phase.

$$m = mark\ phase_{n+1} - mark\ phase_n \tag{1}$$

The greater the difference, the higher the learning gradient and the more beneficial the learning platform is for improving the learning ability. Equation 2 and Equation 3 show the formulation of calculating the mean and standard deviation.

$$\bar{x} = \frac{\sum x}{n} \tag{2}$$

$$s = \sqrt{\frac{\sum (X - \bar{x})^2}{n - 1}} \tag{5}$$

where x is the value in data distribution, and n is the number of data. Besides that, the data are separated into two groups based on the users' experience in learning chemistry. Users in the first group had experience in studying the subject of chemistry, while users in the second group had no experience in studying the subject of chemistry.

I. User Satisfaction Survey

In addition to calculating the scores, a user satisfaction survey was also conducted. The survey form is available in Appendix A. The purpose of performing the survey is to understand the user's satisfaction with the AR learning platform [16]. The survey's questions can be categorized into four groups which are "Attention", "Prefer", Willingness" and "Satisfaction. "Attention" is used to identify the level of user's focus toward the AR learning platform. "Prefer" is used to identify whether users tend to choose to use the AR platform for further learning. "Willingness" is used to identify the level of preference for using the platform. "Satisfaction" is used to identify how users feel about the operation of the platform. It is assumed that the higher the score obtained from the survey, the higher the user's satisfaction with the AR learning platform.

IV. RESULTS AND DISCUSSIONS

Augmented reality (AR) learning platforms are the main goal of this paper. Applications using AR technology have been designed for learning about chemistry. There are two modes of study in this application which are "Lecture" mode and "Sand Box". Both modes required target markers to do so. The AR application can be performed either using a smartphone or headset as shown in Figure 10 and Figure 11 [17].

FIGURE 10. Playing method using a smartphone.

FIGURE 11. Playing method using AR headset.

A. "Lecture" Mode

"Lecture" mode is a mode that is especially for reading and visualizing chemical structure. When users scan the target marker as shown in Figure 12, virtual buttons and objects will pop up and float on top of the target marker as shown in Figure 13. Users can interact with virtual objects by touching the screen. In total, 12 pages of chemical structures are designed for this application.

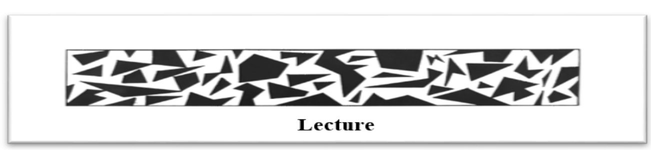

FIGURE 12. Target marker for "Lecture" mode.

FIGURE 13. "Lecture" mode gameplay.

There will be 4 virtual buttons appearing on the marker, named "Back", "Chemical Reaction", "More Information", and "Next". Unlike virtual objects, virtual buttons do not need to be touched through the screen. The users can 'touch' the virtual buttons in the real world. This can be achieved by using an AR camera to detect any overlap between the user's finger and the button. If an overlap occurs, the button will be activated [18].

B. "Sand Box" Mode

"Sand Box" is a mode that allows users to interact with virtual objects. This mode provides the user the opportunity to merge virtual objects by dragging and colliding objects on the screen, which will then become new objects. In this mode, there is no danger when performing chemical reactions as it is performed virtually. This can provide more interactive learning for users when learning chemicals. In this mode, only 16 markers with virtual objects are given. Similar to the "Lecture" mode these objects will appear in the real world. Users can visualize the objects through the screen and interact with the virtual particles by grabbing the target markers. In addition, users can grab the target marker and move it to another marker to combine the objects Figure 14 shows the gameplay for "Sand Box".

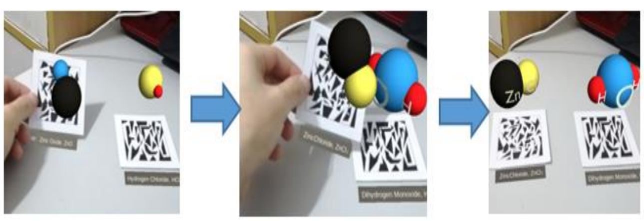

FIGURE 14. "Sand Box" mode gameplay.

Initially, the target marker that shows the virtual zinc oxide particles was grabbed and touched another target marker that shows virtual hydrogen chloride particles. When two particles collide, zinc oxide becomes zinc chloride, and hydrogen chloride becomes dihydrogen monoxide. Currently, there are a total of 8 combinations available in the "Sand Box" mode as shown in Table 3.

TABLE 3. Combination available in "Sand Box" mode.

No.	Reaction (A + B)		Output (C+D)	
	A	B	C	D
1	C	O_2	CO_2	-
2	H_2	O_2	H_2O	-
3	N_2	H_2	NH_3	-
4	ZnO	HCl	ZnCl	H_2O
5	$Pb(NO_3)_2$	2NaCl	$PbCl_2$	$2NaNO_3$
6	Mg	2HCl	$MgCl_2$	H_2
7	MgO	2HCl	$MgCl_2$	H_2O
8	$MgCO_3$	2HCl	$MgCl_2$	$H_2O + CO_3$
9	NaOH	HCl	NaCl	H_2O

C. Experimental results of learning efficiency

Figure 15 and Table 4 shows the learning gradient of the users who has experience in the chemistry.

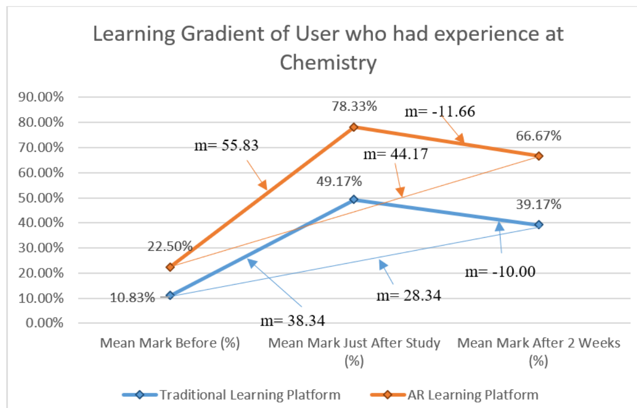

FIGURE 15. Learning Gradient for users with experience at Chemistry.

TABLE 4. Learning Gradient for users with experience at Chemistry.

No. of Learning Gradient	Region	Traditional	AR
1	"After Study" vs "Before Study"	38.34	55.83
2	"After 2 weeks" vs "After Study"	-10.00	-11.66
3	"After 2 weeks" vs "Before Study"	28.34	44.17

Based on Figure 15 and Table 4, the learning gradients 1 and 3 show that the AR learning platform has a higher AR learning gradient compared to the traditional learning platform, indicating that it has better learning efficiency. Even looking at the long term (2 weeks), it also shows a better result in learning efficiency with AR having a value of 66.67% compared to traditional with 39.17%. However, for the learning gradient 2, it can be observed that AR have a value of -11.66 which is lower compared to the traditional value of -10. This is because AR is still a new learning environment for them and they are not yet familiar with it. Regardless, the overall results still show that AR has a higher learning gradient compared to the traditional learning gradient.

Next, Figure 16 and Table 5 show the learning gradient of the users who has no experience in the chemistry.

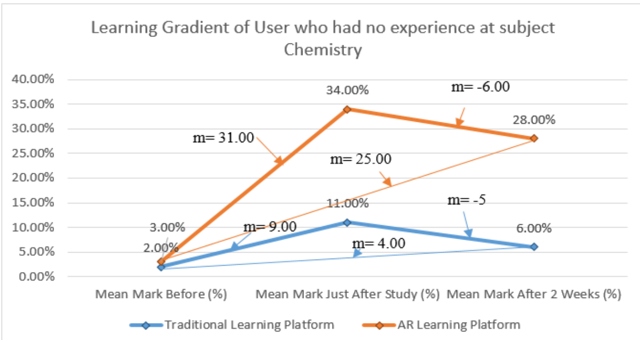

FIGURE 16. Learning gradient for users with no experience at Chemistry.

TABLE 5. Learning Gradient users with no experience at Chemistry.

No. of Learning Gradient	Region	Traditional	AR
1	"After Study" vs "Before Study"	9	31
2	"After 2 weeks" vs "After Study"	-5	-6
3	"After 2 weeks" vs "Before Study"	4	25

Based on Figure 16 and Table 5, it can be seen that the results are similar to the previous results. The learning gradient 1 and 3 show that the AR learning platform has better study efficiency compared to the traditional learning platform. In addition, the result also shows that users are not yet familiar with AR applications, resulting in lower value of AR in learning gradient 2.

TABLE 6. Result comparison between the user who had with who had no experience in Chemistry.

		Who had experience in subject Chemistry	Who had no experience in subject Chemistry
No. of Learning Gradient	Region	AR vs Traditional	AR vs Traditional
1	"After Study" vs "Before Study"	17.49	22
2	"After 2 weeks" vs "After Study"	-1.66	-1.00
3	"After 2 weeks" vs "Before Study"	15.83	21

Table 6 shows the result comparison between the users with experience and the users with no experience in Chemistry. The result shows that users with experience in chemistry will have an increment of 17.49 and 15.83 in score after they switch their learning platform from traditional to AR platforms. As for the user with no experience, there also have an increment of 22 and 21 after switching from traditional to AR platform. As for the learning gradient 2, both of the groups show similar results in which AR is still a new learning environment for them and they are not yet familiar with it. With the upward trend of technology, it is only a matter of time before people become familiar with the AR platform.

D. Result of User Satisfaction Survey

Table 7 shows the user satisfaction survey scores. From the survey form, four categories are being surveyed. In the "Attention" category, the results show that users give a score of 91.64%, indicating that the AR learning platform was able to capture their attention. In the " Prefer " category, all users chose "AR" over "Traditional". This indicates that they would prefer to use AR platforms for learning. In the "Willingness" category, users gave a score of 87.27%, indicating that they would be willing to try and use the AR learning platform again for learning. In "Satisfaction" category, users gave a score of 88.36%, indicating that users are satisfied with the AR learning platform.

TABLE 7. User satisfaction survey respond.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Total
Attention												
1.	4	5	5	5	5	5	5	5	5	4	4	
2.	5	5	5	4	5	5	5	5	5	4	4	
3.	4	5	5	5	5	4	4	4	5	4	5	
4.	4	5	5	4	5	4	5	5	5	2	5	
5.	5	5	4	4	5	5	4	5	5	4	3	
Sub total	22/25	25/25	24/25	22/25	25/25	23/25	23/25	24/25	25/25	18/25	21/25	252/275
												91.64%
Prefer												
1.	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR= 11 Traditional = 0
Willingness												
2.	4	5	5	4	5	4	4	5	3	4	4	
3.	5	5	5	4	5	4	3	4	3	4	4	
4.	5	5	5	4	5	5	4	5	4	3	4	
5	5	5	5	3	5	5	4	5	5	4	4	
Sub total	19/20	20/20	20/20	15/20	20/20	18/20	15/20	19/20	15/20	15/20	16/20	192/220
												87.27%
Satisfaction												
1.	5	5	5	5	3	4	5	5	5	4	5	
2.	5	4	5	5	4	4	5	5	5	4	5	
3.	4	3	5	5	4	5	5	5	5	4	2	
4.	3	4	5	3	5	3	3	4	4	3	3	
5.	4	5	5	5	5	4	5	5	5	3	5	
6.	4	5	5	5	5	5	5	4	5	4	4	
7.	5	5	5	4	5	4	4	5	5	4	5	
8.	4	4	5	5	2	5	3	5	2	4	4	
9.	5	3	5	5	4	3	5	5	5	4	5	
10.	5	4	5	5	5	5	5	5	5	4	4	
	44/50	42/50	50/50	47/50	42/50	42/50	45/50	48/50	46/50	38/50	42/50	486/550
												88.36%

V. Conclusion

In conclusion, an AR learning platform's main goal is to allow users to experience virtual objects that appear in real environments while learning chemistry. The “Chemical Learn” experiments were designed to study the AR platform's effectiveness compared to the traditional platform as well as to conduct user satisfaction surveys. On the AR platform, the information and content of chemistry are displayed interestingly and engagingly, by showing 3D virtual objects with animations. Users can interact with the virtual object by grabbing the target markers and using the virtual button. In addition, the target markets are optimized by changing the gap for the buffer, and patterns with different orientations, sizes, and lengths. This increased the stability of the tracking and also the range of tracking. As for the experiments investigating the effectiveness of the platform, learning gradient 2 shows that the values obtained in the AR platform are slightly lower than in the traditional platform. This is because some users are still not yet familiarise with AR technology. Regardless, the overall results showed that the AR learning platform successfully improved the learning efficiency of users in chemistry subjects compared to traditional learning methods. Moreover, the users participating in the survey are generally satisfied with the AR learning platform. It is believed that with the rising trend of technology, it is only a matter of time before people become familiar with the AR platform.

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Author Contributions

Wei Xiang Lim: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Chean Khim Toa: Project Administration, Writing – Review & Editing;

Kok Swee Sim: Project Administration, Supervision, Writing – Review & Editing.

Conflict of Interests

No conflict of interests were disclosed.

Ethics Statements

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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APPENDIX A

1 = strongly disagree 2 = disagree
3 = neutral
4 = agree
5 = strongly agree

* Required

1. Name *

USS-PART1

2. 1. In overall learning using “AR” got more my attention compare to “Traditional”. *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

3. 2. The material, information, 3D object and animation in “AR” are more eye catching than picture in “Traditional” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

4. 3. I feel study using “AR” is more fun compare to “Traditional” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

5. 4. The lesson in “AR” is more stimulate my curiosity compare to “Traditional” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

6. 5. After study for 10minutes, I fell I still can focus in study by using “AR” compare to “Traditional” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

USS-PART2

7. 1. I more prefer study using: (please do not write I don't like study, assume you forced to study which you prefer). *

Mark only one oval.

- AR
- Traditional

8. 2. I would like to study again for the same lesson using “AR” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

9. 3. I would like to try new lesson using “AR” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

10. 4. I would like to study subject “Chemistry” by using “AR”. *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

11. . I would like to study other subject by using “AR”. *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

USS-PART3

12. 1. I like the graphic of the “AR” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

13. 2. I like the animation of the “AR” *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

14. 3. I like the interaction (game play) of button and object “AR”. *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

15. 4. The “AR” app is easy to use. *

Mark only one oval.

Disagree 1 2 3 4 5 Agree

16. 5. The "AR" study method is easy to set up and install. *

Mark only one oval.

	1	2	3	4	5	
Disagree						Agree

17. 6. I like the "Sand Box" study method in the "AR" *

Mark only one oval.

	1	2	3	4	5	
Disagree						Agree

18. 7. I like the "Lecture" study method in the "AR" *

Mark only one oval.

	1	2	3	4	5	
Disagree						Agree

19. 8. I don't feel lagging in the "AR" apps. *

Mark only one oval.

	1	2	3	4	5	
Disagree						Agree

20. 9. I don't feel dizziness and vomiting while or after using "AR" *

Mark only one oval.

	1	2	3	4	5	
Disagree						Agree

21. 10. I would recommend this app to other people. *

Mark only one oval.

	1	2	3	4	5	
Disagree						Agree