

The Application of Augmented Reality as a Learning Medium for Acid-Base Reactions

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Abstract. Chemistry learning at the junior high school level often faces challenges because many concepts are abstract and difficult to imagine, such as acid-base reactions. To overcome this, Augmented Reality (AR) technology can be used as an interactive and engaging learning medium. This study aims to develop an AR-based learning medium that can help junior high school students understand the concept of acid-base reactions in a more visual and enjoyable way. This medium displays 3D simulations of acid and base solutions, indicator color changes, and reaction results directly through devices such as smartphones or tablets. The results of the trial show that the use of AR in learning can increase students' interest in learning, understanding of concepts, and active participation in class. With an attractive and easy-to-use display, AR is an innovative solution to bring students closer to chemistry concepts that were previously difficult to understand.

Keywords: Acid-base, Augmented Reality, 3D, Learning Media, Multimedia Development Life Cycle.

1 Introduction

In Natural Sciences (IPA) learning, especially chemistry material such as acid-base reactions, junior high school students often experience difficulties because the concepts studied are abstract and difficult to imagine.[1] One solution to overcome this difficulty is to use interactive and interesting learning media. Augmented Reality (AR) technology has been proven to help students understand lessons more easily through clear and enjoyable visualizations[2].

The AR application developed in this study has several key features, such as chemical substance recognition, substance combination simulation, and three-dimensional displays of laboratory equipment. This technology was built using the Unity platform and can be accessed via smartphone, making it easily accessible to students[3]. Through AR, learning that was previously only theoretical in books can now be more realistic and contextual, making it easier for students to understand[4].

This application uses marker-based AR technology, which involves scanning a special marker image using a smartphone camera[5]. Once the marker is recognized, the application will display an animation of the acid-base reaction process in real time, such as when acids and bases are mixed, new substances such as salt and water are formed, and the color of the indicator changes. This allows students to see how the reaction occurs step by step rather than just imagining it. The main advantage of this application over other learning media is the interactive simulation that allows students to "conduct" experiments virtually. Several experiments that are difficult to perform in school laboratories can be simulated through AR, so that students can still learn actively and safely[6]. Through animation, students can see acid-base reactions taking place and understand the process thoroughly.

This application is intended for students of SMP Muhammadiyah 6 Krian who are studying science, as well as for teachers as a teaching aid in the classroom. Teachers can use this application to explain chemistry concepts in a more visual and interactive way[7]. By using marker-based AR, it is hoped that the learning process will become more interesting, improve student understanding, and create an enjoyable learning experience[8].

2 Methodology

The research methodology aims to provide a systematic approach in the application of augmented reality as a learning medium for acid-base reactions using the Software Development Method (MDLC)[9]. This research covers several important stages, starting from the concept, design, material collection, creation, testing, to distribution. The steps in the research to be conducted can be seen in Figure 1.

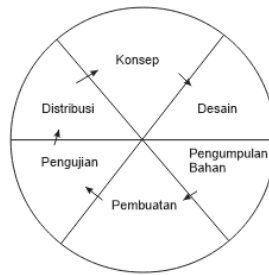


Figure 1. MLDC Diagram[10]

Figure 1. The MLDC Diagram is a step-by-step guide for conducting this research. It helps researchers better understand the flow of the research being conducted. The goal is to identify problems in the research being conducted[11].

3 Results and Discussion

3.1 Concept

At the concept stage, this application was developed using the MDLC (Multimedia Development Life Cycle) method, which serves as a framework for the systematic development of multimedia applications. This method assists in the planning, design, and evaluation of applications to ensure they meet user needs. Figure 2 explains the concept of this application visually and provides an overview of the workflow.

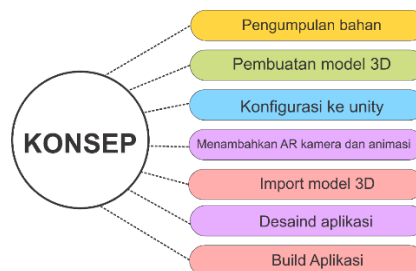


Figure 2. Application Development Concept

3.1.2 Flowchart

The UML concept description, as shown in Figure 3 below, was used to create this application. A flowchart is a graphical representation of a process that describes the steps in sequence using standard symbols. To visualize the workflow of a system, a flowchart design is needed to facilitate understanding of the process being executed. The following is Figure 3.

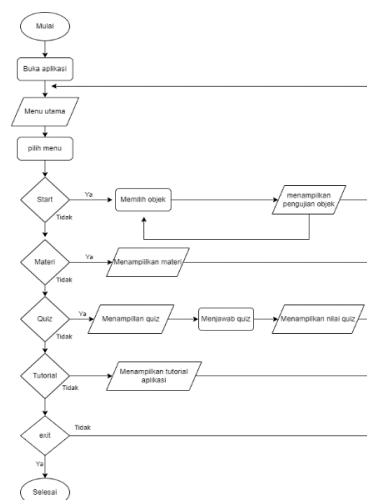


Figure 3. Flowchart diagram

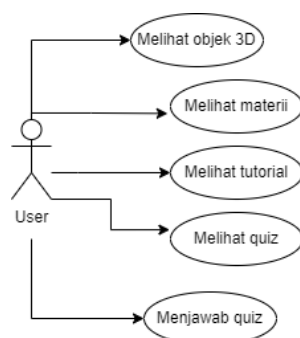


Figure 4. Use Case Diagram

3.1.2 Use Case Diagram

A use case is a description of the interaction or communication between a system and an actor, which includes the exchange of messages and a series of actions performed by the system to achieve a specific goal. In other words, a use case represents the functions that a system should have and perform according to user needs. The image below illustrates the interaction between users, where users can access the application, i.e., users can view 3D objects, see explanations of formulas, access mini quiz features, and view information on the application[10] . See Figure 3. Use Case Diagram.

3.2 Design

This Android-based application is designed to support the learning of acid and base reactions for students at Muhammadiyah 6 Krian Junior High School. It utilizes Augmented Reality (AR) technology to make the learning process more interactive and interesting[13] . This application has six main menus, namely Play for interactive simulations, Material that provides a complete explanation of the concepts of acids and bases, Tutorial as a guide to using the application, AR Camera that displays marker-based reaction animations, Quiz to test students' understanding, and Marker that provides marker images to activate AR objects. By presenting innovative and visual learning media, this application aims to improve students' understanding even though it does not completely solve all learning problems directly. The user interface design of the acid-base AR application can be seen in Figure 5. Main menu, play menu, tutorial menu, material menu, quiz menu, AR camera menu, AR camera menu, 3D object display page.

3.2.1 Main Page

This page contains the play, material, tutorial, and exit buttons. The play button functions to take the user to the next page. The tutorial button is used to take the user to the tutorial menu, and the exit button is used to exit the acid-base AR application.



Figure 5. Main Page

3.2.2 Tutorial Page

This page contains a tutorial explaining how to use the application and the procedures for using each menu in this AR Acid-Base application, enabling users to understand the steps for operating the available features, from starting the simulation, studying the material, to exiting the application easily and effectively.

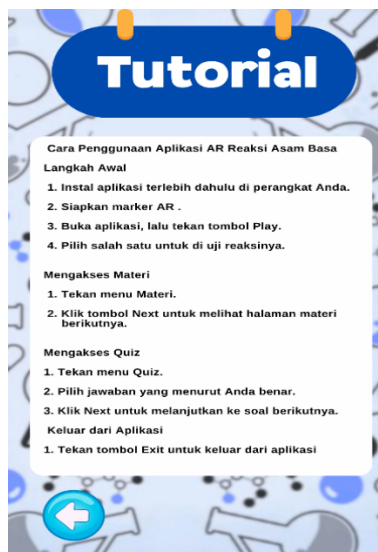


Figure 6. Tutorial page

3.2.3 Material Page

The material page on the AR Acid Base application is a page that contains theoretical explanations about acid and base reactions. On this page, users can learn the basic concepts of acids and bases, their properties, examples of acidic and basic substances in everyday life, and the reactions that occur when the two are mixed. This material is presented in a concise and easy-to-understand manner, aiming to provide a knowledge foundation before users try the Augmented Reality-based simulation.

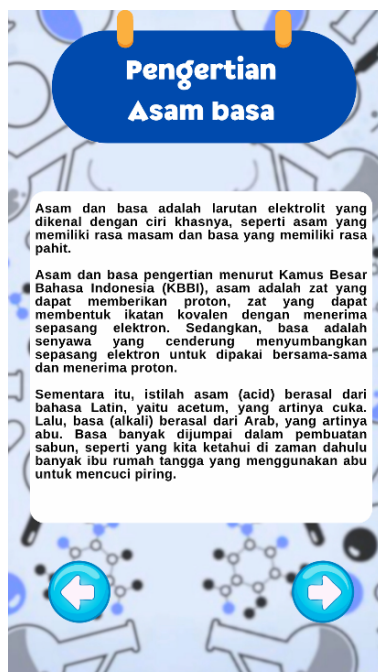


Figure 7. Material Page

3.2.4 Play Page

The Play Page contains several buttons to navigate to the next page: the AR Camera button leads to the 3D testing page, the Quiz button leads to the quiz page, and the User Marker button directs users to a Google Drive link to download markers for testing.

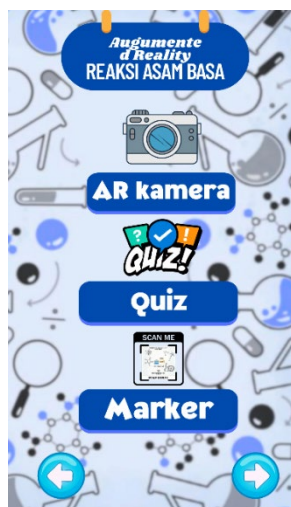


Figure 8. Play Page

3.2.5 AR Camera Page

When the user enters the AR Camera Page, they will be directed to select one of five acid-base reaction tests: orange, soap, chalk, soda, and salt. After selecting the object to be tested, the user will be directed directly to the 3D menu.

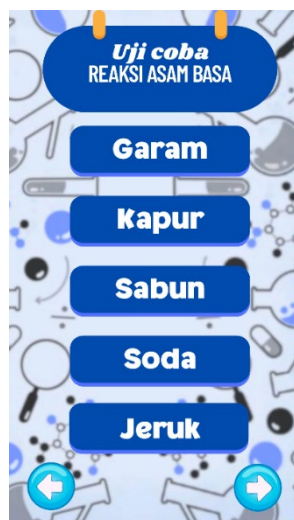


Figure 9. Play Page

3.2.6 Acid-Base Reaction Testing Page

The AR play page display automatically turns on the AR camera when the user enters the AR play page to display 3D objects. Click the Play AR button, then point the camera at the marker or image to display the acid-base reaction object and color change animation.

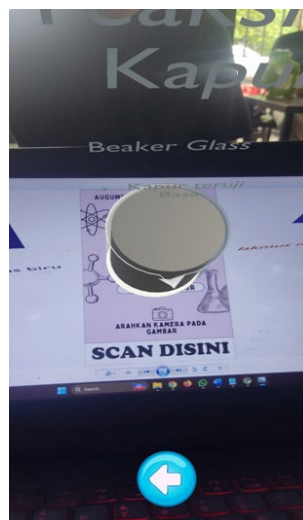


Figure 10. Play Page

3.3 Material Collection

Material collection is the stage performed after the design stage. From the design created in the design stage, the designer needs to collect the materials[14] . Figure 5 shows the original image.



Figure 11. Original Image

3.4 Production

In the production stage, all materials that have been collected will be modified according to requirements, as illustrated in the image showing the application development process for Acid-Base Reactions[15] .

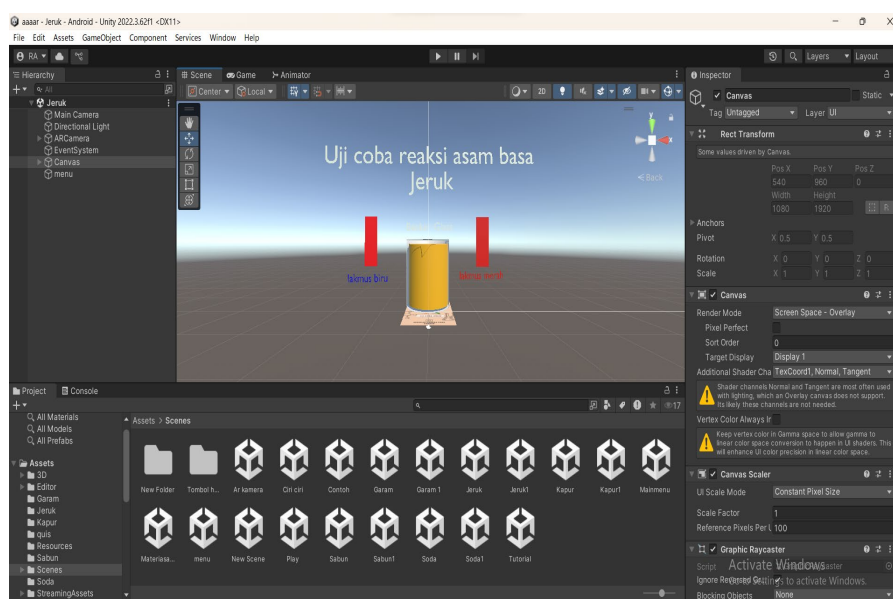


Figure 12. 3D Object Creation

Creating a quiz in Unity is done by creating a UI display using Canvas, which consists of text for questions and several buttons as answer choices. The main script, QuizManager, is used to manage the quiz flow, from displaying questions, filling in text on the answer buttons, to checking whether the selected answer is correct or incorrect. Each question is stored in a data structure such as AnswerData, which contains the question text, a list of answers, and the index of the correct answer. When a button is clicked, the script verifies the correctness of the answer and displays the next question until all questions are completed. All UI elements such as text and buttons must be connected to the script via the Inspector, and their interactive functions are controlled by listeners on the buttons.

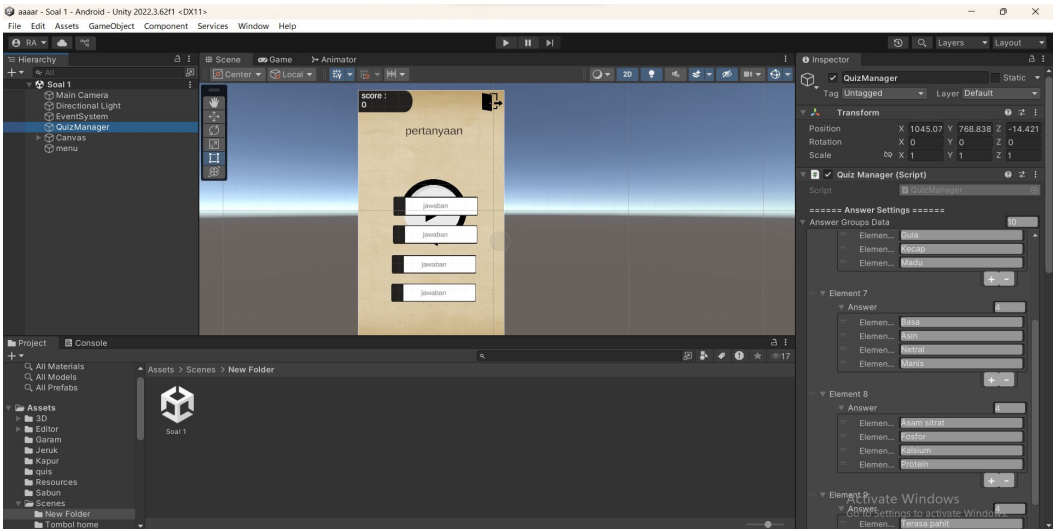


Figure 13. Creating a Quiz

3.5 Testing

In the testing phase, the application is useful for evaluating the effectiveness of the model that has been created[16]. The target audience for testing this application is junior high school students, because the material presented is directly related to their level of understanding[17] . The black-box method and user questionnaire were used in testing this application, because the black-box method is suitable for ensuring that all application features function without checking the program code, making it suitable for evaluating user experience[18] . Meanwhile, the user questionnaire was selected to measure the satisfaction and effectiveness of the application in learning, with data from students and teachers collected using the Likert Scale related to the appearance, ease of use , and benefits of the application. The following is Table 1 of the test results.

Table 1. Testing

No	Test item	System response			Description
		Good	Poor	No	
1.	Play button	✓			
2.	Camera Ar button	✓			
3.	Exit button	✓			
4.	Tutorial button	✓			
5.	Materials button	✓			
6.	Marker button	✓			
7.	Quiz button	✓			
8.	Back button	✓			
9.	Next button	✓			
10.	Play button	✓			

In the "Augmented Reality Acid-Base Reactions" application, the PLAY button will direct users to a submenu consisting of two main options, namely the Camera Menu and Quiz. In the 3D Menu, users can scan markers to display acid-base reaction animations based on AR (Augmented Reality) technology. Meanwhile, in the Quiz menu, users can answer multiple-choice questions related to acid-base reaction material and see their scores and feedback after completing them. The Material button displays a theoretical explanation of acids and bases,

including definitions, properties, and examples of reactions accompanied by supporting illustrations. The Tutorial button provides a complete guide on how to use the application, including steps for scanning markers and accessing AR and quiz features. Finally, the Exit button is used to exit the application.

Table 2. Application Testing Results

No.	Device	Android Version	RAM	Description
1.	Poco X3 Pro	11	8	Successfully executed
2.	Poco X6 Pro	12	12	Successfully executed
3.	Realme C3	10	3	Successfully executed

The results of testing the application on several devices running different versions of Android are shown in Table 2. On the Realme C3 running Android version 10 with 3GB of RAM, the program operates well despite the minimum specifications. Additionally, the program runs smoothly on the Poco X3 Pro with Android version 11 and 8GB of RAM, and runs optimally on the Poco X6 Pro with Android version 12 and 12GB of RAM. This Augmented Reality application, which introduces acid and base reactions, will be published and used as an interactive learning medium. The application will be tested by junior high school students, who are the target users because the learning material is appropriate for their level of education. Feasibility tests will be conducted based on predetermined assessment categories. A score of 1 represents the "very poor" category as the lowest value, while a score of 5 represents the "very good" category as the highest value. Table 3 below explains the Likert scale used in this assessment[19].

Table 3. Score Categories on the Likert Scale

Score	Percentage	Description
1.	0% - 20%	Very Poor (SKB)
2.	21% - 40	Poor (KB)
3	41% - 60	Fairly Good (FG)
4	61% - 80	Good (B)
5.	81% - 100%	Very Good (VG)

The results of the user response questionnaire for the acid-base AR application feasibility test were calculated using a Likert scale with a maximum score of 5 for each question, so that with 10 questions, the maximum score was 50. This score was then multiplied by the number of respondents to obtain the expected score. The frequency value was obtained from the total score given by all respondents, and the feasibility percentage was calculated by comparing the frequency value with the expected score, then multiplying it by 100 percent. This percentage shows the level of satisfaction and feasibility of the application based on user assessments of the appearance, function, and benefits of the application.

Table 4. Questionnaire test

No	Question	Score 1	Score 2	Score 3	Score 4	Score 5
1	Does the animation in this application work?	0	0	0	2	8
2	Does this app run smoothly on your device?	0	0	1	1	8
3	Is the quiz relevant to the material on acid-base reactions?	0	0	0	2	8
4	Is the display clear enough?	0	0	0	0	10
5	Is this application suitable as a learning medium for acid-base reactions?	0	0	0	1	9
6	Does the AR application make it easier for you to conduct virtual acid-base reaction experiments?	0	0	0	1	9
7	Does this app help you understand acid-base reactions better than conventional methods?	0	0	3	1	6
8	Are practice questions or quizzes in the app useful?	0	0	1	1	8
9	Is the main/initial display of the application attractive (user interface)?	0	0	0	2	8
10	Do you feel more interested in learning chemistry after using this app?	0	0	1	1	8

Based on Figure 8, the questionnaire results collected from young people through an online survey show that there were 10 respondents who gave a score of 5 with a total value of 81, a score of 4 with a total of 14, and a score of 3 with a total of 5. Meanwhile, no respondents gave a score of 2 or 1. The assessment of the augmented reality application for detecting drug types and side effects was based on a Likert scale. The maximum score is represented by X, where the "very good" category has a value of 5. This maximum value is calculated by multiplying the highest score by the number of questions, namely $X = 5 \times 10 = 50$. Meanwhile, the ideal score or expected score is represented by Y, which is calculated from the multiplication of the maximum score by the number of respondents: $Y = 50 \times 10 = 500$.

The results of these calculations can be seen in detail in Figure 8, which shows the level of user satisfaction with the application.

f = Total frequency value for each question

T = Total number of respondents

Pn = Likert score

P = Feasibility presentation

Y = Expected score Therefore,

the user satisfaction calculation results are:

$$\begin{aligned} f &= T \times P_n \\ f &= (81 \times 5) + (14 \times 4) + (5 \times 3) \\ f &= (405 + 56 + 15) \\ p &= 476 \\ p &= \left(\frac{476}{500} \times 100\% \right) = 95.2\% \end{aligned}$$

Therefore, the total eligibility percentage is 95.2%.

Based on the evaluation results, the AR Acid Base application received a frequency score of 476 and achieved a feasibility percentage of 98.1%, indicating that this application is classified as excellent and suitable for use as a learning medium. The application of Augmented Reality (AR) technology in this application has proven to be superior to conventional learning methods, as it is capable of presenting interactive 3D models, visual animations, and evaluative quizzes that make the learning process more interesting, easy to understand, and enjoyable for students. This interactive learning not only increases student engagement but also helps accelerate a deeper and more concrete understanding of acid-base reaction concepts. Thus, this application can be used as an effective alternative innovative learning medium to support the understanding of chemistry concepts and improve the quality of learning in the digital era.

3.6 Distribution

During the distribution stage, the Acid-Base Augmented Reality application is planned to be officially published through the Google Play Store platform so that it can be widely accessed by users, especially students and educators. Before the publication process is carried out, this application first goes through a series of testing stages to ensure functionality, content accuracy, and user comfort in the learning process. The testing was conducted directly by teachers and students from SMP Muhammadiyah 6 Krian as part of a field study to obtain feedback and evaluation of the application. Through the direct involvement of the school, it is hoped that this application will truly meet the needs of users in understanding acid and base reaction material interactively. After the entire evaluation and improvement process was carried out based on the results of these trials, the application was then ready to be published and used by a wider audience as an augmented reality-based learning medium.



Figure 14. Application Testing

4 Conclusion

This study successfully developed an acid-base reaction learning application based on Augmented Reality (AR) technology aimed at junior high school students, particularly at SMP Muhammadiyah 6 Krian. This application is designed to present abstract chemistry concepts, such as reactions between acids and bases, in an interactive and easy-to-understand three-dimensional visual form. The application was developed using the Multimedia Development Life Cycle (MDLC) method, which includes the stages of concept, design, material collection, creation, testing, and distribution. This application is equipped with various features, including 3D simulations of acid-base reactions, learning materials, interactive quizzes, usage tutorials, and a marker-based AR camera feature to display reaction animations directly. Testing of the application using the black box method showed that all functions worked well, while the feasibility test using a Likert scale questionnaire showed a user satisfaction level of 98.1%, which is in the excellent category. This application is also proven to be compatible with various Android devices and will be distributed through the Google Play Store to reach more users. Thus, the application of AR technology in learning has proven to enhance conceptual understanding, learning interest, and active student participation in the classroom. This application serves as an innovative and effective solution to overcome challenges in understanding acid-base reaction material, and can be utilized as an engaging, safe, and technologically appropriate alternative learning medium aligned with current educational technology advancements.

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