

Development Of Augmented Reality Learning Media In Chemistry Subject In High School

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ABSTRACT

This study aims to develop chemical bond Augmented Reality (AR) learning media based on Android applications and determine their feasibility. AR media is used in Chemistry class X SMA. Topics developed in this medium are covalent bonding materials and molecular shapes. This Research and Development research was conducted using the multimedia development life cycle (MDLC) model with the stages of concept, design, material collecting, assembly, testing, and distribution. At the testing stage, a feasibility test is carried out through two stages of the validation test, namely the alpha test and beta test. The results of this study indicate that: (1) AR learning media products in chemistry class X were successfully developed with covalent bonds and molecular shapes; (2) the results of testing AR learning media in chemistry Class X obtained very decent results with a percentage of 89.58% in media testing, 91.25% in material testing, and 80.20% in testing prospective users; and (3) this AR learning media received a positive response both from students as potential users and from the subject teacher concerned regarding the easy-to-understand material due to clear visualization and examples as well as an attractive appearance.

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1. Introduction

Senior High School (SMA) has an important role in the development of national education development. One example of a field of science that students must achieve according to the curriculum is chemistry. Chemistry is an inseparable part of Natural Sciences (IPA) which deals with how to systematically find out about natural phenomena. One of the main topics in chemistry is chemical bonding, which has sub-subjects, including: covalent bonds, ionic bonds, molecular shapes, and molecular polarity. The concept of chemical bonds is one of the concepts that is difficult for students to understand [1], because to understand this concept students also have to understand other basic concepts such as the periodic system of elements, Lewis structure and the theory of Valence Shell Electron Pair Repulsion (VSEPR) and Electron Domain theory.

Based on the results of observations and interviews with teachers and students conducted at Tanjungsari 1 Public High School, students had difficulty understanding the chemistry material delivered by the teacher. This difficulty is evidenced by the results of the daily test results for students in class X MIPA 1 and X MIPA 2 at SMA N 1 Tanjungsari showing that 12 out of 62 students (20 percent) in class X got scores above the minimum completeness criteria (KKM) 75. Of the students who have not passed the KKM, 90 percent of them have difficulty solving problems involving chemical reactions and chemical calculations, due to the low understanding of chemical concepts and the lack of students' interest in chemistry lessons. In addition, teachers do not always provide concrete examples of reactions that exist in the environment and are often encountered by students.

Learning chemistry on the topic of molecular shapes based on VSEPR theory is one of the materials that is difficult for students to understand [1][2]. Several previous studies have shown that the factors that make the topic of molecular shape difficult to understand are due to its abstract concept. Chemical bonds are abstract because they identify the properties of a compound without knowing how an atom can bond with each other [3]. Understanding the concepts in chemistry requires three levels of understanding which include the macroscopic, symbolic and microscopic levels. Symbolic characteristics are chemical characteristics qualitatively and quantitatively, namely chemical formulas, diagrams, drawings, reaction equations, stoichiometry and mathematical calculations.

The description above shows that an effort is needed to optimize chemistry learning in class by applying the right approach and media. An understanding of abstract chemical bonds needs to be visualized. Visuals also help motivate students, direct their attention to important concepts, provide a way to repeat information from different perspectives, help remember previous learning, and most importantly, reduce the effort required to learn [4].

To bridge this gap, [5] developed an augmented reality (AR) model to provide alternative learning media for students. AR training provides an opportunity for active and well-received learning in medicinal chemistry. Another study conducted by [6] stated that using AR could improve academic achievement and motivation scores did not differ between the control and experimental groups. In geometry material, AR significantly improves student learning outcomes [7]. AR and have provided positive experiences and enhanced student learning experiences in Chemical Engineering [8].

Starting from these problems, an AR learning media using a smartphone was developed. The use of this chemical AR learning media in the learning process can provide a learning experience that is more than conventional methods. Visuals presented by AR as augmentation are 3D objects. This learning experience triggers a change in learning styles from conventional learning to active and individual learning.

In its application, this learning media uses applications that contain material and quizzes. In addition, there is also a marker in a form that will display 3D objects. This learning media is made so that it is easier for high school students to learn chemical bonds, with a concise appearance and material so that it is hoped that this AR media can be accepted so that it can then be applied to the learning process in the classroom on an ongoing basis.

2. Literature Review

Revolution the fourth industry is realized by the combination of various physical and digital technologies such as artificial intelligence, cloud computing, AR, VR, and Internet of Things (IoT). In the world of education, AR and VR are still relatively new and continue to grow. Oftentimes, AR is interchanged with VR, both of which have a clear distinction between the two "reality". In simple terms, AR enhances, expands and expands reality, whereas VR is designed to simulate or replace reality with a computer generated environment [4].

AR combines the real world with virtual objects so that these virtual objects coexist in the same space as the real world [10]. AR uses digital technology to overlay real-time camera views with virtual components, such as 3D digital visualizations, to create "augmented" or enhanced real-time interactive experiences. This interaction between virtual objects and the real world brings abstract concepts to life and seeks to increase understanding [4]. Briefly, AR attempts to embed synthetic supplements into a real environment [10]. Synthetic supplements can be images, videos, 3D models, text, sound, speech instructions, and more.

AR can be implemented using display devices depending on the type of interaction. The most widely used technologies are: translucent head-mounted displays (HMD), opaque HMDs, hand-held displays (HHD) such as tablets or smartphones, and spatial displays (SD) [9] [10]. Of the several options, AR is most often implemented using a smartphone. Smartphone use in AR provides benefits without incurring additional hardware costs for the user.

Aspect important in AR applications is tracking & registration, due to accurate tracking & registration, augmentations can be aligned correctly. Tracking & registration algorithms are

categorized into three classes such as: (1) marker-based algorithms, (2) natural feature-based (or markerless) algorithms and (3) model-based algorithms [9]. In marker-based algorithms, 2D markers that have unique patterns or shapes are placed on real objects, where the augmentations are superimposed. This pattern selection is an option for AR developers.

AR use in The educational environment is supported by a psychological theory known as constructivism, where learning is an active process of constructing new knowledge based on previous knowledge [11]. Constructivism shifts from passive information transfer to active problem solving and discovery [4][6]. So AR emphasizes that students create their own interpretation of the world of information. Students place learning experiences within their own experiences and that the aim of teaching is not to teach information but to create conditions in which students can interpret information for their own understanding.

3. Method

DevelopmentThe product in this study uses the R&D (Research and Development) method. R&D is a process used to develop and validate educational products [12]. R&D is used to produce products to solve a particular problem and test the feasibility of the product. In accordance with the objectives of this study to produce an AR-based learning media product as a source and means in Chemistry learning activities.

The development model in this project uses the MDLC (Multimedia Development Life Cycle) model [13]. This development model is carried out based on six stages, namely concept, design, material collecting, assembly, testing, and distribution. The details of the development stages are as follows.

1. Concept. This stage is to determine media specifications including learning objectives, target users, program learning content, and evaluation. This stage produces the resulting AR product specifications in the form of what features are needed in the media.
2. Design. This stage is to make detailed specifications regarding the program architecture, appearance and material requirements for the media. The design is made detailed as a guideline in the next stage. The previsualization tool used uses storyboards to describe the description of each scene, listing all the multimedia objects and links to other scenes and flowcharts to illustrate the flow from one scene to another.
3. Collecting Materials. This stage collects materials according to the needs described in the previous stage. These materials are assets in the form of 3D images, 3D objects, animations, and audio.
4. Assembly. At this stage, all multimedia or post-production assets are assembled. Making applications based on storyboards, flowcharts, and navigation structures that have been defined at the design stage.
5. Testing. This stage is to test the feasibility of the product. Testing is carried out through two stages, namely the alpha test and beta test. The alpha test was carried out by media experts and material experts. Furthermore, the beta test is carried out by involving end users, namely students.
6. Distributions. This stage conducts delivery to students in class on the Android platform.

3.1 Research Subjects

Research on developing chemistry learning media with AR was carried out at SMA N 1 Tanjungsari, Gunungkidul, Yogyakarta Special Region. The research subjects were students of class X MIPA.

3.2 Data Collections

Data collection methods used to obtain data and information in this study are interviews, observations, and questionnaires to respondents. Observations in this study aim to observe the use of the media used by the teacher when conveying subject matter, the use of teaching methods, the delivery of material and the attitudes of students in class. The questionnaire generates quantitative data to test the validity and feasibility of AR products.

3.3 Data Analysis

The data analysis technique used is quantitative data analysis. The data to be analyzed is in the form of quantitative values obtained from the results of questions through an assessment questionnaire filled out by material experts, media experts, and students. The steps taken to analyze the data are: determining score guidelines, calculating assessment scores, and calculating the level of eligibility.

Questionnaire or questionnaire assessment is measured using a Likert scale with four points. The scoring score is done by calculating the total score for each instrument item and calculating the total score for each aspect of the assessment. The eligibility level is calculated based on the calculation of the assessment score in the form of a percentage with the following formula

The percentage of results of the eligibility level that has been calculated is then converted into a category that is used as a reference for measuring the eligibility level is presented in Table 1.

Table 1. Categories Percentage Appropriateness

Formulas	Classification
$85\% < X < 100\%$	Very Worthy
$67.5\% < X < 85\%$	Worthy
$57.5\% < X < 67.5\%$	Enough
$25\% < X < 52.5\%$	less worthy
$52.5\% < X < 57.5\%$	Not feasible

4. Results and Discussion

AR media has been developed using the MDLC model consisting of six stages. The results of each stage are described as follows.

4.1 Concept

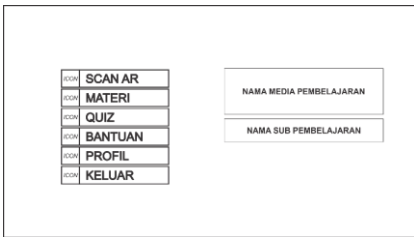
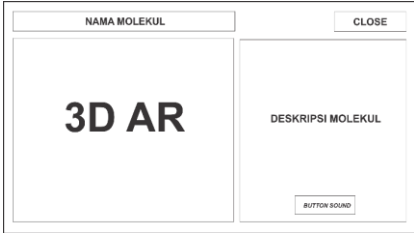


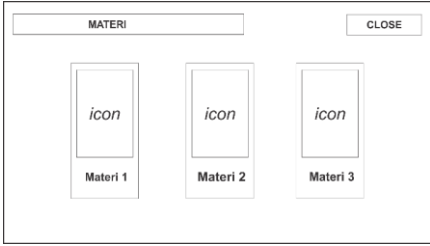
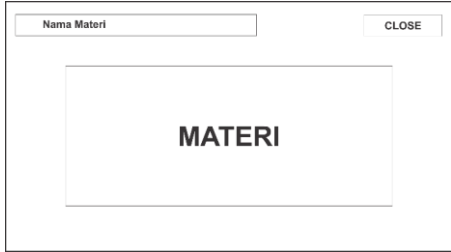


From the results of the analysis, it can be identified the need for learning media with AR features. The specifications are as follows.

1. Product developed for android smartphones with a minimum operating system android 6.0.
2. Application has an AR scan menu feature that can display 3D images of molecular shapes as well as display descriptions and explanations in the form of audio narrations.
3. Application has a material menu that can display core competency pages, basic competencies, learning objectives, and a collection of materials. The collection of material consists of text and images.
4. Application has a quiz menu that can display evaluation questions along with answer choices and can display the final score. The evaluation consisted of 10 multiple choice questions with four answer choices.
5. Application has a help menu that can display information about menus in chemistry AR learning media.
6. Application has an exit menu that functions to end the learning activity.
7. Application requires Card containing marker as a support for the implementation of the developed application containing the forms and names of chemical bonds in the form of a QR code.

4.2 Design

The results of the design are realized in the form of previsualization using storyboards. Storyboards visualize the display sketch of the page to be made in chemistry AR learning media. Table 2 shows some of the previsualization in storyboard form.

Table 2. Storyboards







Appearance	Information
Application Menu	
	<p>The main menu displays the name of the learning media along with the learning sub-chapters which are located on the right panel of the application. Furthermore, on the left panel contains the main menu menus including: (1) scan AR, (2) learning materials menu, (3) quiz menu, (4) help menu, (5) developer profile menu, and (6) exit menu to end the application</p>
AR scan menu	
	<p>This display appears when the user selects the "Scan AR" menu. There are two parts, namely the left panel and the right panel. The left panel is used to view 3D AR. At the top of the panel is the name of the molecule that will appear when the marker is scanned. Next, the right panel is used to see a description of the AR</p>
Material Menu	
	
<p>This view appears when the user selects the "Material" menu. Core competencies and basic competencies are competencies and indicators that must be mastered by students. Learning objectives will display several learning objectives that must be achieved by students after using AR media</p>	
Material Menu	
	
<p>The material menu contains a collection of material related to material in the form of molecular shapes.</p>	
Quiz Menu	
	
<p>The quiz menu is a collection of several questions, which aims to test students whether students understand this material. This quiz contains 10 questions with four possible answers</p>	

4.3 Collecting Materials

This stage produces other learning media components, namely 3D design of molecular shapes, asset images, and audio. To create 3D assets using the Blender Asset 3D software. The assets created using this application are various 3D molecular shapes. Furthermore, to make molecular markers and 2D asset images, the software used is CorelDraw X8. Image assets are made in the form of button images, background images and other images that make the appearance of this learning media look attractive according to the needs and material. The resulting image formats are PNG and JPEG formats.

Based on bond pairs of electrons (BPE) and lone pairs of electrons (LPE), it is easy to predict the shape of the molecule. There are 13 molecular shapes to be drawn, Table 3 only shows the six assets of the AX_mE_n formula from electron domain theory.

Table 3. Electron Domain Theory

Bonding Angles	Electron Domains Around the Central Atom	BPE	LPE	Formulas	Molecular shape
				AX _m E _n	
180°	2	2	0		linear 
120°	3	3	0		Trigonal planar 
<109.5°		2	1		Planar V shape 
109.5°	4	4	0		Tetrahedral 
<109.5°		3	1		Trigonal Pyramidal 
<109.5°		2	2		Planar V shape 

The various molecular shapes in Table 3 were made into 3D assets using the Blender Asset 3D software. Figure 2 shows one form of an asset created using Blender Asset 3D. Furthermore, for each 3D asset, a molecular marker is made in the form of a 2D asset image using CorelDraw software. To complement the molecular shape assets, audio assets are created for each molecular shape. Audio becomes a complement to the shape of the molecule that appears simultaneously when the user scans the marker. Smartphone audio recording process with MP3 audio format.

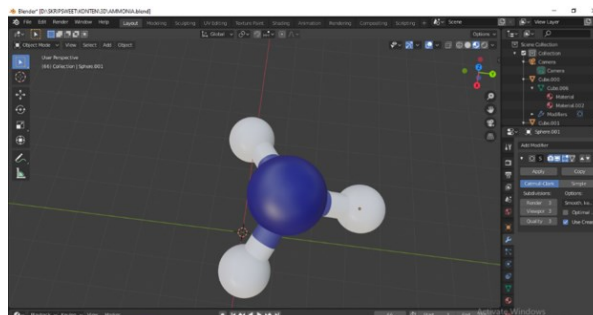


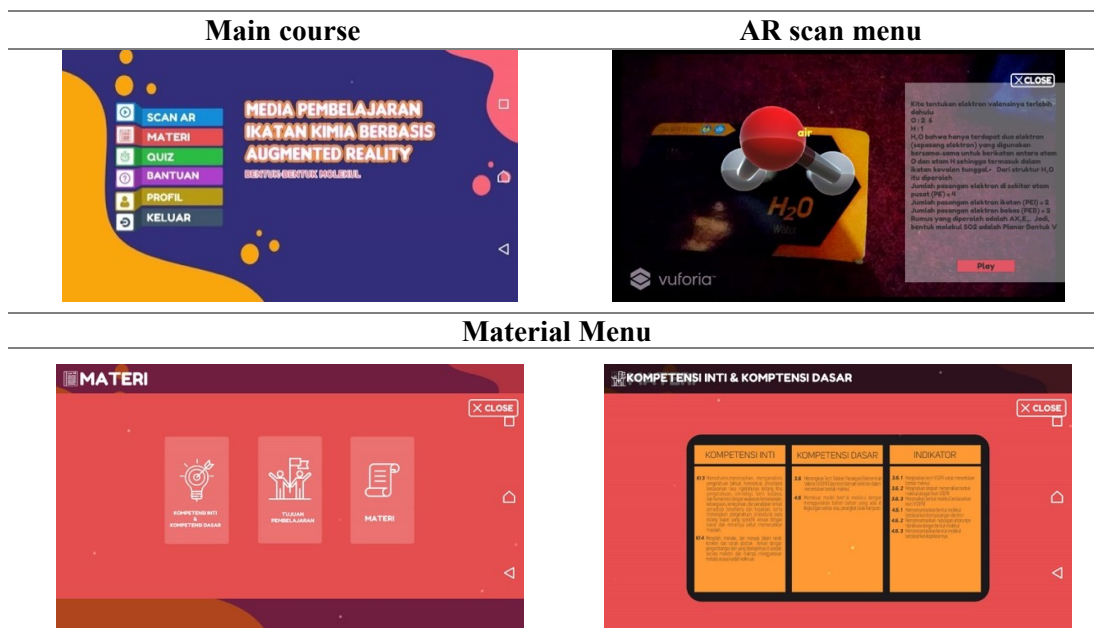
Fig. 1. An example of making an asset in the form of a molecule

The three types of assets in the form of 2D markers, 3D molecules, and audio are then stored in a database. The database used is Vuforia which is an Augmented Reality Software Development Kit.

4.4 Assembly

Learning media assets that have been completed are then compiled based on the storyboard that was created at the design stage. Making applications using Unity software as a game engine. The assembly results are shown in Figure 3. In this figure only four screens are shown for the main menu, the AR scan menu, and some of the material menu menus.

Table 4. AR Media Products



4.5 Testing

The alpha test was carried out by one of the lecturers as media experts and the teacher as a material expert. Alpha testing is carried out based on the development evaluation questionnaire given. Media experts measure three aspects of the system namely

Table 5 is the result of an alpha testing assessment related to the chemical AR learning media that was made.

Table 5. Media Expert Evaluation Result

Aspects	score	Maximal Score	Percentages	Classification
Media design	57	64	89.06	Very Worthy
Technology	19	20	95.00	Very Worthy
Usefulness	10	12	83,33	Very Worthy
Total	86	96	89.58	Very Worthy

Based on table 5 and table 6, the media expert's assessment results obtained a percentage value of 89.58% and the material expert's assessment results obtained a percentage value of 91.25%. When converted according to the feasibility test conversion table, the results of the assessment of media experts and material experts are in the very proper category

Table 6. Material Expert Evaluation Results

Aspects	score	Maximal Score	Percentages	Classification
Instructional design	22	24	91.66	Very Worthy
Instructional content	35	40	87.50	Very Worthy
Usefulness	16	16	100.00	Very Worthy
Total	73	80	91.25	Very Worthy

When converted according to the feasibility test conversion table, the results of the assessment of media experts and material experts are in the very proper category. The note given by the material expert in this test is that AR learning media is good enough to be used as a chemistry learning medium.

The results of the beta tests carried out by students are shown in Table 7. Based on this table, the results of the assessment of students got a percentage value of less than 85% in the feasible category. However, overall the results of the student assessment are in the very decent category.

Table 7. Student Evaluation Results

Aspects	score	Maximal Score	Percentage s	Classification
Message design	302	368	82.02	Very Worthy
Ease of use	146	184	79,34	Worthy
Usefulness	150	184	81.15	Very Worthy
Total	598	736	81.25	Very Worthy

4.6 Distributions

The last stage is submitting to the teacher to be used in the learning process in class. Students try all the features in AR media, especially the Scan AR feature. However, the use has not yet reached the effectiveness test.

Discussion

The research and development of AR learning media is motivated by learning problems at Tanjungsari 1 Public High School, namely the lack of students' understanding of basic chemistry materials using conventional learning methods. In addition, there is also a lack of chemical practice tools which makes the learning process that should be carried out practically only carried out in theory in class. This situation affects the level of students' understanding of the material presented. This AR media has made it easier for teachers to convey material while increasing students' interest and interest in learning chemistry material. In using AR media, students gain new learning experiences that can visualize abstract learning material into 3D images accompanied by audio narration.

The feasibility level of the developed learning media is measured based on the results of the testing or evaluation of alpha testing and beta testing. The summary of the test results is summarized in table 8. Based on the assessment data, the feasibility level of the chemistry AR learning media that has been developed has a very feasible category level.

Table 8. The evaluation results of the feasibility level of AR Media

Evaluation	Eligibility Percentage	Categories
Alpha testing by material experts	91.25	Very Worthy
Alpha testing by media experts	89.58	Very Worthy
Beta testing by students	81.25	Very Worthy

AR emphasizes that students create their own interpretation of the world of information. students place learning experiences within their own experiences and that the aim of teaching is not to teach information but to create conditions in which students can interpret information for their own understanding.

AR learning media development research has several advantages and disadvantages. The advantage of this research is that the product developed received a positive response from both teachers and students as users. The weakness of this research is that it has not yet revealed the effectiveness of the products produced at the level of student understanding.

5. Conclusion

AR media developed based on Android smartphones are equipped with cards that contain QR codes containing information on molecular shapes. AR media developed consists of AR features, core competencies, basic competencies, learning objectives, and a collection of materials. As an evaluation, the application has a quiz menu which can display evaluation questions along with answer choices and can display the final score. The developed learning materials can facilitate the learning of abstract chemical bonds in the form of 3D visualization and sound narration as a complement.

Overall, AR media was received positively by media experts, subject matter experts, and students. The developed chemical AR media has a feasibility percentage obtained from material experts of 91.25%, from media experts 89.58%, and from students of 80.20%. Based on the three test results obtained, the developed chemical AR media is in the category of very feasible to be used as a learning medium that suits the needs of class X high school students.

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