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DEVELOPMENT OF ANDROID-BASED AUGMENTED REALITY LEARNING MEDIA FOR THE CONCEPT OF MOLECULAR GEOMETRY

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Abstract

The integration of Augmented Reality (AR) technology into educational media has the potential to enhance student engagement and understanding of abstract concepts. This study aimed to develop and evaluate the quality of AR-integrated learning media for teaching molecular structures in chemistry. Using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model, this research employed a systematic approach that encompassed five stages of development. The study was conducted with two eleventh-grade classes at a public high school (SMA Negeri 1 Lhokseumawe), involving 66 students as the subjects of the research. Expert validation of the developed media yielded a score of 88, which categorizes it as "Excellent." At the same time, student feedback on usability and engagement resulted in a score of 4.77 in the same category. These results indicate that the AR media is effective and well-received as a supplementary tool for learning molecular structures. The findings highlight the potential of AR technology to enhance conceptual understanding and improve learner satisfaction in the field of chemistry education. Future studies should explore its application across other topics and educational levels to further validate its efficacy and scalability.

Keywords: *Augmented reality; AR; molecular geometry; ADDIE; research and development*

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INTRODUCTION

The education sector is developing in line with the rapid advancement of technology today [1]. Technology is beneficial in helping everyone's work in various fields, one of which is education [1]. Utilizing technology to improve the level of education in Indonesia to be able to compete globally [1][2]. Education plays a crucial role in human life. Based on this statement, every individual has the right to receive educational services, and it is essential to enhance the quality of human resources. [3] Improving the quality of education requires several aspects that can support the learning process. One of the factors that supports the learning process is the use of learning media. Learning media can help students learn and increase interest in learning [4]. Learning media tailored to the material and age level of students can make the learning process more effective [5]. Chemistry is one of the science subjects taught in Senior High School (SMA). Chemistry is a fascinating field to study, but most students find chemistry lessons difficult and confusing because the theory is abstract [6]. Chemistry is not only limited to solving problems, but also includes an understanding of chemical facts, chemical laws, and a wide range of materials, one of the science subjects taught in Senior High School (SMA). The use of technology is one of the innovations, and, of course, it is easy to attract the attention of students today. Therefore, high school teachers are expected to be familiar with technology so that education can be engaging and students are not bored while learning [7]. Strong spatial vision ability to understand structural formulas and translate them into three-dimensional representations to build a picture of molecular shapes [8].

Augmented Reality (AR) technology in education can help students visualize abstract material in 3D, making it easier for them to understand the material [9][10]. This AR media can improve students' understanding of concepts, critical thinking skills, and learning outcomes [11]. Research also shows that Augmented Reality technology can enhance students' understanding of concepts and increase their interest in learning [12]. With the advantages of the Android operating system, developers can create applications freely due to its open-source nature [13]. Based on observations at SMA Negeri 1 Lhokseumawe, as well as interviews with chemistry teachers and classroom observations, the use of learning media in schools is still relatively rare. Usually, only PowerPoint and manual press are used. The manual media used are less engaging because they only utilize simple tools, which can lead to students feeling bored during the learning process [14]. The chemistry teacher at the school also stated that learning chemistry through molecular form

material must be demonstrated in real-life applications to students, so that they can understand the molecular form material. Based on the above explanation, the researcher proposes a solution in the form of developing learning media, specifically an Android-based Augmented Reality application, for molecular form materials. This approach aims to optimize the learning process for students in chemistry. To address these needs, the researcher will conduct a study entitled "Development of Android-Based Augmented Reality Integrated Learning Media on Molecular Shape Chemistry Materials."

METHOD

This research employs the ADDIE model of the R&D (Research and Development) research method. This research method aims to produce a specific product and evaluate its effectiveness [15]. The products that will be created in this research are in the form of software or applications that contain Augmented Reality (AR) integrated learning media. The ADDIE development model is the model used by the Researcher in this Study. This model was first used at the University of Florida in 1975 [16]. Analysis, design, development, implementation, and evaluation are the five key steps outlined in the ADDIE model's development process. [17] According to this research model, a different procedure applies to each stage.

The initial stage of the ADDIE development model involves determining students' learning needs by analyzing problems that occur during the learning process [18][19]—the researcher examined the literature study and direct observation of learning conditions in schools. The second stage in the ADDIE model is the planning stage. At this stage, the researcher begins to design learning media that will be developed based on the analysis previously carried out.

The results of the previous design were used for the development stage of AR chemistry learning media. After that, the validator will check the results of the development. The learning media products being developed will then be validated by media and materials experts. The fourth step involves using pre-made and updated learning materials or conducting trials. This stage is known as implementation or field trial, where chemistry learning media is applied to the learning process of students at school. The products that have been developed are tested on students at SMA Negeri 1 Lhokseumawe. At this stage, two classes are participating in the test, each consisting of 33 students. Evaluation is the final stage in the ADDIE development model. After expert lecturers on the learning media carried out validation to ensure that it is valid and suitable for use as a teaching medium. Validation and Feasibility of Learning Media, namely the validation of subject matter experts and media experts with a score range of 1-5 for each question item according to Table 1.

Table 1. Validation scoring criteria

Criteria	Score
Excellent	5
Good	4
Fairly Good	3
Poor	2
Extremely Poor	1

The average score of validation and feasibility of learning media can be obtained using the following formula [20]:

$$X = \frac{\sum x}{n}$$

Where:

X = Average score
∑ x = Total Score
n = number of items

The average scores that have been obtained previously are converted by the validation and feasibility criteria of learning media based on the guidelines referred to in the following table:

Table 2. Learning Media Quality Score

Score range	Category
$\overline{X} > \overline{Xi} + 1.8$ SBi	Excellent
$\overline{Xi} + 0.6$SBi$< \overline{X} \leq \overline{Xi} + 1.8$ SBi	Good
$\overline{Xi} - 0.6$SBi$< \overline{X} \leq \overline{Xi} + 0.6$ SBi	Fairly Good
$\overline{Xi} - 1.8$ SBi$< \overline{X} \leq \overline{Xi} - 0.6$ SBi	Poor
$\overline{Xi} \leq \overline{Xi} - 1.8$ SBi	Extremely Poor

The maximum score obtained in the questionnaire on the validation and feasibility criteria of learning media is five, and the minimum score is 1. Then the quality criteria for learning media can be determined according to the following table:

Table 3. Learning Media Criteria

Score Interval	category
X > 4.21	Excellent
3.40 < X ≤ 4.21	Good
2.60 < X ≤ 3.40	Fairly Good
1.80 < X ≤ 2.60	Poor
X ≤ 1.80	Extremely Poor

RESULTS AND DISCUSSION

The analysis stage is the initial stage in ADDIE's development model. At this stage, an analysis is conducted of three key aspects: problem analysis, needs analysis, and material analysis. The second stage in the ADDIE model is the design stage, which begins with defining the content,

which allows the formation of the overall design [21]. Here are the steps taken at the *design stage*:

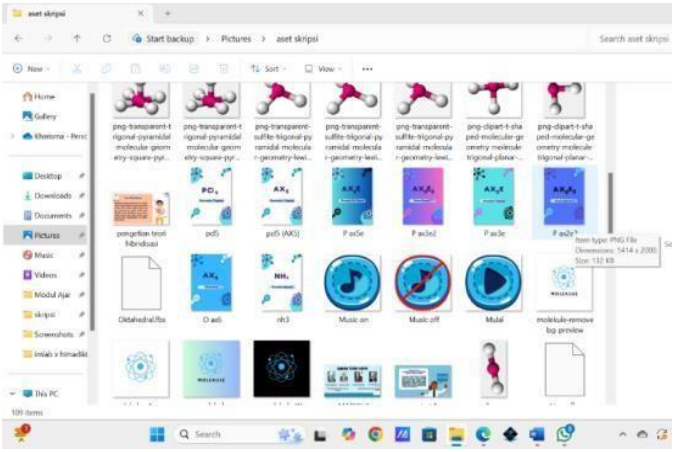

Figure 1. Groups of objects and images used in media

The three-dimensional objects contained in the media are 3D models of molecular shapes taken from the internet of 3D model making. At the same time, other objects, such as images, are collected from various internet sources and adjusted to meet the media's needs through image editing.

The media developed consists of marker cards, material slides, and 3D AR shapes of molecular shape models. In the early part, students will start the application by pressing "*start*," then will be directed to the menu slide section, which contains a selection of materials and *AR scans*. Here is the initial view, application menu, and marker card.

(a)

(b)

Figure 2. a) The main menu of the app, and (b) Markers of the app

On the initial display slide, a question mark icon serves as a guide for use in the developed media. This slide contains instructions for using and directing the camera on the marker card so that the 3D model of the shape of the molecule can be seen. Furthermore, with these instructions for use, students can follow the directions to avoid mistakes when *scanning markers*.

Figure 3. User manual of the app

This slide is part of the material that contains material learned in class XI phase F, odd semester. The material explanation consists of several slides on the application and is complemented by images, tables, and formulas learned on the form material molecule. Students can choose all the materials they want to know, which are available on the app. The following is the presentation of the material.

Figure 4. Presentation of Materials

The core functionality of the developed learning media, referred to as Scan AR, is designed to leverage augmented reality technology for interactive learning. When the camera sensor of a device is directed at a specific marker card, the system recognizes the marker and generates a corresponding 3D model of the molecular shape in real-time as depicted in Figure 5. This feature provides an immersive visual representation, allowing students to explore molecular structures dynamically from multiple angles, thereby enhancing their spatial understanding and engagement with the material [22].

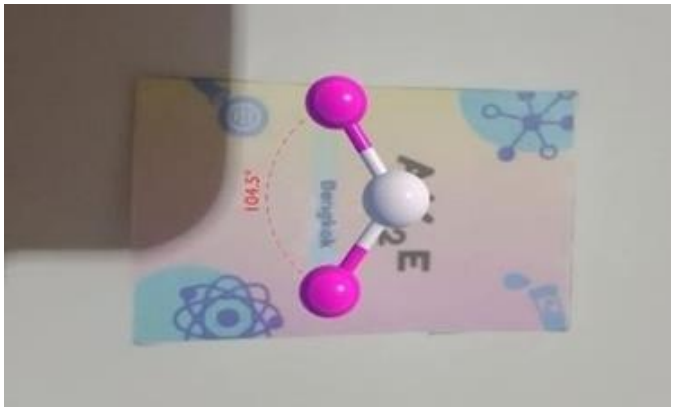

Figure 5. The water molecule in 3D mode

Product validation is the third stage in the ADDIE development model, specifically the Development stage. At this stage, validation is conducted on the media and materials. Media validation encompasses four key aspects: media design, media attractiveness, use, and benefits. The material validation consists of five factors: the structure of the material, the accuracy of the material, the presentation of grammar and punctuation, and the level of difficulty of the material. Each aspect is validated by two validators, media experts and material experts who are lecturers at Malikussaleh University. The results of the quantitative expert assessment will later be changed to qualitative according to the category. The results of media validation and the materials contained in the developed media are presented in Table 4.

Table 4. Validation of Media and Material Experts

Validation	Score (%)	Category
Media	80	Good
Material	92	Excellent
Mean	88	Excellent

The overall validity test results for the nine aspects yielded a score of 88%, placing it in the "Excellent" category. The first validator gave a score of 4.08, and the second validator gave a score of 92%. Therefore, the validated media falls into an excellent category. Both validators argue that Android-based AR media is classified as "Excellent". The determination of this category was obtained after going through a revision process based on suggestions and inputs provided by validators [23][24]. Based on these results, the research can be continued to the next stage. The media validation data can be seen in the image below:

The next stage in the ADDIE model is implementation. This stage was conducted at a public high school, located in the *Banda Sakti* district of Lhokseumawe city. This stage is divided into two, namely the initial product trial and the final product trial. Furthermore, at the end of the test, the researcher administered a questionnaire to the eight students, which was developed specifically for the media. The aspects assessed on the response questionnaire are appearance and satisfaction. The data from the initial product testing on students is presented in Figure 7. This stage involves an initial product trial with two teachers, who also serve as validators, to assess the feasibility of the media, and eight students from SMA Negeri 1 Lhokseumawe to determine the students' response to the developed media. The details of the initial product test results are as follows:

Media Feasibility Testing by Teachers

The media quality test for teachers is a feasibility study conducted on the developed media. This test is performed to assess the feasibility of the media and evaluate the improvements made to the media before it is tested on students. The result is given in Table 5.

Table 5. Validation of media and materials experts

Validation Aspect	Score (%)	Category
Learning media	96	Excellent
Content	87	Excellent
Total Average	93	Excellent

Student Response

This trial was conducted on eight students to assess their initial response to the developed media. This trial is included in the initial product trial, which is performed to determine the media criteria that the final product trial will follow if the developed media is suitable for use based on the test results. The initial testing of this product was conducted by distributing the learning media, designed for eight students, online in the form of an Android (.apk) file. After that, students installed the application on their respective smartphones, and then the researcher gave instructions on how to use the media.

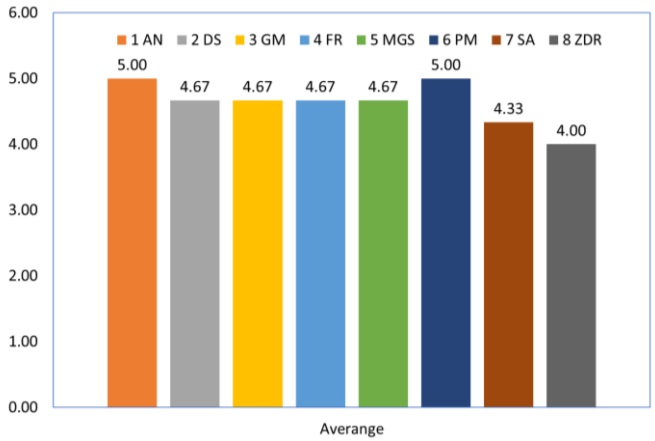

Figure 6. Student's initial response to the app

Based on the results of the test of student response to the initial product, an average score was obtained in both aspects assessed, namely the display aspect with a score of 4.59 and the satisfaction aspect of 4.68, with this, the total average score in the developed media was 4.62 with the

category of "Excellent". Thus, the developed media can be used in the final product trial.

Final Product Test

The final product trial was conducted after undergoing a series of validation stages by validators and an initial response trial with students. Based on the results of previous tests, satisfactory results were obtained, indicating that the product had reached its final stage and could be tested to gather the necessary data. The purpose of this test is to collect the data needed for the research in the form of student responses to the media and concept understanding data, both before and after the use of the developed media. This stage was tested on 66 students in grade XI at SMA Negeri 1 Lhokseumawe. Based on the test results, it is evident that the average score obtained by students was 4.77, as per the score criteria table, indicating that this score falls within the "Very Good" category. This student's response data is the second time the response data has been taken. In the first stage, initial response data from 8 students was obtained, which was used as the initial response data. The initial response data had a lower score compared to the final product response data, which still falls within the same category, namely the "Very Good" category. Based on these results, it can be noted that the media developed is suitable for use by students as one of the learning media options [25].

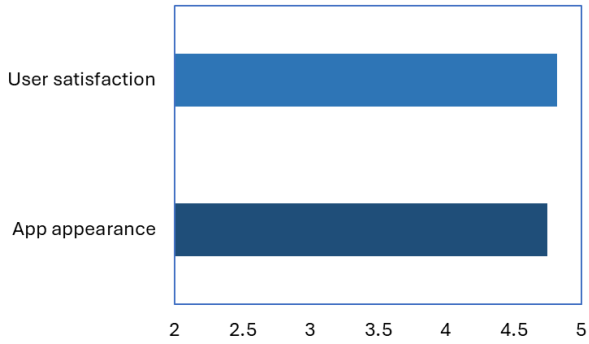

Figure 7. Student response toward the quality of the app

Figure 7 illustrates the evaluation of two aspects of an augmented reality learning application: "User Satisfaction" and "App Appearance," both rated on a scale from 2 to 5. The results indicate high ratings for both parameters. User satisfaction achieved a score slightly below 4.5, suggesting that users found the app highly satisfactory in terms of functionality and engagement. Meanwhile, the app's appearance received a score of approximately 4.8, indicating that its design and visual appeal were rated even higher. These results reflect a well-designed application that effectively meets user expectations both in terms of usability and aesthetic. This indicates that the developed media has met the criteria for decent appearance and satisfaction [26].

CONCLUSION

An Android-based augmented reality (AR) learning media for molecular shape materials was successfully developed to enhance students' conceptual understanding. The media is designed to be both engaging and interactive, utilizing Android devices equipped with camera sensors and marker cards. This functionality enables students to view realistic 3D representations of molecular shape models in real-time. Following comprehensive validation by experts, teachers, and student testing, the AR-integrated learning media was rated in the "Excellent" category, demonstrating its effectiveness and suitability as a teaching tool.

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